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OF GREAT BRITAIN

**GEMMOLOGICAL ASSOCIATION
OF GREAT BRITAIN
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CHAROITE, A SPECTACULAR, NEW, PURPLE MINERAL*

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In June 1977 a spectacular purple vase was brought to the Institute for investigation by Mr C.R. Cavey, of Roughgems Ltd. The vase was a forerunner of other material to be imported, possibly in some quantity, from the Charo river area in the Murun Massif, north-west Aldan, Yakutsk ASSR, USSR. The importers were told that the material was known as charoite.

As will be seen from the colour plate the charoite is of varying shades of vivid purple; on the Munsell System of colour notation the hues are between 2.5P and 5P, the values between 4 and 6 and the chroma between 6 and 10; a typical colour is 2.5P 5/10. It has a distinct fibrous appearance and wraps around subordinate masses of a greenish black mineral some of which appears to have been corroded during some episode in its history, but other areas show stellate acicular development. The vase also shows 'pools' of a pale greenish-grey translucent mineral, a prismatic orange mineral and small specks of a silvery metallic mineral with dark green haloes. The overall mineral assemblage is most unusual.

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Specific gravity measurement on the vase and a small slab both gave a value of 2.68. Refractive index determinations from the flatter surfaces gave values around 1.55 for the charoite and 1.52-1.53 for the areas of greenish-grey mineral. A scraping of the charoite from the base gave an x-ray powder diffraction pattern, which could not be matched in the Powder Diffraction File (JCPDS), with strong lines at 32Å, 12.42Å, 3.34Å, 3.20Å, 3.12Å, 2.97Å, and 2.79Å. Spacings as large as 32Å are not commonly recorded from minerals and this line is easily missed without the use of a low-angle collimator and beam trap. A semi-quantitative analysis was then obtained using the Energy-dispersive x-ray analyser on the Geoscan electron microprobe. The results indicated approximately 55% SiO_2, 20% CaO, 8-10% K_2O; 2-3% of BaO and Na_2O by weight and traces (less than 1%) of Fe, Al and Mn. Thus the charoite is essentially a calcium potassium silicate.

From x-ray and optical examination we were able to identify in the rock, greenish-black aegirine-augite, pale greenish-grey potash-feldspar (microcline), prismatic orange tinaksite (a titanium, sodium, potassium silicate described from the same area, (Rogov *et al.*, 1965)). The rock is dominated by the fibous purple charoite which has low birefringence, positive elongation, with an extinction angle of only a few degrees.

We have since learned that the purple mineral has now been fully investigated by the Russians (Rogova *et al.*, in press), who propose a formula of $(Ca,Na)_2KSi_4O_{10}(OH,F).H_2O$. The name charoite, which was first published in October 1976 (Nikol'skaya *et al.*, 1976), has been approved by the International Mineralogical Association and since a full mineralogical account is in press it was inappropriate that we should pursue our studies further. However, material is now becoming available commercially and it seems desirable that sufficient information should be presented to allow identification.

In conclusion, charoite occurs as a fibrous purple mineral (but also appears in a fine grained form) which dominates a spectacular metasomatic rock formed at limestone contacts from the Murun massif, north-west Aldan, USSR. Refractive indices on polished charoite surfaces are around 1.55, and the specific gravity of the rock is 2.68. Charoite appears inert under both UV radiations (but its purple colour and the visible violet radiation from the lamps makes accurate observation difficult); the associated feldspar glows

Vase (18.5 cm high) showing fibrous purple charoite wrapping around black aegirine-augite, with 'pools' of greenish-grey microcline and orange tinaksite, Charo River, north-west Aldan, Yakutsk, USSR.

a dull red under long wave (365 nm) radiation. There is no distinctive absorption spectrum apart from partial general absorption of the green. The hardness is between 5 and 6 on Mohs' scale.

A fine vase of charoite is now on display in the Geological Museum, London, kindly lent by Roughgems Ltd, London. Finally we should like to thank colleagues in the IGS for assistance in many ways.

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ON THE COMPOSITION OF GEM SCAPOLITES

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INTRODUCTION

Scapolite is a group name applied to a solid solution series between two end-members. The end-members are marialite, $Na_4Al_3Si_9O_{24}Cl$, and meionite, $Ca_4Al_6Si_6O_{24}CO_3$. Petrologists frequently subdivide the group further using the names mizzonite and dipyre for intermediate compositions, but since the scapolite group is a two-member series, the gemmologist uses but two names. Scapolites with appreciable sulphate content are known, but have not yet been encountered as gem material.

Hence, scapolites with Ca>Na (in atom per cent) are meionite, and those with Na>Ca (in atom per cent) are marialite. Since few

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gem scapolites have been chemically analysed, this effort was initiated to determine as precisely as possible the compositions of gem scapolites from different localities, and to determine whether or not gem material is limited to any given composition.

PREVIOUS WORK

For an overview of gem scapolite, the reader is referred to Webster (1975). Scapolites from Espirito Santo, Brazil, and Madagascar were examined by Perizonius (1966) and found to be meionite, adopting the nomenclature discussed previously. The yellow scapolites from Umba, Tanzania, were described in detail in an excellent paper by Zwaan (1971), who also noted and photographed the inclusions present in the material. Bank and Nuber (1970) described the scapolites from Entre Rios, Mozambique. For a more detailed explanation of scapolite chemistry, the reader is referred to the work of Evans *et al.* (1969).

PHYSICAL PROPERTIES

Meionites have a higher density than marialites, but the density is not a reliable indicator of composition due to the complex ionic substitutions prevalent in most scapolite. The refractive indices of this uniaxial negative gem are far more reliable as an indicator of composition. Both the refractive indices and the birefringence increase with increasing calcium content, and reliable charts have been prepared which correlate the refractive indices with composition (Deer *et al.*, 1963 and Bank, 1970). The refractive indices for the four faceted gems examined in this study are given in Table 1. The determinations were made using sodium light and a

TABLE 1

OPTICAL DATA FOR SELECTED GEM SCAPOLITES

NMNH#	*Locality*	*Colour*	*Species*	ε	ω	*Birefringence*
G1819	Madagascar	Colourless	Marialite	1.552	1.569	0.017
G1818	Madagascar	Colourless	Marialite	1.546	1.562	0.016
G3674	Burma	Pink	Marialite	1.545	1.558	0.013
G3783	Burma	Lt Yellow	Meionite	1.554	1.587	0.033

all measurements ± 0.003

Rayner Dialdex refractometer. All of the examined gems and gem rough were also examined with ultraviolet, since most scapolites exhibit fluorescence in ultraviolet radiation. The results of these observations are noted, together with the chemical analyses, in Table 3.

CHEMISTRY — WET CHEMISTRY

A gem-quality scapolite from Brazil weighing about 20 carats was subjected to a full wet-chemical analysis. The sample was crushed to 60-80 mesh size for use as an electron microprobe standard. The sample portion <80 mesh was ground in a boron carbide mortar for chemical analysis.

The general scheme of analysis followed methods described in the literature: Peck (1964), Jarosewich (1966), Hillebrand *et al.* (1953). Silica was filtered off after double dehydration with HCl, followed by ignition and volatilization with HF. Further recovery of silica was made in the R_2O_3 precipitate. The iron was determined

TABLE 2

WET-CHEMICAL ANALYSIS OF
BRAZILIAN MEIONITE

SiO_2	49.78%
Al_2O_3	25.05
FeO	0.17
CaO	13.58
Na_2O	5.20
K_2O	0.94
CO_2*	2.5
SO_3	1.32
Cl	1.43
H_2O^{+}*	0.21
	100.18
O=Cl	0.32
TOTAL	99.86

Specimen # R6600
analyst: J. Nelen
*J. Norberg

colorimetrically as the *o*-phenanthroline complex. The aluminium was weighed as the 8-hydroxyquinolate. Calcium was precipitated as the oxalate and ignited to CaO. Separate samples were used for CO_2—volatilization with an HCl/HF mixture and absorption on ascarite; the alkalies—flame photometrically; H_2O^+ by the Penfield method; chlorine—as silver chloride; and sulphur—as barium sulphate. Appropriate blanks were carried through the various steps and corrections made accordingly. The analysis is given in Table 2.

CHEMISTRY—MICROPROBE ANALYSES

Nineteen gemmy scapolites from the collections of the Smithsonian Institution were analysed. All the samples were of facetable quality except one from Canada. The lot was comprised of 7 cut gems from the exhibit hall, and 12 uncut gemmy crystals. The samples were analysed using an electron microprobe with an operating voltage of 15 kV, and a sample current of 0.15μA. The data were corrected by computer using Bence-Albee correction factors. The standard used for all elements was the Brazilian scapolite cited in Table 2. The microprobe analyses of seventeen of these samples are given in Table 3, in order of decreasing calcium content.

CHEMISTRY—GENERAL COMMENTS

The gem scapolites examined in this study are all mixtures between marialite, $Na_4Al_3Si_9O_{24}Cl$, and meionite, $Ca_4Al_6Si_6O_{24}CO_3$. None of the samples examined were pure end-members. The ionic substitutions involved in the series are complex; in mixtures between marialite and meionite, aluminium increases and silicon decreases as calcium increases. Further, calcium-rich members of the series have substantial $CO_3^=$ (carbonate) and sodium-rich members contain chlorine. Hence, only end-member marialite and meionite have simple compositions. It is obvious from an examination of the summations of the analyses in Table 3, that calcium-rich members have low summations. This is due, for the most part, to the presence of carbon which is not detectable by microprobe analysis. Small amounts of water (>1.00% in some meionite analyses) are also not detectable by microprobe and lower the summations slightly.

TABLE 3

MICROPROBE ANALYSES OF GEM SCAPOLITES

LOCALITY	NMNH#	SiO_2	Al_2O_3	FeO**	CaO	K_2O	Na_2O	Cl	SO_3	O=Cl	TOTAL	%Me*	body colour	Ultraviolet luminescence short-wave	Ultraviolet luminescence long-wave	Species
Burma	G3783	45.33	27.15	0.31	17.38	1.10	2.82	0.64	0.00	0.15	94.58	72	colourless	medium pink	weak pink	Meionite
Quebec, Canada	R13120	47.07	25.67	0.04	15.99	0.50	3.95	0.41	1.22	0.09	94.76	67	yellow-green	medium yellow	strong yellow	Meionite
Tanzania	136405	48.39	25.57	0.01	15.47	1.08	3.63	0.56	0.66	0.13	95.54	64	yellow	medium yellow	strong yellow	Meionite
Madagascar (?)	R6570	50.04	25.25	0.16	13.80	0.94	5.13	1.41	1.54	0.32	97.95	57	colourless	medium pink	weak pink	Meionite
Minas Gerais, Brazil	B16098	49.39	25.00	0.22	13.79	1.03	4.80	1.32	1.61	0.30	96.86	57	light yellow	medium pink	weak pink	Meionite
Mogok, Burma	R11157	49.02	24.95	0.21	13.71	1.03	4.94	1.37	1.64	0.31	96.56	57	light yellow	medium pink	weak pink	Meionite
Minas Gerais, Brazil	133041	49.88	24.97	0.20	13.45	0.99	5.17	1.37	1.53	0.31	97.25	56	light yellow	medium pink	weak pink	Meionite
Minas Gerais, Brazil§	R6623	49.24	24.75	0.13	13.06	0.90	5.43	1.48	1.05	0.34	95.70	54	light yellow	medium pink	weak pink	Meionite
Brazil	123502	50.86	24.37	0.10	11.93	0.91	6.18	1.78	0.66	0.41	96.38	50	light yellow	medium pink	none	Meionite
Sri Lanka	G3238	51.53	24.31	0.07	11.59	0.95	6.22	1.59	0.20	0.37	96.09	49	light pink	light orange	medium orange	Marialite
Madagascar	G1819	51.21	23.62	0.13	11.22	0.60	6.79	1.76	0.76	0.40	95.69	47	colourless	medium pink	light pink	Marialite
Madagascar	G1818	51.77	23.66	0.14	10.90	0.57	6.80	1.90	0.76	0.44	96.06	45	colourless	medium pink	light pink	Marialite
Betroka, Madagascar	117358	54.80	22.64	0.36	8.60	1.70	7.69	2.85	0.43	0.65	98.42	36	colourless	medium pink	light pink	Marialite
Tanzania	....	55.79	22.23	0.21	7.89	1.32	8.37	2.69	0.55	0.62	98.43	33	light yellow	medium pink	light pink	Marialite
Tanzania	134794	55.32	22.21	0.20	7.30	1.59	8.64	2.93	0.79	0.67	98.31	30	brown-yellow	medium pink	none	Marialite
Entre Rios, Mozambique	132483	55.91	22.41	0.08	7.30	1.38	8.85	3.11	0.16	0.71	98.49	30	colourless	medium pink	none	Marialite
Burma	G3674	55.02	22.62	0.05	7.25	1.82	8.66	2.90	0.29	0.69	97.92	30	pink	light orange	medium orange	Marialite

§ - from Rio Pardo, Minas Gerais, Brazil
* - percentage of the meionite end-member
** - total iron calculated as FeO
accuracy of data ± 3% relative
all samples have less than 0.10% MgO

DISCUSSION

It is apparent from the analyses presented in Table 3 that the compositions of the gem material examined in the study vary from meionite $_{72}$-marialite$_{28}$ to meionite$_{30}$-marialite$_{70}$. All four specimens from Brazil are meionite, the calcium-rich end-member, and are quite similar in composition. The examined Madagascar gems, however, are marialite, the sodium-rich end-member. One sample, #R6570 is of questionable locality and the (Madagascar?) designation indicates this uncertainty of its provenance. Given the fact that the other Madagascar scapolites are marialite, this may very well be a Brazilian specimen.

Unlike the Brazilian meionites, the Madagascar marialites do vary widely in composition. Burmese scapolites also have widely varying compositions and it is noteworthy that the most sodium-rich and most calcium-rich gems examined in this study do come from Burma. The sample numbered G3783 is a superb 288 carat colourless gem and may be the largest cut scapolite in existence, in addition to being the most calcium-rich. Also of Burmese origin are some white or grey chatoyant gems, which yield very fine cat's-eyes. Due to the cabochon-cut and the requirement that we must have a flat surface for accurate microprobe analyses, only semi-quantitative analyses could be performed on these two gems. The resultant analyses (not given here) indicate these Burmese chatoyant scapolites have compositions near a mid-point in the series. The light yellow material from Tanzania, studied by Zwaan (1971), is marialite, as Zwaan noted in his excellent description of the material.

The most unusual scapolite the authors have seen was brought to their attention by Mr Herb Obodda, a noted American gem merchant. This scapolite, reportedly from Tanzania, has a very strong yellow body colour and the piece examined is facetable. The fluorescence of this material in ultraviolet radiation is remarkable for a gem mineral. The fluorescent colours are a strong yellow in short wavelength ultraviolet and an extremely intense strong yellow in long wavelength ultraviolet. There is no phosphorescence. Only a tiny chip of the material was available for analysis and the optical properties were not measured. However, the material does come in pieces large enough to cut gems of several carats. This yellow scapolite is very weakly fluorescent in x-radiation with a light yellow fluorescence and phosphorescence. This yellow gem material is a meionite, unlike the other Tanzanian gems examined, and has a composition very close to the opaque Canadian material (#R13120), which has a similar if somewhat less intense fluorescence.

In summary, gem scapolites have varying compositions. The Brazilian gems examined are meionite and the Madagascar gems examined are marialite. Light yellow Tanzanian scapolites are marialite, and the composition of Burmese material varies widely.

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AN INSIGHT INTO CRYSTAL GROWTH TECHNIQUES

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1. INTRODUCTION

What are single crystals and why are they important?

A crystal is an ordered structure on an atomic scale; in a single crystal this order persists in three dimensions to the external boundaries, unlike a polycrystalline or ceramic solid which is composed of many smaller crystals, often of random orientation.

For the physicist interested in measuring the properties of materials, or the technologist making devices, an ordered assembly of atoms provides the ideal or optimum arrangement for the production of useful physical properties, in particular co-operative phenomena, e.g. lasers, oscillators. This is in contrast to a polycrystalline solid, where the grain boundaries between the crystallites not only interfere with physical processes but even dominate the bulk properties. Unfortunately, perfect single crystals do not exist in nature, and the scientist has to accept the fact that even in the laboratory as-grown crystals will contain imperfections on a micro- or macro- scale.

From the viewpoint of the crystal grower the role of imperfections also has important implications. To understand the reason why, we must examine how real crystals grow. The underlying theme throughout will be the control of growth processes, since only by understanding and control of the underlying mechanisms can the crystal grower hope to achieve an acceptable product.

2. THE BASIC GROWTH PROCESS

To produce an ordered solid (crystal) from relative disorder, e.g. gas, liquid or solid, involves a phase transformation and a change in the volume free energy—thus some *driving force* is necessary. The most common driving forces in crystal growth processes are produced via a concentration gradient (ΔC) or a

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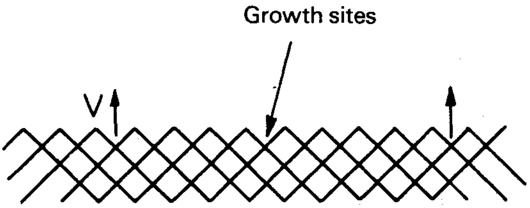
temperature gradient (ΔT), though others are possible, e.g. electrochemical potential via an applied voltage.

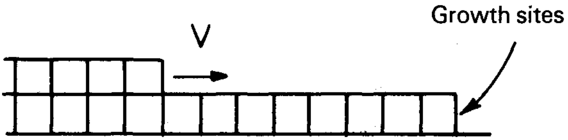
It is usual to analyse a growth system theoretically in terms of a single driving force—but invariably several operate in parallel with one dominating.

The overall driving force causes a net flow of atoms down the gradient to the solid interface and the subsequent removal of evolved latent heat. It is obvious that surface processes at this *growth interface* play a vital role. It is here that atoms finally become incorporated into the crystal, possibly after diffusion across the surface, and the manner in which they do so determines the final ordering in the crystal. The growth rate and the subsequent perfection of the bulk crystal lattice will depend on (a) the magnitude of the driving force and (b) the physical nature of the interface.

Two extreme types of interface will be mentioned here and denoted *rough* and *smooth.* A comparison of the two (Fig. 1)



'ROUGH' INTERFACE
≡ NON-HABIT PLANE



'SMOOTH' INTERFACE
≡ HABIT FACE

FIG. 1

reveals a fundamental difference: a rough interface always has available growth sites over the whole surface, while a smooth interface only offers growth sites at steps and growth must proceed by lateral spreading of layers. In this case, to grow at low supersaturations, i.e. small driving force, it is necessary to have a continuous source of new layers, and the existence of spiral sources, or other defects due to slipped planes of atoms, does provide these in practice. It is thus interesting to note that the presence of defects can actually aid the growth process. A practical demonstration of this is that under identical conditions damaged crystals will grow faster than perfect ones.

In general, for a given magnitude of driving force, growth is easier on a rough interface as there is no surface diffusion process to be driven. Put another way, we expect faces corresponding to rough faces to grow at lower supersaturations. Since a smooth interface corresponds to one face of a faceted crystal, while a rough face is generally a non-equilibrium face, which tends to grow out and disappear, it is not surprising to find that slow growth processes such as solution or gel growth produce faceted crystals and vice-versa.

3. CONTROL OF GROWTH PROCESSES

Qualitatively, we can see that the magnitude of the driving force controls the growth process by determining the growth rate. This implies that we should have means to control ΔC, dominant in solution growth, or ΔT in melt growth. A typical practical method would be to use a temperature sensing element with some feedback loop to the input heating source.

Problems in controlling the interface via growth rate arise if there are fluctuations in the latter caused by

(i) temperature fluctuations—external cause:

(ii) non-steady flow—internal cause (hydrodynamic).

In the presence of impurities, or in a multi-component system, either too fast a growth rate or lack of affinity of the impurity for the lattice can cause a 'pile-up' of atoms ahead of the interface, leading to a local reduction of liquidus temperature. This is a condition known as constitutional supercooling (CSC) and the presence of this renders the interface unstable with the possibility of breakdown and gross inclusions under adverse conditions (Fig. 2).

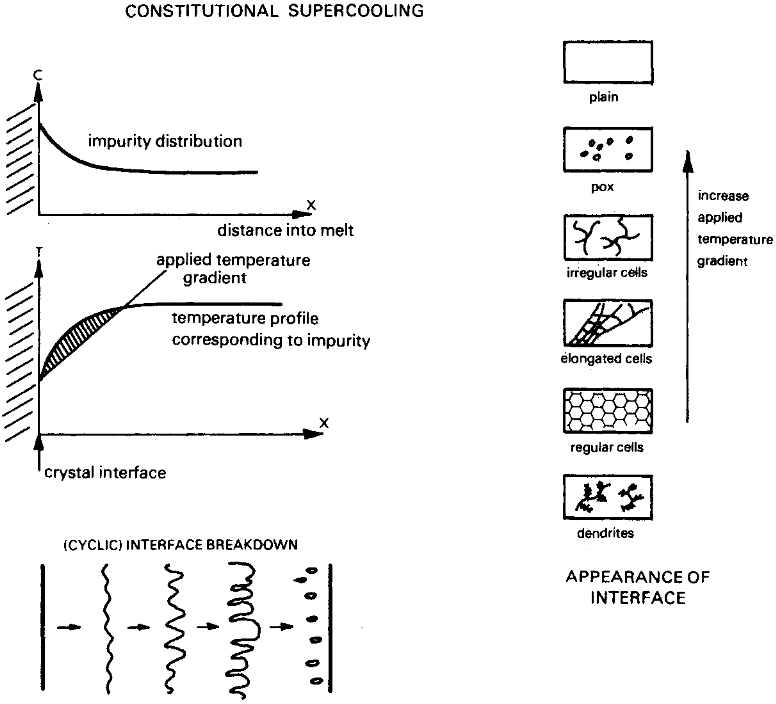


FIG.2

The effect of this can be seen in natural crystals as included bubbles, 'veils' of solution and foreign particles.

In general, the onset of breakdown can be minimized by (a) reducing growth rate, (b) improving temperature control, (c) altering geometry, (d) use of steep temperature gradient at interface etc., depending on the particular case involved.

The crystal orientation—and hence the nature of the growing interface—can be controlled, *a priori,* by the use of appropriate seeds, the 'quality' and preparation of which play a vital role in the subsequent growth, e.g. certain defects may be propagated. Seeds need not be of identical material, but must be chemically compatible and usually a close match in lattice parameter.

4. DOPING AND HYDRODYNAMICS

It might be thought surprising that hydrodynamics should be at all relevant to crystal growth. However this can be made clear by a general example, i.e. in any liquid system (also gaseous) where there is a temperature gradient not aligned with g, the force of gravity, then convection can occur. Convection, being a random fluid flow process is undesirable for a crystal growth situation as it represents a process which cannot be controlled. Convection can be used in certain cases to aid homogenization prior to growth, but its occurrence during growth leads to fluctuations at the interface which affect both stability (via CSC) and the momentum boundary layer width, δ, due to the relative motion between solid and liquid which must be zero at the solid. Let us see how this happens.

We can define a segregation coefficient k_o which is simply the ratio of dopant in the crystal to that in solution (Fig. 3). Analysis for a moving (i.e. growing) interface gives

$$k_o = \frac{k^*}{k^* + (1-k^*)\exp(-f\delta/D)}$$

Here f is the growth rate, D is the diffusion coefficient of dopant and k* is the segregation coefficient at the interface, differing from k_o due to the concentration drop due to diffusion across the interface, i.e. if δ small $k_o \rightarrow k^*$, or if f large (fast growth) $k_o \rightarrow$ unity.

Additionally the dopant concentration in the crystal will reflect variations in both f, e.g. due to temperature fluctuations, and in δ due to the fluid flow effects under discussion.

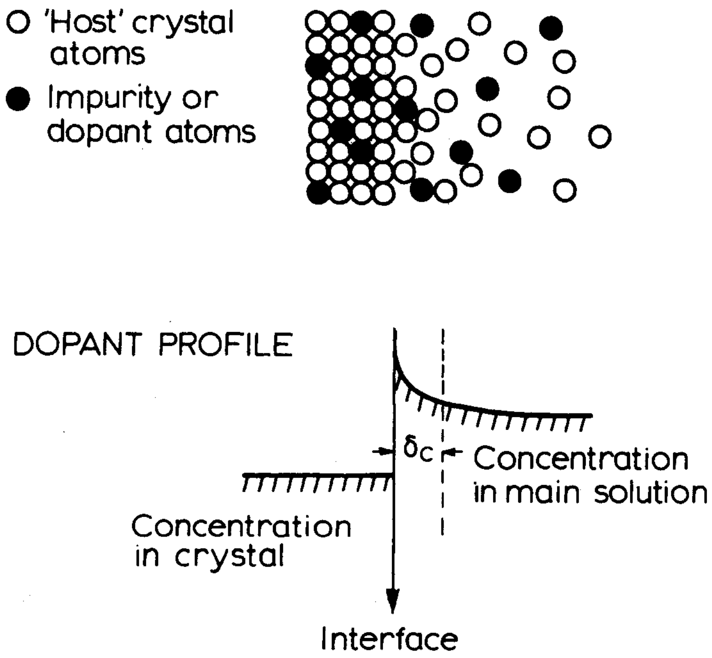
5. CLASSIFICATION OF GROWTH PROCESSES

Before considering any process in detail, it is worthwhile to consider a classification scheme which covers all growth processes. This provides insight and understanding of how various processes are related.

Firstly, a word regarding purity. It is to be understood that *all* systems contain some impurity, i.e. even semiconductor materials are seldom better than 99.9999% purity. We define a *pure* system as one which contains no deliberately added impurity. Examples of *impure* systems would be

(i) solvent in solution growth;
(ii) dopant to modify properties, e.g. semiconductors, lasers, phosphors;
(iii) halide to provide volatile species in vapour growth.

We shall also distinguish between *Batch* and *Continuous* processes.



$$\frac{\text{SEGREGATION}}{\text{COEFFICIENT}} = \frac{\text{AMOUNT IMPURITY IN CRYSTAL}}{\text{AMOUNT IMPURITY IN SOLUTION}}$$

If S.C. < 1 impurity <u>rejected</u> at interface.

For a growing crystal under steady-state conditions

$$k_{eff} = \frac{k^*}{k^* + (1 - k^*)\exp(-V\,\delta_c/D)}$$

k_{eff} is effective S.C.

k^* is S.C. at interface

FIG. 3

CLASSIFICATION OF GROWTH PROCESSES

A. BATCH PROCESSES

Transformation	*Pure System*	*Impure System*
S→S	Strain Anneal	—
L→S	Directional Freeze§	Solution Growth
V→S	Condensation	—

B. CONTINUOUS PROCESSES

Feed	*Growth Zone*	*Pure*	*Impure*
S→	S→S	Phase Transformation	—
L→		CuCl Growth	Gel Growth
V→		—	—
S→	L→S	Zone Melting§ - Verneuil§	Travelling Solvent§
L→		—	Monotectic Growth
V→		Volatile Feed - Verneuil	VLS Process
S→	V→S	Evaporation →Condensation	Chem. Vap. Transport§ (or Carrier Gas)
L→			
V→		—	—

§Most Important Industrial Processes

FIG. 4

CHOICE OF GROWTH TECHNIQUE

(1)	Melting Point?	0—1200°C	Bridgman
		0—2200°C	Pulling or Verneuil
		>2200°C	Fluxed Melt
(2)	Water Soluble?		
	(a) Near Ambient	0—60°C	Water Solution
	(a) Higher Temp./Press	0—600°C	Hydrothermal
(3)	High Vapour Press? Stable on heating in Vacuo, Air, Inert Gas?		Vapour Transport Fluxed Melt Sealed Bridgman
(4)	High Viscosity when Molten →Glassy?		Solution, Flux, CVT
(5)	Melts Congruently?	Yes -	Bridgman Pulling
		No -	Solution, Flux, CVT

Purity	—	Containerless techniques Vapour Phase
Orientation	—	Seeding and Control
Size	—	Relate to time for Diffusion Lim. Process, or Melt Growth
Perfection	—	Slower Growth Technique Unconfined Process
Toxicity	—	Sealing, Fume extraction, Solution

FIG. 5

i.e. *Batch*—a fixed amount of material is processed:
Continuous—new material is added during growth process.

Then, for a single stage (batch) process, there are three transformations,

i.e. $$\left.\begin{array}{l}\text{(solid) S}\\ \text{(liquid) L}\\ \text{(vapour) V}\end{array}\right\}\rightarrow\text{S(crystal)}$$

and for a two-stage process, nine are possible (see Fig. 4). It should not be expected that all of these will correspond to *practical* growth processes, and in fact, several are either not found or are quite rare in practice.

It is not intended here to describe growth processes in detail; rather we shall compare some of the most important industrial processes to illustrate important similarities and differences and show a few examples of other processes which are used in the laboratory to grow important technological crystals. The factors influencing the choice of a particular technique are indicated in Fig. 5.

6. DIRECTIONAL FREEZING TECHNIQUES

These are all melt growth processes and heat flow controlled. In the diagram (Fig. 6) the directions of heat flow are indicated. There will usually be some degree of fluid motion, initially laminar, which may become turbulent in extreme conditions. Where there is also relative motion between growth interface and fluid, the flow may more easily become complex and adversely alter the interface shape (Fig. 7), e.g. change from rough to smooth. Conversely, without rotation, flexibility in control would be lost. Thus, the pulling technique is the most versatile of these processes. The crystal diameter is controlled by the rotation speed and the undercooling, while the growth rate is controlled by the pulling speed with a theoretical upper limit set by the rate at which latent heat can be extracted.

They are all important industrial batch processes except that under special circumstances the Czochralski can be made continuous.

Examples of materials grown:-
Kyropoulos : alkali halides
Bridgman : rare earth fluorides
Czochralski : YAG, ruby, silicon

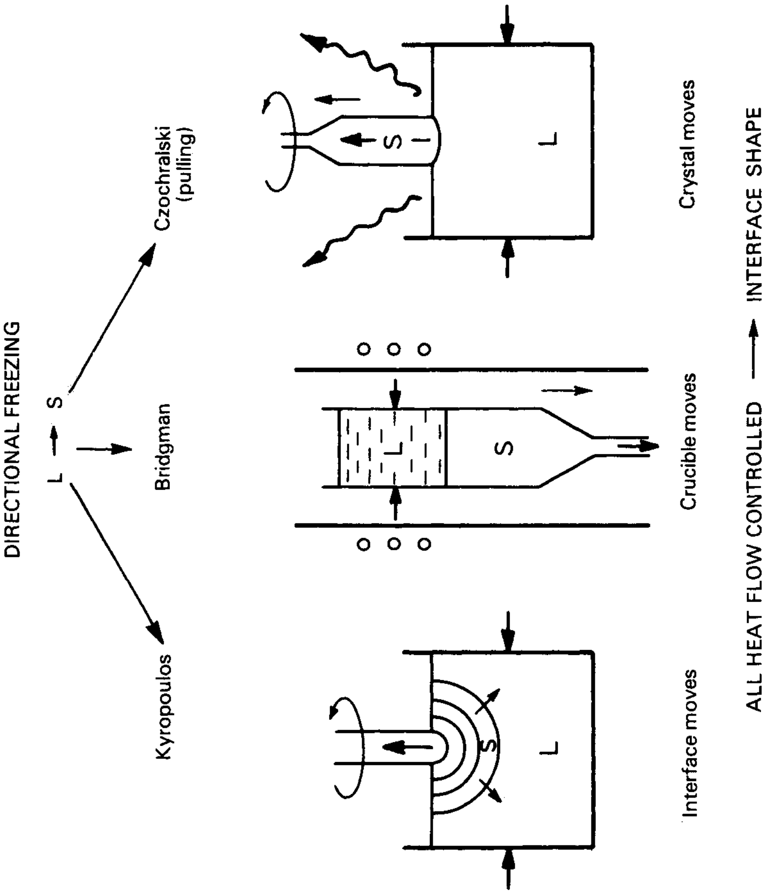

DIRECTIONAL FREEZING
L → S
Czochralski (pulling)
Bridgman
Kyropoulos
S
L
S
L
S
L
Crystal moves
Crucible moves
Interface moves
ALL HEAT FLOW CONTROLLED → INTERFACE SHAPE

FIG. 6

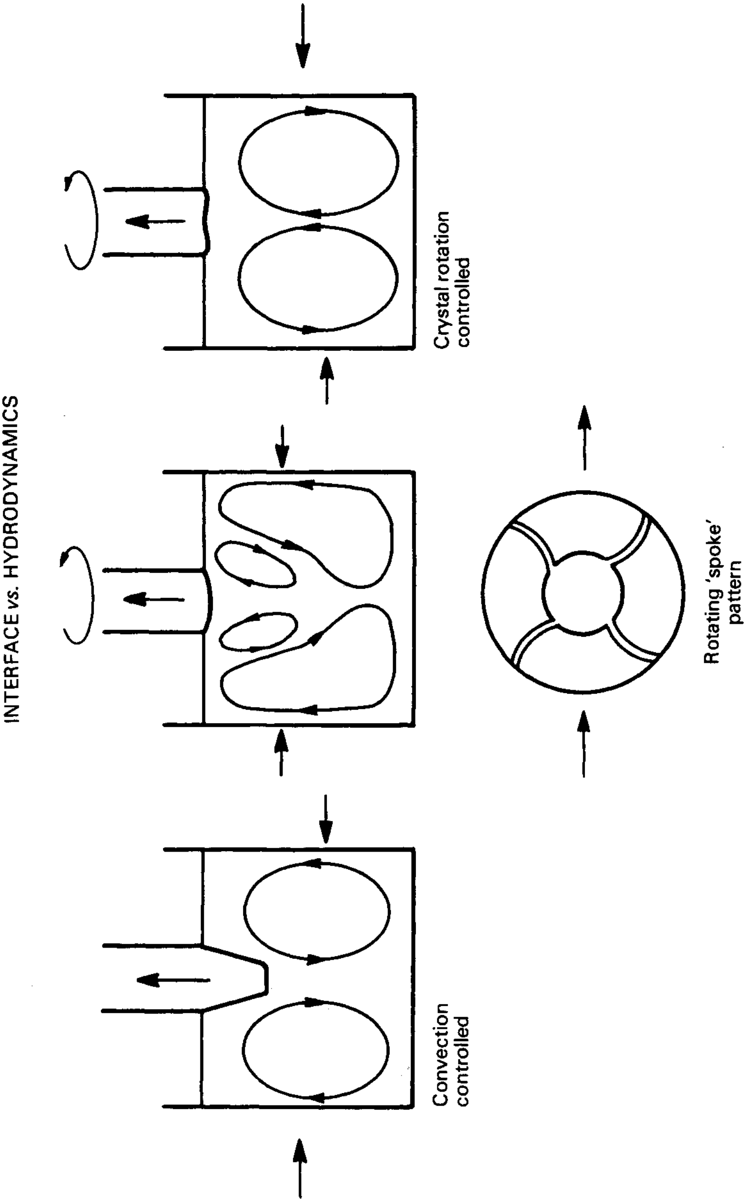

INTERFACE *vs.* HYDRODYNAMICS
Convection controlled
Crystal rotation controlled
Rotating 'spoke' pattern

FIG. 7

7. SOLUTION GROWTH TECHNIQUES

The major techniques are illustrated schematically in Fig. 8. Apart from the different temperature and/or pressure regimes in which these operate, the methods of growth are quite similar.

Supersaturation, (ΔC), is generated by solvent evaporation, slow cooling or temperature gradient transfer of some source material. Water solution or hydrothermal processes are invariably seeded, while the fluxed melt process usually relies on spontaneous nucleation for the growth of new crystalline materials for research. Seeds can be used, e.g. for growth of larger YIG crystals, although this is more difficult to achieve in practice.

Good fluid mixing is necessary to obtain good growth. Mechanical stirring is used in water solution growth, while the presence of lateral or vertical temperature gradients promotes convective mixing in the other techniques.

Referring to the solubility diagram, the means by which supersaturation arises in the various cases is illustrated, where the solid line is the solubility curve, the dotted line represents the 'growth curve' and the lower curve the metastable limit. XY represents the cyclic process (solvent circulation). It should also be noted that for isothermal evaporation the system remains essentially at B, at a fixed ΔC for growth; while (slow) cooling causes the system to move down the growth curve where ΔC may gradually vary. This has implications for control of surface kinetic processes which are activated processes, varying with the driving force.

For the growth of large crystals, growing three-dimensionally, linear cooling leads to a linear growth rate which falls off $\propto$ $(\text{time})^3$. The effect of this can be seen when growing doped (transparent) crystals in which doping varies over the cross-section. This can be particularly marked in cases of spontaneous nucleation; when the nuclei form initially, the growth rate is very rapid before the system returns to the growth curve, and such crystals while of good appearance contain highly dendritic centres. With a knowledge of the solubility curve a suitable cooling programme can be devised which maintains the growth rate linear, and in the presence of seed crystals good control over the properties may be achieved.

An important practical consideration is that, generally, melt growth techniques provide the fastest growth rates, of the order of

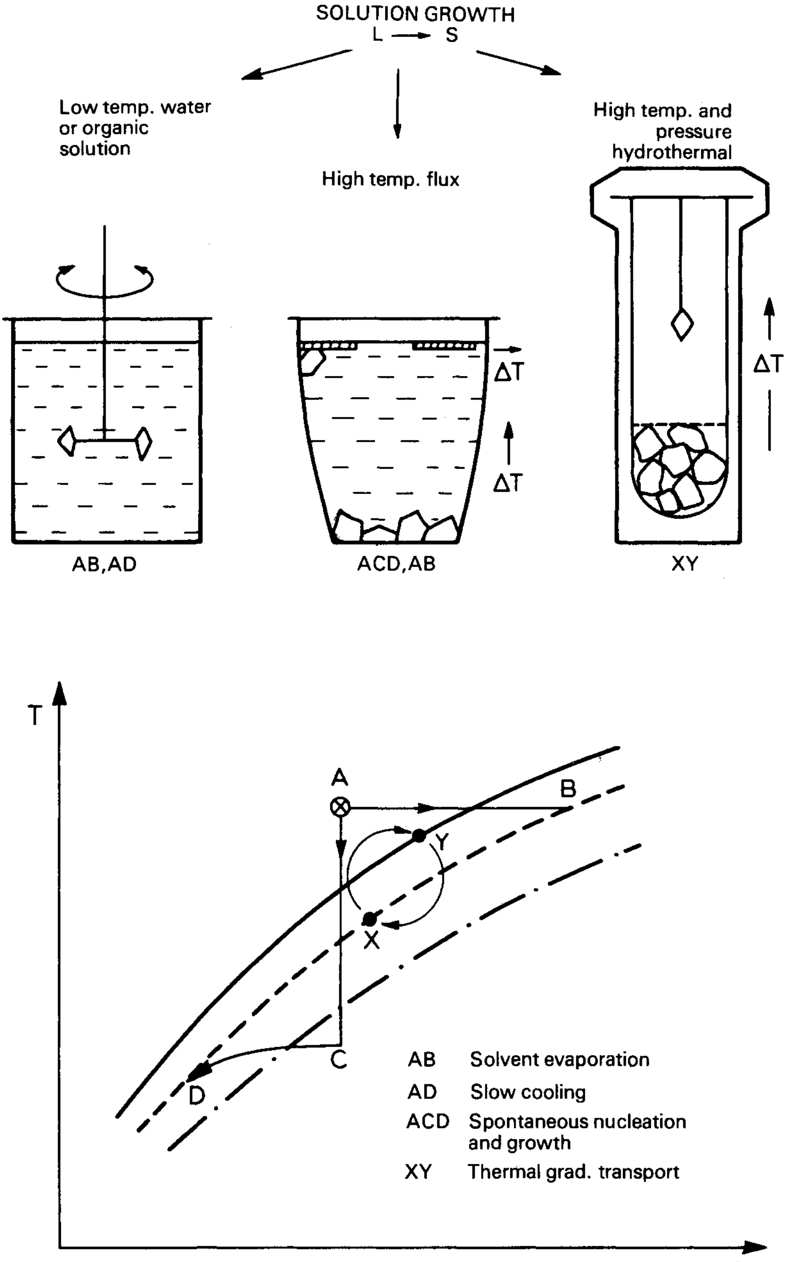
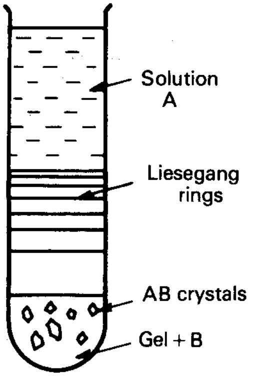

SOLUTION GROWTH
L → S
Low temp. water or organic solution
High temp. flux
High temp. and pressure hydrothermal
ΔT
ΔT
ΔT
AB,AD
ACD,AB
XY
T
C
A
B
Y
X
C
D
AB Solvent evaporation
AD Slow cooling
ACD Spontaneous nucleation and growth
XY Thermal grad. transport

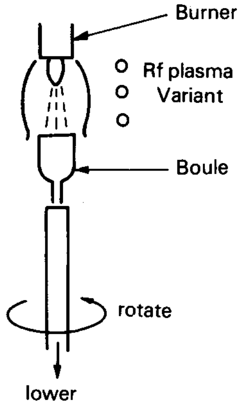
FIG. 8

GROWTH PROCESSES



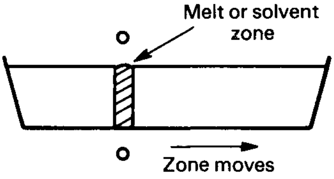
GEL GROWTH

$L \rightarrow S \rightarrow S$



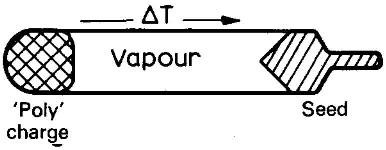
VERNEUIL

$\binom{S}{V} \rightarrow L \rightarrow S$



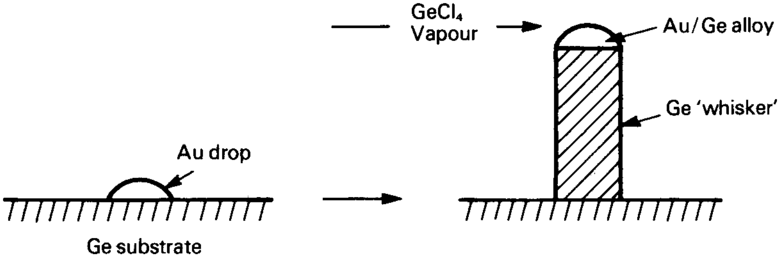
ZONE CRYSTALLIZATION

$S \rightarrow L \rightarrow S$



CHEMICAL VAPOUR TRANSPORT

$\binom{S}{L} \rightarrow V \rightarrow S$



VLS PROCESS

$V \rightarrow L \rightarrow S$

FIG. 9

cms/hour or more, whereas in solution techniques growth rates are diffusion limited to ∼mms/day, a difference of 1000:1. Thus it would be expected that the former would be preferred for production processes, apart from the fact that when growth has to take place over weeks or months there are many more chances for 'control failures', e.g. due to power cuts!

Despite this, solution techniques are notable for the production of large crystals (> 100 grams) of certain classes of materials—particularly for ferroelectric and electrooptic applications.

Water solution—ferroelectric and electrooptic; TGS, KDP, etc.
Fluxed melt —magnetic oxides; YIG, ferrites, etc.
Hydrothermal —quartz, etc.

8. OTHER IMPORTANT TECHNIQUES

In Fig. 9 are illustrated a selection of other important and/or interesting growth techniques we shall describe briefly:—

(a) Gel growth

Can be used to grow certain sparingly soluble materials when one component is contained in a gel, while the second diffuses slowly from a solution in contact with the gel. This is a very slow process but requires little apparatus, e.g. large test tubes or simple glass geometries can be used. Materials grown include calcium tartrate, lead iodide, cuprous chloride.

(b) Verneuil process

This is still used to provide alumina etc. for watch bearings and 'sapphire' styli (though the former usage may decrease somewhat with the current advent of digital quartz watches!): a drawback, however, is that the feed powder must be capable of being prepared sufficiently free-flowing.

As a technique it can be considered akin to an inverted pulling process—the important difference is that here the molten zone is a thin layer ∼ 20μm thick and is sensitive to temperature fluctuations caused by variations in gas flow and powder feed. It is not then surprising that Verneuil grown material tends to have many defects such as microscopic inclusions of bubbles and unfused powder together with dopant 'banding', e.g. in ruby, as a result of periodic onsets of CSC.

As a result, the technique is not used for the production of electronic materials but is still a valuable research tool as its range can be extended to high temperatures by use of tricone burners or gas plasma and refractory crystals can be grown, e.g. rare earth oxides.

(c) Zone crystallization

An important process, mainly used for purification and doping of semiconductors and metal alloys when multi-pass, multi-zones are used. In particular cases, if the rate of zone passage is slow, preferential crystallization results. For oxide materials a molten solvent zone can be used; other geometries are possible, e.g. 'sandwich' or spot diffusion.

A vertical geometry is used in electron beam float zoning for the production of pure silicon.

(d) Chemical Vapour Transport (CVT)

Vapour transport processes are important for the production of (semiconductor junction) electronic devices by diffusion of various dopants from the vapour. This is mostly carried out in a flow system with inert carrier gas. CVT, in contrast, is a sealed tube process in which a second component is added to a solid so that entirely gaseous species are formed at the growth temperature. In a temperature gradient a cyclic process occurs via a reversible reaction, e.g.

$$Y_2O_{3(g)} + 3Cl_{2(g)} \leftrightarrows 2YCl_{3(g)} + 3/2\ O_{2(g)},$$

somewhat analogous to the transfer process involved in hydrothermal growth.

For the growth of many oxides and chalcogenides, ampoules are usually constructed from silica and located in a suitable temperature gradient inside a tube furnace typically in the range 1150 °C→900 °C.

The ampoule tip can be constricted in such a way that, in conjunction with pulling the ampoule through a reverse gradient, this tip is first cleaned and then the site for preferential nucleation. In a similar manner to crystallite selection in unseeded Czochralski growth, a dominant crystallite usually will emerge to grow into a small boule.

From the viewpoint of control, an inert gas, e.g. argon, can be introduced to limit transport and stabilize the interface against breakdown.

The VLS process is an interesting variant of the flow system and in a way resembles vapour-fed miniature Verneuil growth. At one time it was hoped that by suitable deposition of gold overlays on germanium complex structures could be grown which would avoid masking and etching techniques but it proved too difficult to control growth and composition.

9. NEW DEVELOPMENTS

It seems unlikely that any radically new growth method remains to be invented, though variations on existing themes are many and some novel applications do occur. We list below some interesting developments as illustrative examples which are shown in Fig. 10.

(1.) Flux/vapour technique: a combination of two techniques (L→V→S), i.e. material transport in PbF_2 vapour at 1200 °C to produce highly perfect alumina crystals with ratio of surface area: thickness of 1000:1.

*(2.) EFG process. E*dge-defined *F*ilm-fed *G*rowth is a variant of the Czochralski process in which a shaped die is used in the melt to control crystal cross-section. Growth of Si, Al_2O_3, $MgAl_2O_4$ is possible at high speeds (cms/sec) to produce cheap substrates and solar cells. The melt interface is replenished by capillarity and the crystal strip or fibre is wound onto a drum. This offers a semi-continuous process but it is difficult to control ST effects which lead to breakdown of the interface and cause strings of bubble inclusions.

*(3.) LPE process. L*iquid *P*hase *E*pitaxy. This is used for the growth of thin magnetic layers from fluxed melts for magnetic bubble layers. The novelty is the use of a horizontal rotating disc substrate to give control of the boundary layer. Thin ($\sim 10\mu m$) single crystal films can be grown in about 5 or 10 minutes. Growth is isothermal, hence compositional control is good, due to the fact that the addition of 10% B_2O_3 to PbO melt allows a supercooled state to persist for periods up to 20 hours.

(4.) Capillary growth. Certain organic crystals can now be crystallized (as single crystals) in lengths of hollow optical glass fibre. The orientation is controlled by temperature gradients as the freezing interface is traversed along the core of the material filled fibre. These will be important 'active elements', i.e. light modulators, in the new generation of optical fibres.

NOVEL GROWTH TECHNIQUES

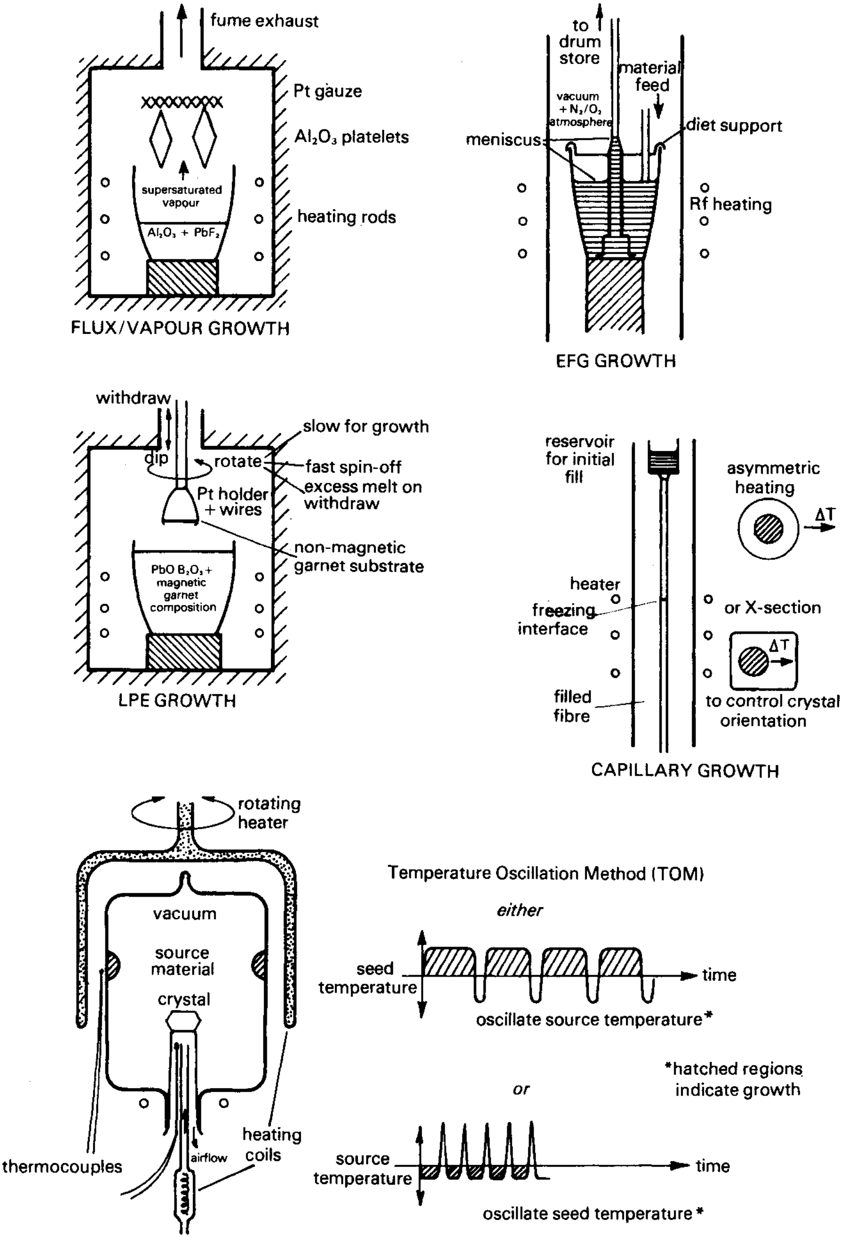


FIG. 10

*(5.) TOM. T*emperature *O*scillation *M*ethod. Here advantage is taken of the fact that if the growth temperature is cycled about a mean value—due to surface-to-volume free energy differences—small crystal nuclei evaporate faster than large ones. This principle is used to control vapour growth processes in which even a small supersaturation produces multiple nucleation. By adjusting conditions single nuclei can be selected and then, by altering the relative evaporation/cooling periods, grown into large single crystals.

(6.) Space processing. The Space-Lab project offers the possibility of material processing in zero-g conditions. The most obvious benefit might be thought to be absence of convection leading to striation-free crystals, but evidence from key experiments suggests that surface tension effects may predominate in zero-g. Certainly there are interesting transport effects occurring in these conditions, but in general the proposals for exploitation do not seem to match up to the opportunity. It needs perhaps the idea of actual *space* processing, i.e. the ultimate crucible-less technique would be a molten spherical charge in orbit round the space-shuttle, heated by giant parabolic mirrors. The details of multiple access, manipulation and method of freezing the melt is left to the imagination of the reader!

Whatever the context, it is hoped that this article will help the reader to follow future developments of crystal growth processes with more understanding.

ACKNOWLEDGEMENT

I should like to express my thanks to Dr E.A.D. White for my introduction to crystal growth and much subsequent encouragement.

[*Manuscript received 5th February, 1977.*]

FURTHER DEVELOPMENTS IN SYNTHETIC MATERIALS

By M.J. O'DONOGHUE, M.A., F.G.S., F.G.A.

(based on a lecture delivered to the North-West Branch of the Gemmological Association on 10th February, 1977)

Zinc sulphide (ZnS) has a hexagonal variety as well as the cubic one well-known to mineralogists as zinc blende or sphalerite. The hexagonal variety is wurtzite and it is this which has been prepared by Diehl(1) at the University of Freiburg, West Germany. Doped with Co^{2+} the crystals are a magnificent bright green; those doped with Ni^{2+} are yellow and those with Cu^{1+} are blue. The crystals I have examined show prism and pyramid forms with some parallel growth. Diehl measured the refractive index of this material on the Gemeter and found it to be 2.30 ± 0.005. Hardness was 3-4 on Mohs's scale and the specific gravity 4.06 g cm^{-3}. The crystals are made by the chemical transport method; this involves vaporizing the required compound from a polycrystalline or amorphous source at a high local temperature, transporting it down a temperature or pressure gradient and depositing it on a substrate or seed crystals at a lower temperature. It is interesting to note that wurtzite is generally found associated with sphalerite in nature; it is the high-temperature modification of ZnS and is formed by heating sphalerite above 1020 °.

Although yttrium ortho-aluminate, $YAlO_3$, has been known for some years and regarded in some quarters as a possible diamond simulant, it is not easy to obtain and has never come close to rivalling YAG in the simulant field. It has a hardness of about 8½, refractive index of about 1.90 and a specific gravity of 5.36 g cm^{-3}. Grown by the Czochralski process, it was intended for laser use after doping with Nd. For laser use a material must have sharp fluorescent lines (cf. the emission lines in ruby), strong absorption bands and a high quantum efficiency for the fluorescent transition required. Such qualities are best shown in solids which can incorporate small amounts of elements in which optical transitions can be made between states on inner and incomplete electron shells. This is why the transition metals and the rare-earth

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or lanthanide series, with the actinides, are so important. Rare earths give sharp absorption lines (cf. the absorption spectrum of some apatites in which Nd occurs): they are sharp because the electrons involved in the transition from one shell to another are shielded by outer shells from the surrounding crystal lattice. Rare earths are elements in which the differentiating electrons lie in the third highest energy level: in the transition elements they lie in the second highest energy level, and those elements in which the outermost or highest energy level is the area of electronic differentiation are the most stable of the elements and combine unwillingly (though some fluorides such as XeF_4 have been synthesized). To act as a suitable laser host, a crystal or glass needs to have good optical, mechanical and thermal properties to stand up to operating conditions, so a high degree of hardness, high refractive index, lack of internal strain and resistance to radiation-induced colour centres are all important. Corundum, which fulfils these criteria, was naturally one of the first laser hosts to be tested. It acts as an excellent host for chromium, since the Al site is about the ideal size for incorporation of Cr: Nd-doped corundum cannot be made, since the Al site is too small for rare earths.

With these points in mind we can examine yttrium orthoaluminate further. It has high conductivity and hardness: it is anisotropic and grows faster than YAG. Distribution coefficients for rare-earth dopants are nearly ideal. In addition the anisotropic character of $YAlO_3$ means that particular directions of the rod can be selected for particular properties. Most of the material has been doped with Nd and the fluorescence occurs in three strong lines at 1.0645, 1.0725 and 1.0795 μm. Laser action has been achieved with Er^{3+}, Ho^{3+} and Tm^{3+} as well as with Nd^{3+}.

However, during the growth process Fe^{3+} was found to have entered the crystals; it appears to have arisen from volatilization of some part of the ceramic insulation used; the identity of the impurity was ascertained by checking the EPR spectra of all possible elements involved in the crystal growth process; only that of Fe^{3+} resembled that of the crystal in which the impurity was observed. Naturally the presence of iron as an inhibitor of fluorescence renders the material unsuitable for laser use, and for this reason it no longer appears in this connexion on the market. So far no way of growing the material free from Fe has been discovered.(2)

Three fluorides have been synthesized by Diehl(1); $RbMnF_3$, LiF and MnF_2. $RbMnF_3$ is grown by the Czochralski method and has a hardness of 4, specific gravity of 4.31 g cm^{-3} and refractive index of 1.428. It is a pinkish-brown in colour. LiF, also grown by the Czochralski process, has a hardness of between 3 and 4, specific gravity of 2.64 g cm^{-3} and refractive index of 1.392. Together with $RbMnF_3$, it crystallizes in the cubic system; when doped with chromium, a yellow colour is obtained. MnF_2 is a member of the tetragonal system and has a hardness of 4, specific gravity of 3.93 g cm^{-3} and refractive indices of n_o 1.475, n_e 1.505. The birefringence is 0.030. The colour is reddish or brownish pink.

It is interesting to note that with the divalent fluorides charge compensation is necessary when trivalent rare earths such as U are used as dopants. Trivalent uranium in CaF_2 gives a fine bright red, while divalent samarium in the same host gives green. Charge compensation can occur in a number of ways; one is where a mineral contains ions in both oxidized and reduced oxidation states. An electron can be transferred between the states so that one is oxidized and the other reduced. Similar transfer can occur between ions of different transition elements; Nassau(3) quotes Fe^{2+}–Ti^{4+} to give the blue in sapphire. The energy which arises from the movement of the electrons causes absorption of light.

The zinc tungstate, sanmartinite $(Zn, Fe, Ca, Mn)WO_4$, occurs with tungsten ores in a quartz vein at Los Cerrillos in the Argentine Republic. A member of the monoclinic crystal system it has a specific gravity of 6.70, but the refractive index has not been adequately measured. It should be possible to do so before very long, since sanmartinite has been synthesized using the Czochralski process. The colour is a purplish-brown.

Proustite,Ag_3AsS_3, might very well be mistaken for cuprite if both were encountered as cut stones. Both are very red with a metallic lustre. Proustite has been made by the hydrothermal method; it is a member of the hexagonal crystal system and is used for laser modulator and semiconductor work. It is soft, 2½-3 on Mohs's scale; the specific gravity is approximately 5.55-5.64 and the refractive index n_o 3.08, n_e 2.79. Surface alteration occurs on prolonged exposure to light: this also occurs with cuprite.

In a previous paper on synthetic materials I mentioned* the flux-melt growth of spinel, quoting the examples of red from doping with chromium and green from cobalt, together with yellow from the addition of iron or nickel. Through the kindness of Mr J.D.C. Wood, of Imperial College, I have recently obtained specimens of a dark blue spinel, like the previous examples octahedral in form: these are coloured by Cu.

Zirconium oxide, ZrO_2, has appeared as a diamond simulant and may be quite successful in this role, although, as in the case of gadolinium gallium garnet, early production was prone to discoloration. It crystallizes in the cubic system and has a hardness of between 8 and 9 on Mohs's scale; the specific gravity is 5.7 $g\ cm^{-3}$ and the refractive index is 2.15. The dispersion is 0.060. Gübelin(4) has recently produced a paper on this material. A product, known as 'Djevalith' after the Swiss manufacturer Djevahirdjan, is described in this paper, in which the properties are given as RI 2.17, dispersion 0.06, SG 5.65, hardness 8½.

A recent material first tested for laser use is lanthanum beryllate, $La_2Be_2O_5$; for laser work it is doped with Nd. La^{3+} is the largest of the rare-earth ions and so has the largest distribution coefficients for other trivalent rare-earth ions. Known as BEL, boules of this material are more easily grown than YAG and other materials based on the yttrium ion. BEL has a thermal conductivity less than half that of YAG. The patent specification(5) for the material (there described as beryllium lanthanate) states that the crystals may contain up to 50 atomic % dopant substituted for the lanthanum. Preferred crystals of the invention are those with the formula $Be_2La_{2-2x}Z_{2x}O_5$, where Z is a dopant from the group Pr,Nd,Sm,Eu,Gd,Tb,Dy,Ho,Er,Tm and Yb; mixtures from elements in the group are also used. X represents the fraction of lanthanum sites in the crystal which are occupied by the Z ions and has a positive value not greater than about 0.2 and preferably about 0.007 to 0.015. During growth it is essential to avoid contamination with such impurities as strontium and mercury, which have ionic radii similar to that of lanthanum^{3+}. Such impurities create colour centres which interfere with laser action either by dissipating energy as heat or by radiating it at wavelengths which do not persist.

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*J.Gemm., 1976, XV, 3, 121.—Ed.

Czochralski growth is preferred for this material; La_2O_3, BeO and dopant being placed in a crucible and heated until molten. Z (the desired dopant) is added as a compound from the group Z_2O_3, $Z_2(CO_3)_3$ or $Z(NO_3)_3$. Iridium is preferred as crucible material and an oxygen-free atmosphere is maintained around the apparatus by the introduction of an inert gas such as argon or helium. The seed crystal which is brought into contact with the surface of the melt is usually also beryllium lanthanate.(6)

So far very few vanadates have been synthesized; yttrium ortho-vanadate, however, is now frequently grown by the Czochralski process after earlier melt-grown production proved unsuitable for laser work through problems encountered during this method of growth. The material was phased out for a time, until new growth methods were found to be more successful. YVO_4 crystallizes in the tetragonal system and resembles zircon in its crystallographic structure; all rare-earth vanadates have this structure and form solid solutions with YVO_4. Pure YVO_4 is colourless; a yellow form reported by Rubin and Van Uitert(7) is thought to have been grown in a slightly reduced atmosphere. This material has a broad absorption peak near 420 nm: SG has been calculated at 4.30(8).

The growth of zircon has been reported by a number of workers and crystals suitable for gem use were mentioned by the present writer in the previous paper(9). Wanklyn(10) has recently reported the growth of zircon from flux systems, including PbO-V_2O_5, this method giving deep blue crystals where the proportion of V_2O_5 was sufficiently large. Yellow crystals were obtained by doping with Tb and green by doping with Cr.

Laser action in silicate oxyapatites has been noted, particularly in CaLa SOAP(calcium lanthanum silicate oxyapatite)—the formula is $CaLa_4(SiO_3)_3O$.(11) When doped with Nd the storage of energy is about five times that of YAG, and a further advantage is that large crystals can be grown relatively cheaply. Low thermal conductivity and a low laser damage threshold may militate against its frequent use.(12) In recent years synthetic scheelite (calcium tungstate, $CaWO_4$) has been proposed as a diamond simulant. Like so many others it has never been seriously used in this connexion because its research and industrial use was found to be limited. The reason for this was the proneness of the boules to fracture even when well annealed, and when rods were made from the boules many had to be discarded. When doped with Nd^3 the absorption spectrum shows a large number of fine lines. The rare earth substitutes for Ca but is in a trivalent oxidation state so that charge compensation is needed; for laser work substitution of Na^+ for Ca^{2+} was found to be best.(13)

It is worth noting that although from time to time new substances with possible gem application are reported the industrial or research potential of the material can rarely be followed up by gemmologists; the result is that textbooks are overloaded with uncritical listings of interesting but irrelevant substances. The materials discussed above may in some cases be suitable for gem use: others are now discarded for reasons which I hope are apparent. The reasons for the neglect of some materials are also relevant for others not discussed above.

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DID PROFESSOR NACKEN EVER GROW HYDROTHERMAL EMERALD?

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ABSTRACT

Gemmology sources state that Professor Nacken grew hydrothermal emerald. Detailed examination of the original literature sources usually cited, of the technical problems involved, and of three different lots of surviving Nacken emeralds leads to the conclusion that Nacken grew emeralds only from the flux. Some conclusions can be drawn as to the nature of the technique employed and the composition of the flux. The two-phase inclusions in Nacken emerald are shown to consist of a flux-composition glass and a gas bubble.

A. INTRODUCTION

Professor Richard Nacken (b. Rheidt, Germany, 4th May, 1884, d. 8th April, 1971) is well known for his pioneering work on the hydrothermal growth of quartz crystals.[1, 2, 3] In the field of gemmology, he is best known for his early work on synthetic emeralds.

In gemmological sources (e.g. Webster[4]) and elsewhere[5] it is stated that Nacken's emeralds were grown by the hydrothermal technique. This conclusion was based on two types of evidence: reports of interviews with Nacken by Sawyer[2] and Van Praagh;[3] and the occurrence in Nacken emeralds of two-phase inclusions apparently composed of a fluid and gas-bubble.

Work for a detailed report on 'Synthetic Emerald: The Confusing History and the Current Technologies'[6] led to a re-examination of the Nacken emerald problem. Study of the primary references, of the known technology of hydrothermal emerald growth, and of some surviving Nacken emeralds indicates that a hydrothermal origin for Nacken emerald cannot be supported.

B. THE PRIMARY REFERENCES

Two primary accounts are usually quoted as evidence that Nacken grew hydrothermal emerald. The first is the post-war

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C. EXPERIMENTAL

Three lots of Nacken emeralds were studied, designated A, B, and C, shown in Figure 1 (this figure appears in colour in Ref. 6.):

A. Three crystals, shown on the left in Figure 1, obtained via F.H. Pough from G.O. Wild of Idar-Oberstein.
B. Five crystals, three of which are shown in the centre of Figure 1, were loaned by the British Museum (Natural History), number BM 1958, 541 'made by Professor Nacken in 1926', courtesy of Mr P. Embrey.
C. Eleven crystals, four of which are shown at the right of Figure 1, were loaned by the British Museum (Natural History), number BM 1946, 87 'see Min. Abs. **10**, p. 104', courtesy of Mr P. Embrey.

Examination techniques included microscopy, scanning electron microscopy (SEM) in both x-ray energy dispersive and element mapping modes, and infrared absorption spectroscopy (IR). The SEM work was performed on an ETEC Autoscan, operated at 20 kV, and a KEVEX model 5100C x-ray energy spectrometer. IR data were taken from a Cary Model 14 double beam spectrophotometer at room temperature.

D. RESULTS

The crystals examined were generally well formed prisms showing both first order and second order prism faces, usually from seven to ten in number. Typical outlines are shown in Figures 2A to D. Some crystals had perfectly developed basal pinacoids, but these were accompanied in many of the crystals by adjacent curved surfaces showing fine striations as indicated in Figure 2A. The morphological feature that was most surprising was the complete absence of any evidence of attachment points, indicating that the crystals had grown as 'floaters'.

Infrared spectra were taken on crystals from each group. Those from groups A and B showed complete absence of water in their spectra, giving curves such as those of Figure 3D and thus confirming flux growth for these crystals.[10, 11] Group C crystals however showed spectra of the Figure 3B type, indicative of both Type I and Type II water as shown in Figure 4. This indicates the presence of a low to medium amount of alkali in these crystals, and such spectra had been observed previously only in natural beryl and emerald.[10, 11]

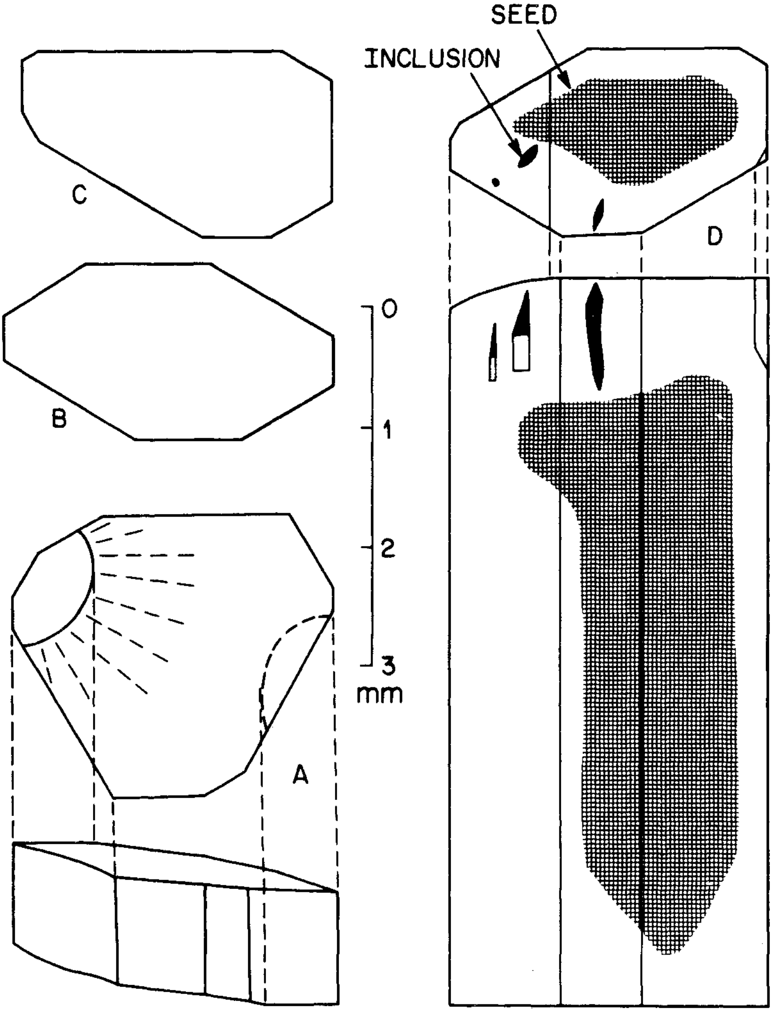

FIG. 2. Drawings of some Nacken emeralds; A and C from Group B, B from Group A, and D from Group C showing pale seed crystal.

intelligence report on Nacken's work by G.B. Sawyer.[2] Reporting on his discussion with Nacken, Sawyer wrote: '. . . He referred to an old research originally on beryl *or* emerald and corundum for watch bearings. The general procedure used by Nacken . . . made *quartz* crystals 1″ in diameter by the hydrothermal method . . .' (There follow details of *quartz* growth conditions; then some biographical data.) '. . . In the evening, we visited Professor Nacken again and he showed us emerald crystals which he had grown in 6 to 8 days . . .' (Further details on *quartz* growth follow; parenthetical comments and emphasis added). Note the absence of a statement as to how the emerald crystals had been grown.

The second source usually quoted for a Nacken hydrothermal emerald is Van Praagh.[3] This is an article on Nacken's hydrothermal quartz work based on his intelligence interview. Near the end he includes this paragraph: 'Although outside the scope of this article, it is interesting to note that Nacken used with success a similar hydrothermal method for the synthesis of other minerals, including felspars, micas, and beryl. *He made large numbers of synthetic emeralds, using a trace of chromium to produce the colour. Hexagonal prisms weighing about 0.2g were grown in a few days. A number have been sent to the Mineral Department of the British Museum for full examination'* (emphasis added). Note that none of these hydrothermal felspars, micas, or beryl (not 'emerald') has ever been reported elsewhere. Also note that once again the technique used to grow the emeralds in the last three sentences is not explicitly stated.

As against these two rather equivocal reports must be ranged more positive evidence that Nacken did grow emerald from the flux ('flux-melt' growth in Great Britain). Merker, based on yet another intelligence interview, mentions both lithium molybdate[7] and potassium vanadate;[8] and lithium molybdate flux growth is also ascribed to Nacken by Fischer.[9] As part of a study on the role of water in emerald, Wood and Nassau[10, 11] found water to be absent in a Nacken emerald, accordingly indicating a flux origin. No reports appear to exist which demonstrate the presence of water in any Nacken emerald.

This evidence thus indicates that Nacken did grow flux emerald, but is indefinite as to the existence of any Nacken hydrothermal emerald.

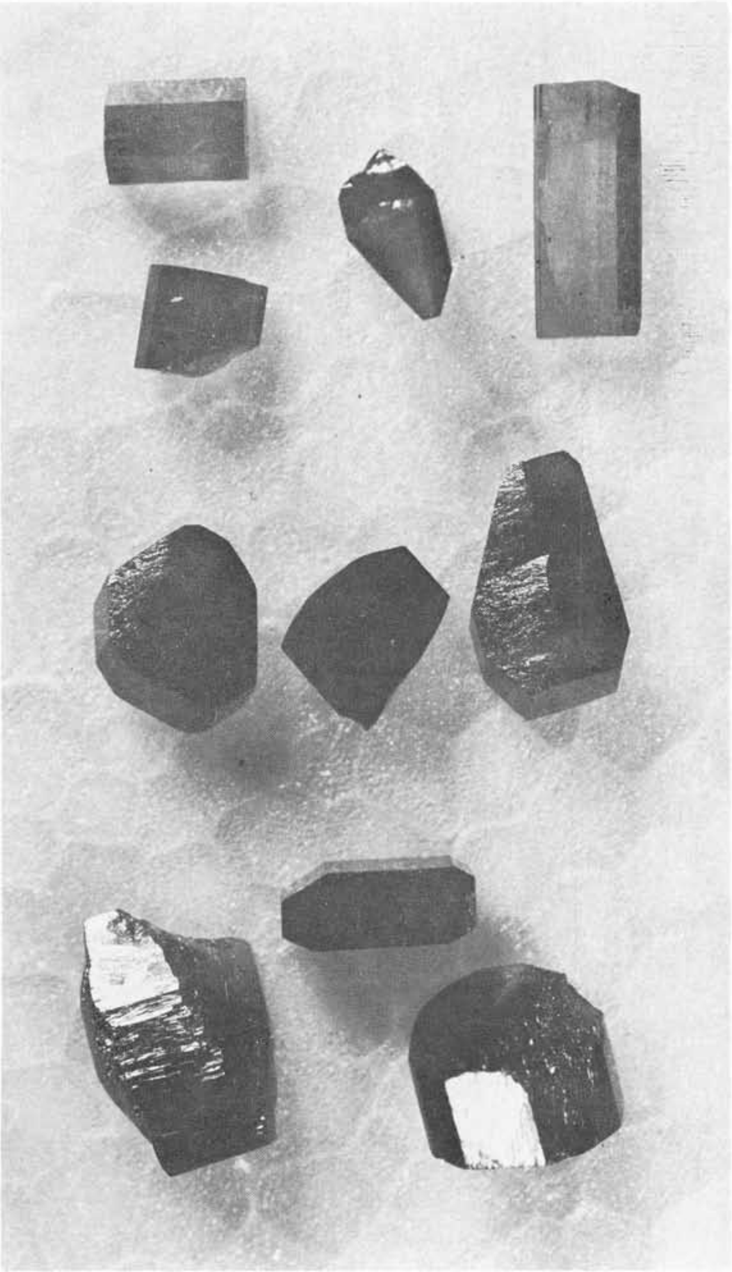

FIG. 1. Three lots of Nacken emeralds; largest is 5 mm across and weighs 0.51 ct. Left to right Groups A, B, and C.

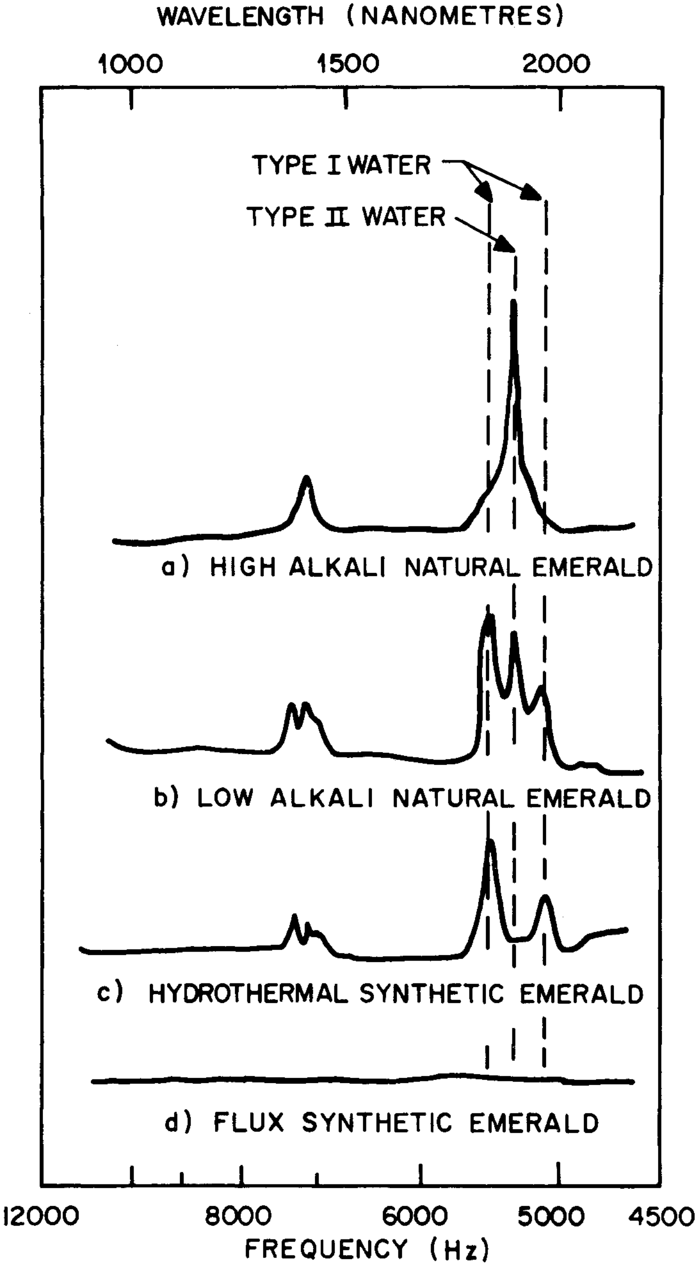

FIG. 3. Infrared water absorption bands in emeralds: natural (a) and (b), hydrothermal (c), and flux (d).

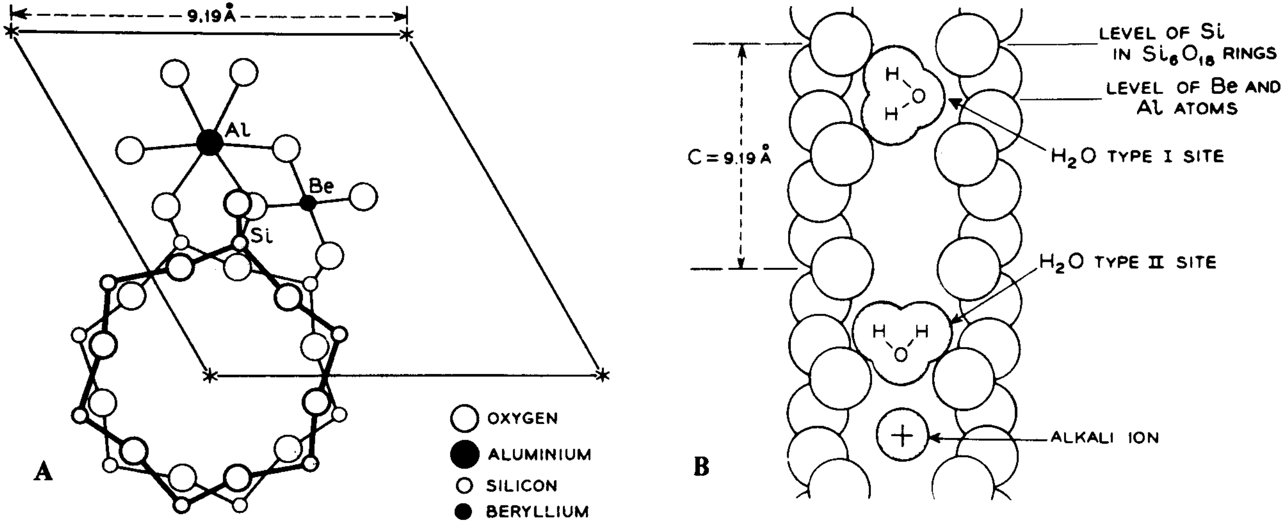

FIG. 4. The structure of beryl (A) showing the channels as seen looking down the optic axis and the two types of water in the channels (B).

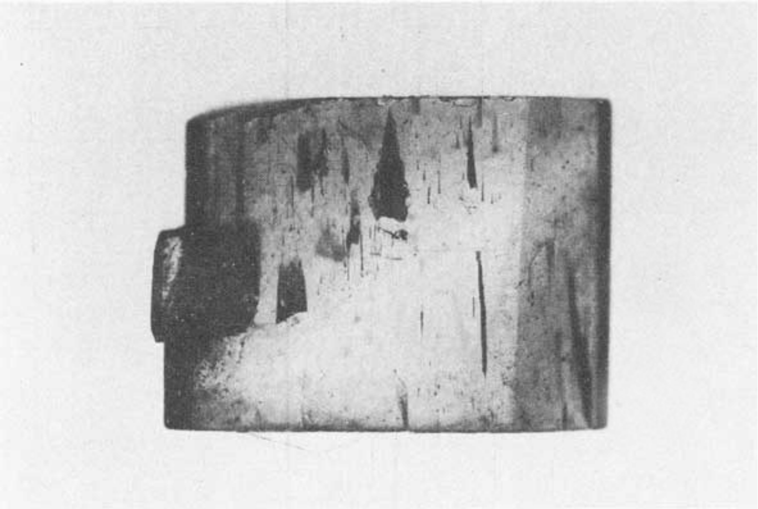

FIG. 5. Nacken emerald crystal from Group C polished down to the triangular flux inclusion, also showing pale central seed region (crystal is 2½ × 3½ mm).

Close examination of these crystals indicated that colourless (or close to colourless) natural beryl seeds had in fact been used in growing the group C crystals. The pale centres of these crystals can be seen in the crystals on the right in Figure 1 and also in Figure 5, a partly polished crystal slice from Group C photographed in transmitted light. Another crystal from this group is shown in Figure 2D. The deeply coloured emerald regions surrounding the seeds showed the same inclusion characteristics as were found in crystals of Groups A and B.

Inclusions in the Group A and B emeralds and in the emerald regions of the Group C crystals were of five types:

(i) Curved veil-like or wisp-like feather inclusions of the type usually associated with flux-grown emerald. Some of these occurred in irregularly oriented twisted networks, Figure 6A, others in flat sheets, oriented perpendicular to the optic axis, Figure 6B;

(ii) Cuneiform nail-type inclusions, Figure 6C, which in emerald are generally caused by the nucleation of a crystal of phenakite followed by a tapering inclusion. In all instances these inclusions pointed towards the surface of the nearest basal pinacoid, suggesting a more rapid growth parallel to the optic axis than in other directions;

(iii) Two-phase inclusions giving the appearance of a fluid-filled cavity with a gas bubble as shown in Figures 6D and E, sometimes also occurring in the tapering section of large nail-type inclusions, Figure 6F;

(iv) Small clusters of crystals, Figure 6G, probably phenakite; and

(v) Rare large tapered inclusions of a dark-brown colour and polycrystalline in appearance.

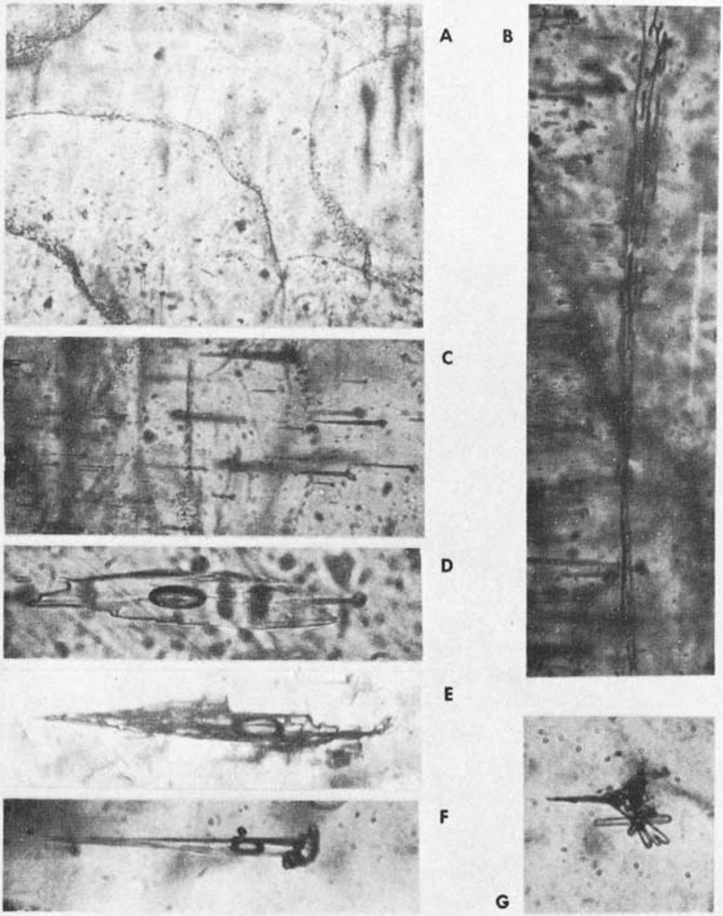

FIG. 6. Inclusions in Nacken emeralds: A and B 'veils'; C 'nails'; D to F two-phase inclusions; and G crystals of phenakite(?). Magnifications: A50 × ; B,D, and E100 × ; C 200 × ; F and G 300 × .

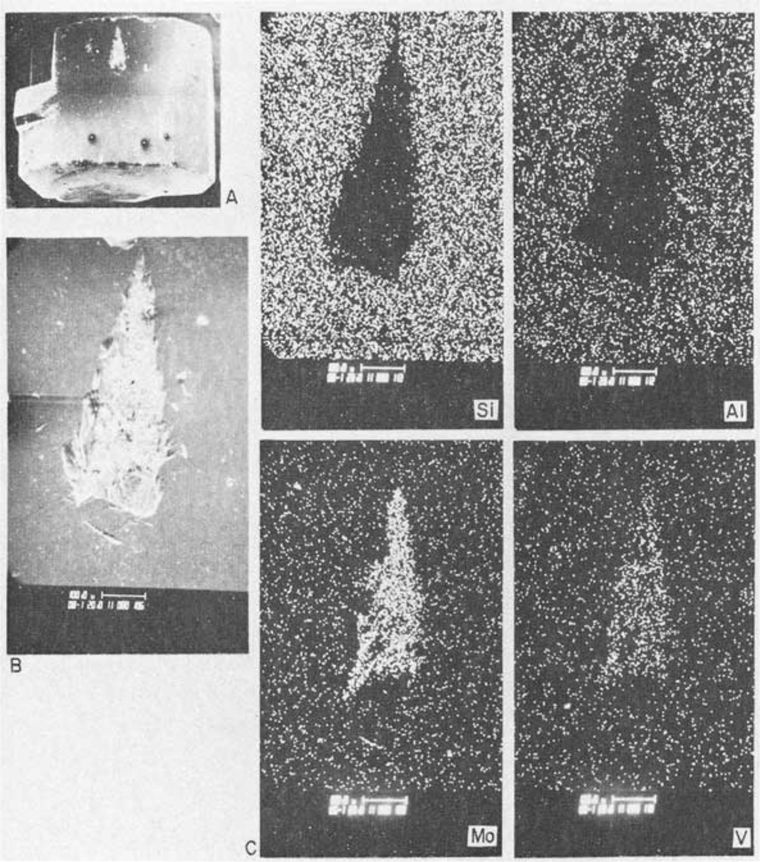

FIG. 7. Scanning electron microscope examination of the crystal of Fig. 5: A and B secondary electron images, C elemental mapping using x-ray emission from the elements shown. Scale bars are 100 μm long.

In general, these inclusions were similar to flux-grown emerald inclusions shown in gemmology texts.[4, 12, 13, 14]

A crystal of Group C containing the largest inclusion of Type (v), triangular in shape and approximately 1 mm × 1/3 mm, was ground and polished so as to expose the inclusion. This crystal is seen in transmitted light in Figure 5 and as a scanning electron photomicrograph in Figure 7A. Energy dispersive analysis of the emitted x-rays in the emerald region of this crystal gave the spectrum of Figure 8A, showing the expected aluminium, silicon, and trace of chromium (beryllium and oxygen cannot be detected in this examination). Several other crystals gave similar curves.

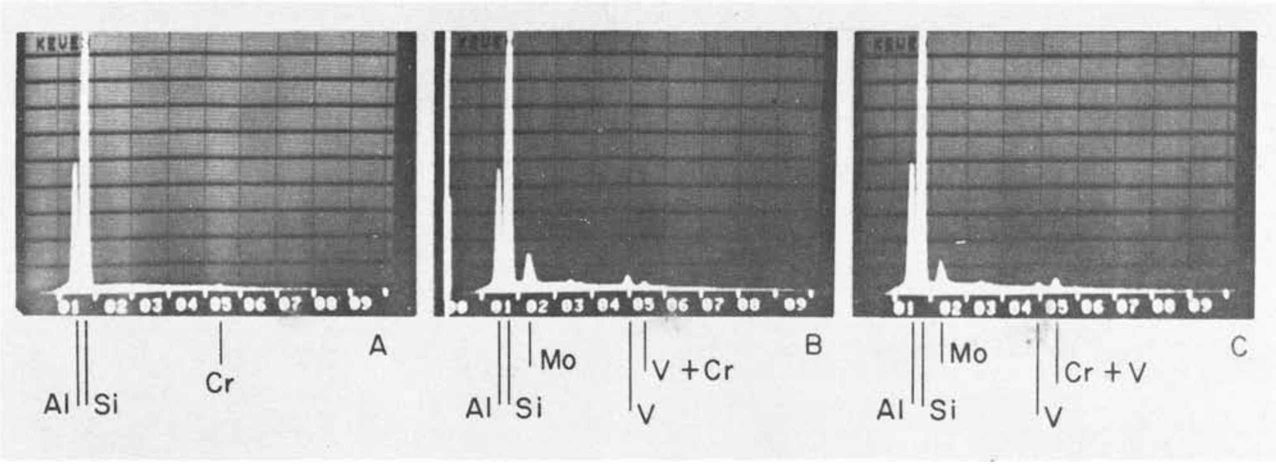

FIG. 8. Energy dispersive x-rays from emerald (A) and from Emerald plus flux inclusion (B) in the crystal of Fig. 5, and (C) from an inclusion such as that of Fig. 6D in a crystal from Group B.

When the exposed inclusion, shown in Figure 7B was included, both molybdenum and vanadium were now seen as in Figure 8B, but no potassium (lithium cannot be detected). In the element mapping mode of Figure 7C it can be seen that Al and Si are essentially absent in the inclusion contents, but much Mo and somewhat less V are present in the inclusion only. Outside the inclusions, Figure 7C shows only background for Mo and V. This indicates a flux composition of MoO_3 and V_2O_5, in all probability combined with Li_2O.

Attempts to move the bubble in two-phase inclusions with heat were unsuccessful. A crystal of Group B showing a two-phase inclusion similar to those of Figure 6D and E was thinned down to expose some of the inclusion filling, which gave the spectrum of Figure 8C. This resembled Figure 8B, except that the chromium peak was significantly higher. Coupled with the fact that the inclusion filling appears to be transparent, isotropic, and solid, this leads to the conclusion that such two-phase inclusions involve trapped flux containing the ingredients of beryl with extra chromium, but in a vitreous state. This glass apparently did not crystallize and also did not completely solidify until enough cooling had occurred to produce a shrinkage bubble, probably containing some oxygen which such a melt would be expected to emit on cooling.

E. DISCUSSION

A careful analysis of the equivocal wording of the Sawyer[2] and Van Praagh[3] reports leads to the conclusion that neither specified the emerald growth technique used by Nacken. The reports of the use of flux by Merker[7, 8] and of Fischer[9] are confirmed by the analyses of the flux inclusion of Figure 7C and Figures 8B and C. The demonstration that the apparent 'fluid' in the two-phase inclusions is in fact a glass removes the only other evidence pointing to a hydrothermal origin. Additional confusion may have been caused by the presence of natural beryl seeds in some of Nacken's emeralds.

Quite decisive is the fact that growth in an alkaline hydrothermal medium, such as that used by Nacken for quartz[1, 2, 3] can yield beryl and aquamarine, but not emerald[15] (the chromium precipitates in all but acid media). This has been discussed elsewhere.[6]

It is interesting to place Nacken's emerald work in the historical context of other early emerald growth investigators.[6] Hautefeuille and Perrey had originally described fluxes based on lithium molybdate and lithium vanadate,[16, 17] and Espig and others at I.G.-Farben had worked from 1911 until 1942 to perfect the lithium molybdate process to produce their 'Igmeralds'. Details of this process were not published until 1960,[18] however, while Nacken discontinued his emerald work in 1927 or 1928.[7]

Despite the apparent independence of these two investigations we can nevertheless deduce that almost exactly the same process was used, based on the absence of attachment points discussed in section D above. For the I.G.-Farben process, as described by Espig[18] and shown schematically in Figure 9, employed the growth of floating emerald crystals as described previously.[6] The only difference appears to be that Nacken added some vanadium oxide to the flux.

This leads to two rather intriguing speculations which suggest themselves. Could it be that Nacken was a consultant to I.G.-Farben? This might explain his reticence in revealing growth details

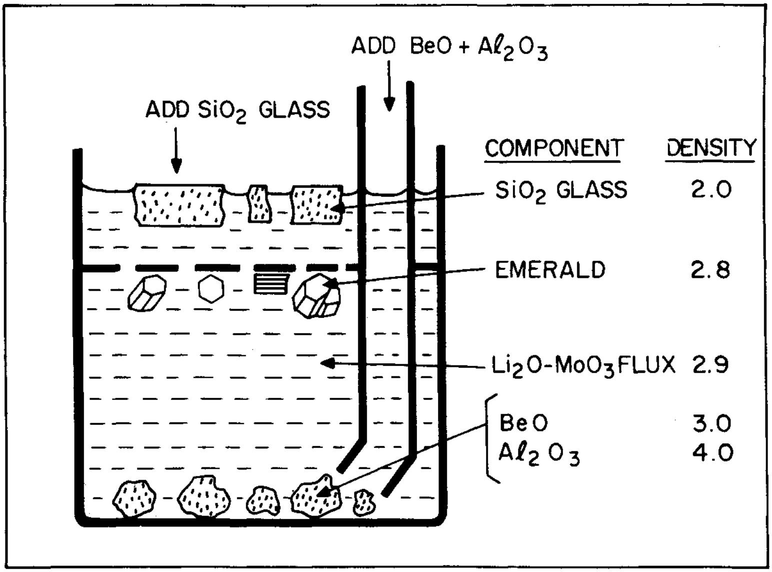

FIG. 9. Schematic diagram of emerald flux-growth apparatus made of platinum as used by Espig at I.G.-Farben.

even although he himself does not appear to have made any attempt to commercialize. From this we could then suggest that the 'secret' ingredient to which Espig alludes[18] as being necessary to produce a good colour in flux emerald in addition to chromium may in fact have been the vanadium present in Nacken's flux.

Quite apart from these speculations we can conclude with certainty that Nacken grew emeralds from a molybdate-vanadate flux (probably lithium-containing), using a floating growth technique similar to Espig's as shown in Figure 9. There is no shred of evidence for any hydrothermal emerald growth by Nacken, so that the question posed in the title of this article can be answered simply as 'No'.

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[*Manuscript received 10th June, 1976*]

THE MARTIN MGA-1 GEM ANALYSER: A REPORT

By P.G. READ, C.Eng., M.I.E.E., M.I.E.R.E., F.G.A., F.I.S.T.C.

This instrument, like the Gemeter and the Jeweler's Eye, enables a faceted gemstone to be identified by measuring the amount of infrared energy reflected from its surface. The intensity of the incident infrared energy is assumed to be constant, and the intensity of the reflected beam, although not an absolute measure of reflectivity, is used to indicate the relative reflectivity of the gem.

The Gem Analyser (Figure 1) has two ranges, the lower one covering glass to corundum, and the upper one YAG to rutile. The meter scales are calibrated directly in the names of the more common gem minerals and synthetics. Unlike the Gemeter and the Jeweler's Eye, which contain few electronic components, the Gem Analyser employs six transistors, a zener diode and two integrated circuits. These components are mounted on a fibre-glass printed circuit board (Figure 2) together with two range switches and the sealed infrared lamp/detector assembly.

The function of the electronic components is to maintain the accuracy of the readings over a wide range of battery voltages and ambient temperatures. This is effected by means of a voltage regulator in series with the battery supply (Figure 3) and a stabilized supply to the infrared emitting diode (LED). To minimize the effects of extraneous light, the current supply to the LED is modulated by a timing generator. The output from the detector is then demodulated to extract the electrical information on the intensity of the reflected beam, which is amplified and fed to the meter.

The manufacturers, Martin Precision Instrument Inc., P.O. Box 829, Saratoga, CA 95070, U.S.A., claim that the instrument will operate satisfactorily from 0 to 55 degrees centigrade, and from 0 to 95% relative humidity. The nine volt battery is said to have a life in excess of 100 000 operations (without the need for recalibration).

When using the Analyser, it is necessary (as with all reflectivity meters) to ensure that the surface of the gemstone under test is clean and that there is no dust in the aperture of the test platform.

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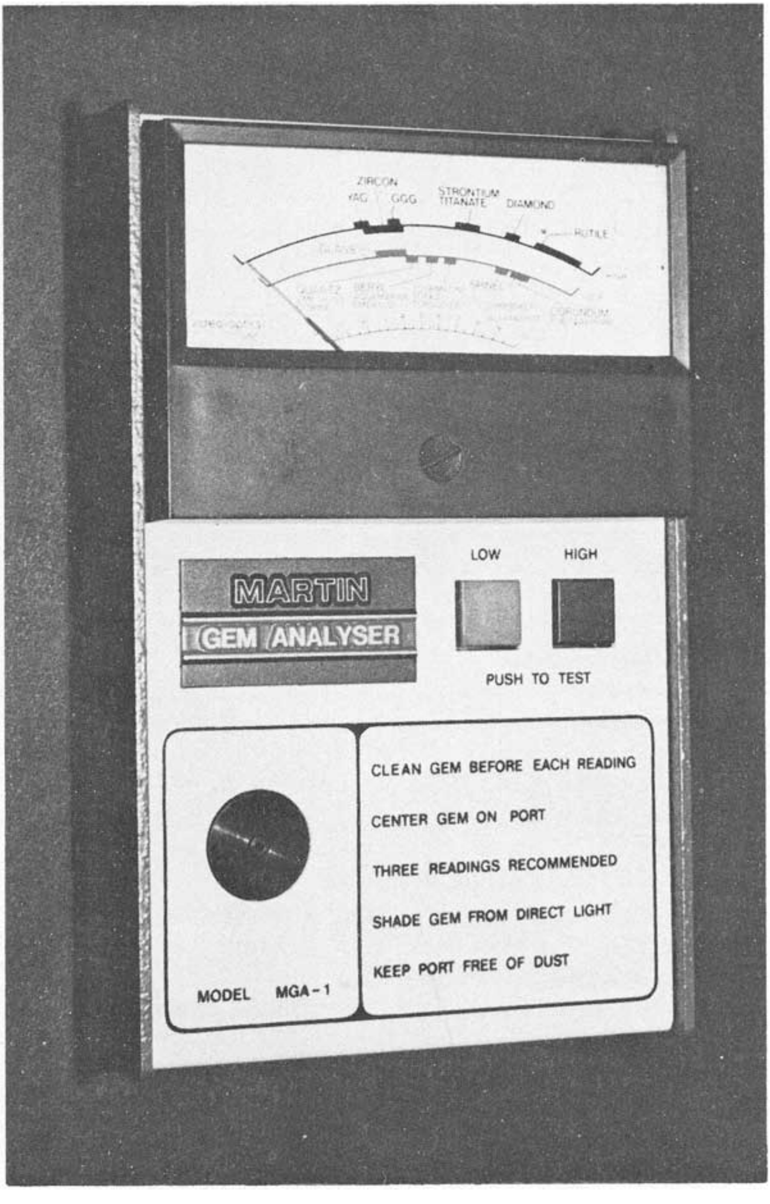

Figure 1. The Martin Gem Analyser, showing the circular test platform at the lower left corner.

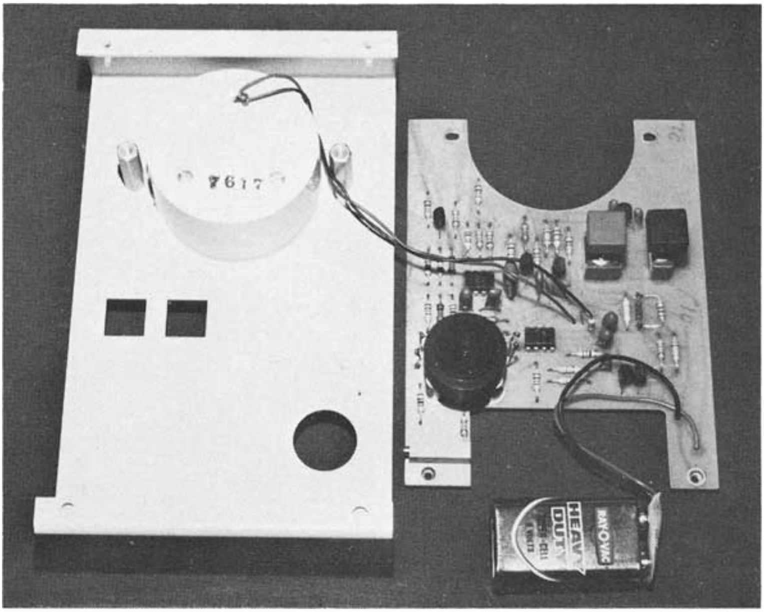

Figure 2. The dismantled Analyser with the front panel and meter on the left and the printed circuit board on the right.

The stone is placed on the raised rim of the test platform aperture and the appropriate range button is pressed. The aperture rim is provided so that mounted stones, having claws which protrude beyond the plane of the table facet, can be accommodated. Unfortunately, it can sometimes be difficult to ensure that the gem is sitting squarely on the rim. This requirement is most important as any tilting will cause a large error in the reading. In practice, it was found that this problem could be best resolved by making sure that the stone was placed symmetrically over the aperture so that there was no tendency for it to over-balance.

When taking a reading, it is also advisable to shield the stone from any strong external light. This can be done by covering the stone with the cupped left hand while operating the range test button with the right one. Failure to shield the gemstone results in a slightly increased meter reading. The degree of error depends on the level of ambient light, but usually does not exceed 1/16 inch on the scale. As is normal with this type of instrument, any surface scratches or grease/dirt on the tested facet lowers the reading appreciably.

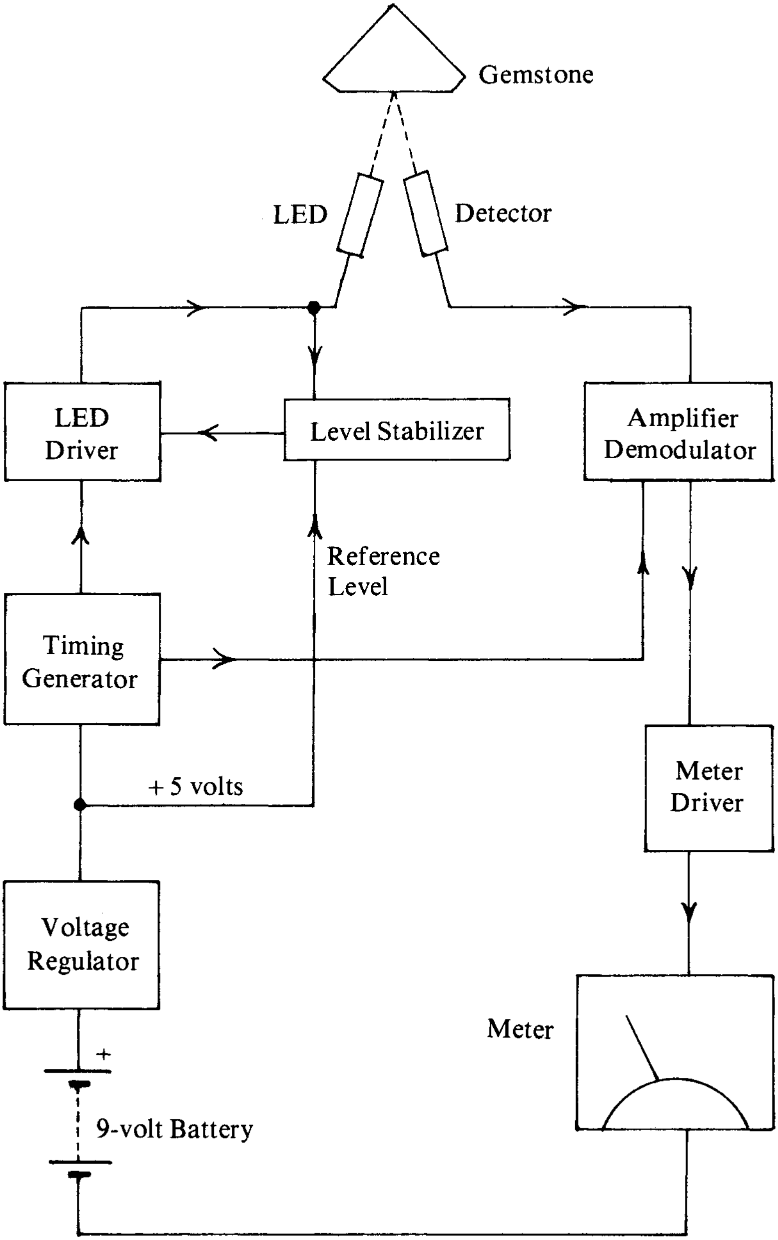

Figure 3. Block diagram of the electronic circuit.

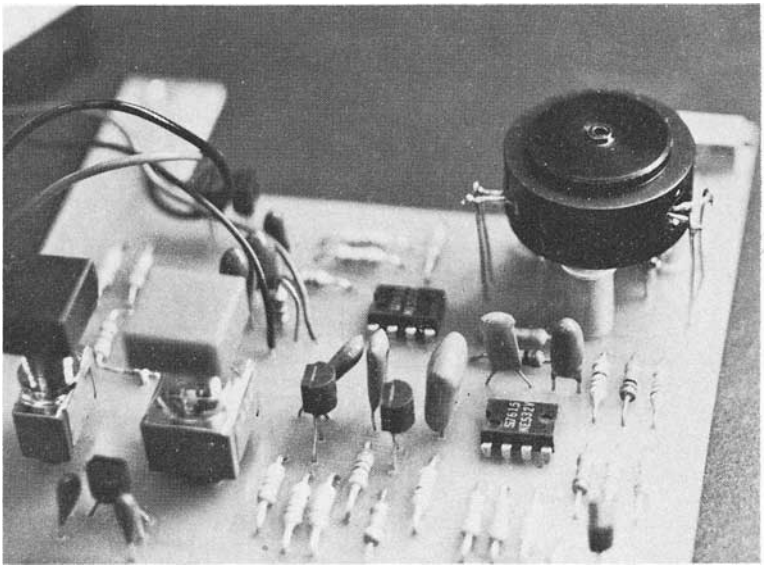

Figure 4. View of the printed circuit board showing the sealed lamp/detector assembly at the top right corner.

The lamp/detector assembly (Figure 4) appears to contain four active elements instead of the normal two (LED and photo detector). These probably comprise a dual LED/detector array, but as the assembly is sealed it was not possible to check either the identity or orientation of these elements.

The Gem Analyser was tested with polished diamonds, and with a selection of polished diamond simulants. The simulants included white synthetic spinel, white zircon, strontium titanate, YAG, synthetic rutile and GGG. In all cases the readings were well within the appropriate calibrated bands on the meter scales. Repeatability for individual stones was also very good. Even the octahedral faces of an unpolished diamond crystal gave the correct reading.

While the Martin Gem Analyser is more expensive at $400 than either the Gemeter or the Jeweler's Eye, it is virtually unaffected by wide fluctuations in ambient temperature and by falling battery voltage, and should never need recalibrating under normal circumstances. The dimensions of the Analyser are 165 × 108 × 45 mm (6.5 × 4.25 × 1.75 inches) and its weight is 600 grams (21 ounces).

[*Manuscript received 14th October, 1977*]

GEMMOLOGICAL ABSTRACTS

IGEA (J.). *Identificación espectrográfica del ámbar.* (Spectrographic identification of amber.) Boletin del Instituto Gemologico Español, **16**, 13-19, 1977.

Examination of the region between 9.5 and 11.5 μm shows interesting differences between types of amber and some of its imitations. The spectrum of ambroid is far less complex than that shown by the natural material. Graphs (not giving figures) illustrate the paper. M.O'D.

JONES (R.W.). *Arizona: heartland of gems.* Lapidary Journal, **31**, 1, 90-112, 1977.

An account, illustrated in colour, of the more important gem materials found in Arizona. These include agate, cordierite, azurite, malachite, cuprite, feldspars and turquoise. M.O'D.

LAREIDA (S.). *Die Mineralien-Fundgebiete im Bergell.* (Mineral sources in Bergell.) Lapis, **2**, 5, 25-31, 1977.

The Bergell, better known by the Italian name of Val Bregaglia, lies in the south-eastern part of Switzerland and extends into Italy. The country rock is granite and some pegmatites are found. The area has been divided into three zones, the second lying roughly to the south and east of the first and the third in the extreme east. Minerals of the first zone include chalcopyrite, pyrite, green to greenish-black spinel, aragonite, scheelite,bismuthinite, chrysoberyl (rare and in association with beryl), beryl in the yellow and aquamarine varieties, very small zircon crystals and black tourmaline. Minerals of the third zone include fluorite, quartz, titanite, prehnite, lazurite and stilbite. M.O'D.

LARSON (P.), HONERT (J.). *Rose quartz of the Black Hills.* Lapidary Journal, **31**, 2, 534-8, 1977.

Rose quartz occurs in granitic pegmatites; some stones display asterism and others dendrites of pyrolusite. The main mines are described. M.O'D.

LIEBER (W.). *Leuchtende Kristalle.* (Luminescent crystals.)Lapis, **2**, 5, 10-13, illus. in colour, 1977.

A brief account of the history of work on mineral fluorescence with particular reference to fluorite. M.O'D.

NASSAU (K.). *The non-single-crystal synthetics: turquoise, opal, etc.* Lapidary Journal, **31**, 1, 18-31, 1977.

A copy of Dr Nassau's article 'How to define non-single-crystal synthetics' which appeared in Gems and Gemology, 1976, XV, 7, 194-8, with the addition of colour plates. The original article was abstracted in J.Gemm., 1977, XV, 7, 396.
M.O'D.

OWENS (V.S.). *Unakite.* Lapidary Journal, **31**, 1, 182-4, 1977.

Unakite is a mixture of quartz, feldspars and epidote and shows a wide variety of colours. The main localities in the United States are in Virginia, North Carolina and Tennessee. M.O'D.

PFEFER (J.). *Pala, a 'jewel' of a name.* Lapidary Journal, **31**, 1, 202-10, 1977.

The Pala Valley in southern California is described and illustrated, with particular reference to the tourmaline mines of the area. M.O'D.

POUGH (F.H.). *Alexandrite.* Mineral Digest, **8**, 69-73, illus. in colour, 1977.

A general review of the alexandrite variety of chrysoberyl. M.O'D.

RIEDERER (J.). *Der Edelsteinbergbau in Ceylon.* (Gemstone-mining in Ceylon.) Aufschluss, **28**, 41-7, 1977.

Reviews the occurrence and price ranges of Ceylon gemstones. M.O'D.

SCHIFFMANN (C.A.). *Un nouveau substitut du diamant: l'oxyde de zirconium artificiel.* (A new diamond substitute—artificial zirconium oxide.) Revue de Gemmologie, **51**, 9-11, 1977.

Diamond and some of its simulants, including zirconium oxide, are illustrated in colour. Constants are $n_D = 2.177$, reflective power 0.137 (compared to 0.172 for diamond), dispersion 0.065, hardness 8½, specific gravity 5.66. M.O'D.

SHAUB (B.M.). *Thomsonite.* Mineral Digest, **8**, 24-30, 1977.

The attractive banded zeolite was named for the Scottish chemist, Thomson, in 1820; it occurs in fibrous masses showing schiller or chatoyancy or as nodules with a radial structure of fine acicular grains. Distinct orthorhombic crystals are rare. It is a hydrous silicate of sodium, calcium and aluminium with the formula $NaCa_2(Al_5Si_5O_{20}).6H_2O$. Specific gravity is 2.3-2.4 and the hardness 5-5½. The commoner colours are shades of yellow, brown, red and green, though snow-white specimens have been found. Most thomsonite is found in the basalt rocks of the Lake Superior region and especially round Isle Royale, Michigan. M.O'D.

TAKAGI (K.), IKEDA (T.), FUKAZAWA (T.), ISHII (M.). *Growth striae in single crystals of gadolinium gallium garnet grown by automatic diameter control.* Journal of Crystal Growth, **38**, 206-12, 1977.

Crystals of $Gd_3Ga_5O_{12}$ grown by automatic diameter control show periodic growth striae whose spacing depends on the period of RF power fluctuation. They can be eliminated by decreasing the amplitude of fluctuation to less than 1%.

M.O'D.

TERRILL (B.). *Field trips in the Baltimore, Maryland area.* Lapidary Journal, **31**, 1, 82-140, 1977.

Accounts of amateur prospecting in various areas including the State Line Pits on the Maryland-Pennsylvania border (for the williamsite variety of serpentine) and Little Switzerland, North Carolina (for emerald). M.O'D.

TRUEBE (H.A.). *Lapis lazuli in the Italian Mountain area of Colorado.* Lapidary Journal, **31**, 1, 54-80, illus. in colour, 1977.

Two notable sources of lapis lazuli have been found on Italian Mountain in western Colorado; the mountain is located at the intersection of the Elk Mountain fold-belt and the Castle Creek fault zone. Lapis lazuli is formed in a particular stratigraphic horizon in the Pennsylvanian age Belden formation near intrusive bodies. Sodalite, calcite, pyroxene and pyrite group minerals are discussed. The quality of the material found is quite high, second grade on the GIA scale. M.O'D.

VACHER (A.). *Étude sommaire des cavités tubulaires dans des aigues-marines.* (Summary study of tubular cavities in aquamarines.) Revue de Gemmologie, **50**, 4-6, 1977.

Some aquamarine crystals from Brazil were observed to contain cavities arranged in various crystallographic directions. The contents of the cavities include water and carbon dioxide and some are corroded by the contact of foreign bodies.

M.O'D.

BOOK REVIEWS

BÖGEL (H.), SCHMIDT (K.). *Kleine Geologie der Ostalpen.* (Little geology of the Eastern Alps.) Ott Verlag, Thun, Switzerland, 1976. pp.231. Illus. in black-and-white. Fr 39.

This well-produced text is intended as a general coverage of the Alpine geology covering approximately the area running eastwards from Vaduz up to Graz and Eisenstadt. This area is shown in a pull-out map and a number of illustrations in the text depict specific areas. An extensive bibliography includes references to articles in journals and there is a name- but no subject-index. Illustrations are of a high quality and the book as a whole is clear and authoritative. It should be read in conjunction with its companion 'Kleine Geologie der Schweiz' published by the same firm.

M.O'D.

BRANSON (O.T.). *Turquoise, the gem of the centuries.* Treasure Chest Publications, Santa Fé, New Mexico, 1975. pp.62. Illus. in colour. £9.00.

This book is composed entirely of coloured illustrations of turquoise from mines in the United States. These are exhaustively covered and the standard of the reproduction is high. An invaluable book for those wishing to distinguish pieces from specific locations and also treated material. M.O'D.

WENINGER (HANS). *Die alpinen Kluftmineralien der österreichischen Ostalpen.* (The alpine cleft-minerals of the eastern Alps of Austria.) 25 Sonderschrift der Zeitschrift Der Aufschluss, Heidelberg, 1974. pp. 168. Illus. in black-and-white and in colour. DM 20.00.

Eleven maps accompany this authoritative work, which covers the main mineralized areas of Austria. The book is arranged in alphabetical order of minerals and each entry shows chemical composition, crystal system and habit with the main localities of occurrence. There is a comprehensive bibliography, index of minerals, list of major localities and, most interestingly, a list of Strahler (crystal collectors), who can, no doubt, be contacted by those wishing to acquire specimens. M.O'D.

ASSOCIATION NOTICES

NEWS OF FELLOWS

On the 24th September, 1977, Mr M.J. O'Donoghue, M.A., F.G.S., F.G.A., attended the conference of the Deutsche Gemmologische Gesellschaft at Idar-Oberstein and read a paper entitled 'The pegmatites of the Pala District of San Diego, California'.

On the 22nd October, 1977, Mr A.E. Farn, F.G.A., gave a lecture entitled 'The Jade Umbrella' to the Wessex Branch of the National Association of Goldsmiths.

On the 5th November, 1977, Mr D. Wilkins, F.G.A., gave a talk on 'Findings and Keepings' to the Wessex Branch of the N.A.G.

MEMBERS' MEETINGS

London

A meeting was held on 10th October, 1977, at the Central Electricity Generating Board Cinema, Newgate Street, London E.C.2, when two films were shown. The first film, entitled 'World of Diamonds', illustrated the passage of diamonds from the mines through the various stages of sorting, valuation and sales, and in addition, showed the services provided by the C.S.O. to support its basic function. The second film, 'It's all done with minerals', showed the excitement, the muscle and brain and the movement in man's endeavours to recover the minerals and metals the world must have.

Midlands Branch

On the 21st October, 1977, a meeting was held at the Imperial Hotel, Temple Street, Birmingham, which marked the 25th anniversary of the Branch. A talk was given by Mr T. Solomon, F.G.A., entitled '25 years as a gemmologist'.

North-West Branch

A meeting was held on 21st September, 1977, at Church House, Hanover Street, Liverpool 1, when Mr E.A. Jobbins, B.Sc., F.G.A., spoke on 'Gem surveys in Brazil and Guyana'.

The second Annual General Meeting of the Branch was held on the 26th October, 1977, when Mr H. Eakins, F.G.A., was elected Chairman and Mrs D.M. Brook, F.G.A., Secretary. This was followed by a slide-show depicting the 'Exotic forms and colours of the mineral world'. which included precious and base metal ores and gemstones.

South Yorkshire Branch

At a meeting held on the 31st October, 1977, at Sheffield City Polytechnic, Mr M.J. O'Donoghue, M.A., F.G.S., F.G.A., gave a talk on 'Minerals of Central and East Africa'.

COUNCIL MEETING

At a meeting of the Council held on Wednesday, 5th October, 1977, the following were elected to membership.

FELLOWSHIP

Baldock, Edward J., Neston, Cheshire. D. 1977
Bapat, Suresh B., Bombay, India. D. 1977
Beard, Paul, Nottingham. D. 1977
Bennett, Lise C., Rochester. D. 1977
Borgen, Jennifer A., Fredrikstad, Norway. D. 1977
Brewer, Peter C., Scarborough. D. 1977
Chadderton, Yvonne E., Royton, Lancs. D. 1977
Clayton, Keith M., Cranleigh. D. 1977
Collier, Alan, Preston. D. 1967
Cooper, Dorothy A., Reddish, Stockport. D. 1977
De Waele, Carine G., Ghent, Belgium. D. 1977
Elkington, Mary, Solihull. D. 1977
Gade, Fredrik G., Snarøya, Norway. D. 1977
Gotch, Takeshi, Amsterdam, Holland. D. 1977
Grater, Jane, Salisbury. D. 1977
Grimbly, Margaret S., Plymouth. D. 1977
Henocq, James E.R., Croydon. D. 1977
Henocq, Rosemary S., Croydon. D. 1977
Horn, David E., Ripon. D. 1977
Kortenaar, Francois L., Schagen, Holland. D. 1977
Lancaster, David J., Johannesburg, S. Africa. D. 1977
Lawson, Wendy A., Nottingham. D. 1977
Litchfield, Jeane, Hahnbach, W. Germany. D. 1977
Main, Arthur M., Southport, Qld, Australia. D. 1977
Manzke, Lothar, Geneva, Switzerland. D. 1977
Meintjes, Arthur H., Stellenbosch, S. Africa. D. 1977
Mennie, Ruth, New Ferry. D. 1977
Muije, Cornelius S., Louisville, Ky, U.S.A. D. 1977
Norström, Stig E., Skärholmen, Sweden. D. 1977
Price, Grenville J., Nottingham. D. 1977
Rimmer, Robert J., Southport. D. 1977
Schinkel, Anthony, Southport. D. 1977
Semmes, Granville M., New Orleans, La, U.S.A. D. 1977
Sepp, Arne, Cape Town, S. Africa. D. 1977

Sierstorpff, John v. Francken, Rheinbrohl, W. Germany. D. 1977
Sukumaran, T.M., Colombo, Sri Lanka. D. 1977
Tillander, Paula, Helsinki, Finland. D. 1977
Tose, Christine, Middlesbrough. D. 1977
van der Meulen, Anne W., London. D. 1977
Walz, Sylvia E., Langenhagenl, W. Germany. D. 1977

TRANSFERS FROM ORDINARY MEMBERSHIP TO FELLOWSHIP

Aron, Mass K., Nugegoda, Sri Lanka. D. 1977
Ayres, Thomas D., Farnham. D. 1977
Cavey, Christopher R., London. D. 1977
Clarke, Kathleen D., London. D. 1977
Conrad, Donald B., N.Y., U.S.A. D. 1977
Cooper, Roy, Disley. D. 1977
Duroc-Danner, Jean M., Geneva, Switzerland. D. 1977
French, Anthony J., Brockenhurst. D. 1977
Haskings, Theresa M., Wollaton. D. 1977
Hemphill, S.I., Pacific Grove, Ca, U.S.A. D. 1977
Henrich, Francis J., Normandale, Lower Hutt, N.Z. D. 1977
Hood, Glynis M., Melville, Johannesburg, S. Africa. D. 1977
Kapukotuwa, Senerath L.B., Rajagiriya, Sri Lanka. D. 1977
Kaye, Ian D., London. D. 1977
Kennedy, Padraic J.T., B.C., Canada. D. 1977
Kim, Young C., Seoul, Korea. D. 1977
Kizawa, Masakatsu, Santa Monica, U.S.A. D. 1977
Knight, David J.R.E., London. D. 1977
Mayur, Dave, London. D. 1977
Moriuchi, Masana, Niigata-Pref., Japan. D. 1977
Nachimson-Palacci, Rosy, Geneva, Switzerland. D. 1977
Ng, Kevin K.F., Singapore. D. 1977
Paillard, Eva, Paris, France. D. 1977
Peace, Reginald J., Beverley. D. 1977
Pfersich, François A., London. D. 1977
Prickett, John D., Auckland, N.Z. D. 1977
Robinson, Kenneth W., Milton Keynes. D. 1977
Simon, Horace, (Jnr), Shreveport, La, U.S.A. D. 1977
Stonebanks, Judith M., Maidenhead Thicket. D. 1977
Talgeri, Jayshree G., Poona, India. D. 1977
Thomson, Paul R., Hobart, Tasmania. D. 1977
van der Maden, Pieter, Vlissingen, Holland. D. 1977
White, Paul T., Seattle, Wash., U.S.A. D. 1977
Woodhall, Jon W., Qld, Australia. D. 1977

ORDINARY MEMBERSHIP

Acheson, Jeffrey D., Johannesburg, S. Africa.
Acuna, Olinto, Tunbridge Wells.
Adachi, Mitsujo, Saitama, Japan.
Akiyama, Masashi, Hokkaido, Japan.
Amendra, Don H., Colombo, Sri Lanka.

Amoroso, Robert E., Boston, Mass., U.S.A.
Asagai, Osamu, Osaka, Japan.
Asano, Osamu, Yokohama-City, Japan.
Barker, Maxwell, Salisbury, Rhodesia.
Basich, Marco, Ca, U.S.A.
Bastiampillai, Sauarimuthu B., Woodford Bridge.
Bell, Lloyd M., Kan., U.S.A.
Black, Lewis C., London.
Boast, William E., Cheadle.
Boyd, Warren F., Toronto, Ont., Canada.
Brown, Harold G., Glossop.
Brunner, Ernst, Vienna, Austria.
Busaracome, Suwin, Wellington, N.Z.
Callow, Russell D., Brentwood.
Campbell, Donene N., North Auckland, N.Z.
Cannon, Robert, Cheshire.
Catley, Reginald A.J., Salisbury, Rhodesia.
Chadwick, John H., Clacton-on-Sea.
Charlton, Mary Ellen, Hexham.
Cheng, Ricky K.M., Birmingham.
Cheung, Kai Y.E., Hong Kong.
Cheung, Li Yau, Hong Kong.
Cheung, Shu W., Tokyo, Japan.
Chisholm, George T., Bradford-on-Avon.
Chosokabe, Yukuto, Nagoya-City, Japan.
Clare, Alan A., Tehran, Iran.
Coulson, Juliet L., Oxted, Surrey.
Crane, Alison R., Ill., U.S.A.
Davies, Clive H., London.
De Silva, G. Ranjan J., Singapore.
Dirk Hurchalla, Robert, Singapore.
Doo, Suen Hoi D., Tokyo, Japan.
Douglas, James S., Auckland, N.Z.
Ebrahimjee, Mustanseir, Harrow.
Elias, Abdul A., Mombasa, Kenya.
Endo, Tadashi, Sendai-City, Japan.
Evans, How M., Qld, Australia.
Fernandez, Michel, Vitry-sur-Seine, France.
Fernandez, Peter, Bangalore, India.
Foucart, Micheline, De Pinte, Belgium.
Franklyn, Rodney L., Liversedge.
Frey, Robert L., London.
Fung, Tsee Hung, London.
Geikler, Patricia, Tehran, Iran.
Gnanam, Janaki M., Colombo, Sri Lanka.
Goldfarb, Lawrence S., Ohio, U.S.A.
Gryska, Stephanie M., Worksop.
Haentjens Dekker, Gerardus R.J., Amsterdam, Holland.
Harris, Vernor G., Tex., U.S.A.
Hartgrove, Patricia M., London.
Hartstone, Jeremy L., London.
Hashimoto, Masaki, Chiba-ken, Japan.
Hattori, Toshikazu, Osaka-City, Japan.
Healey, David, Hong Kong.
Heatlie, James W.M., Edinburgh.
Hirayama, Hiroji, Nigata-City, Japan.
Hirosawa, Kenji, Kobe, Japan.
Ho, Chow Kee, Singapore.
Ho, Kennedy, Bangkok, Thailand.
Huby, Michael, Hutton Cranswick.
Hussain, Surajul H., Mountlavinia, Sri Lanka.
Ide, Takemi, Tokyo, Japan.
Ikeda, Koichiro, Nagoya-City, Japan.
Imaizumi, Yoshihiro, Kanzaki-District, Japan.
Inoue, Yoshiaki, Tokyo, Japan.
Jibiki, Emiko, Nagoya-City, Japan.
Ipekdjian, Denise V., Antwerp, Belgium.
Janiak, Jerzy, Poznan, Poland.
Jasinski, Jozef, Poznan, Poland.
Jenkins, Philip T., Groote Eylandt, Australia.
Jibiki, Emiko, Nagoya-City, Japan.
Jivraj, Hussein A., London.
Kahn, Adrianne H., Pine Bluff, Ark., U.S.A.

Kanako, Watabiki, Chiba-ken, Japan.
Kanegae, Yoko, Tokyo, Japan.
Kato, Mitsuru, Tokyo, Japan.
Kawakami, Sumiyo, Osaka, Japan.
Keiko, Nakanishi, Tottori-ken, Japan.
Kijo, Chiyoko, Tokyo, Japan.
King, Larry G., Texas, U.S.A.
Kipps, M.J.D., Cape Town, S. Africa.
Kita, Keiko, Osaka, Japan.
Kiyama, Tsutomu, Kyoto, Japan.
Kleijn-Jonker, Heleen, Hong Kong.
Kobayashi, Shigeki, Ishikawa-District, Japan.
Kobayashi, Yoshikazu, Long Beach, U.S.A.
Kodama, Mariko S., Tokyo, Japan.
Kohara, Sachiko, Tokyo, Japan.
Kojima, Machinaka, Tokyo, Japan.
Koni, Kazuhiro, Kanazawa-City, Japan.
Konrad, Jerry, Edinburgh.
Kun-Siu, Liao, São Paulo, Brazil.
Kuriyama, Kazuo, Tokyo, Japan.
Kurotaki, Akira, Tokyo, Japan.
Larson, Robert M., Rio de Janeiro, Brazil.
Lasley, Stanley R., Oreg., U.S.A.
Lee, Horace, Staines.
Leith-Smith, Jean E., Hong Kong.
Levine, Carolyn E., Hong Kong.
Lieu, Mai V., Brussels, Belgium.
Maeno, Yoshiyuki, Matto-City, Japan.
Mahoney, Stephen, London.
Makita, Haruaki, Hanno-City, Japan.
Mannai, Mohamed, Bahrain.
Marriott-Smith, Richard L., Horam.
Marsh, Charles E., Fla, U.S.A.
Matheson, James D., Cal., U.S.A.
Mato, Kazuyoshi, Tokyo, Japan.
Miura, Hiroyuki, Sagamihara-City, Japan.
Miyazaki, Shuji, Tokyo, Japan.
Mizuno, Yuzi, Nagoya-City, Japan.
Montoya, Angel J., Bogota, Colombia.
Morimoto, Towa, Kyoto, Japan.
Mui Siu-Ching, Joanna, Kowloon, Hong Kong.
Nakamura, Makoto, Tokyo, Japan.
Nathanson, Daniel P., London.
Neall, Patricia A., Romford.
Neo, Nobushige, Osaka-City, Japan.
Nishino, Tomoji, Tokyo, Japan.
Nobumisto, Takagi, Kanagawa Ken, Japan.
Norkin, Mark M., Ca, U.S.A.
Nose, Yoshishige, Matsumoto-City, Japan.
Ogata, Norihiko, Kanagawa, Japan.
Ohno, Hiroshi, Suginami-ku, Tokyo, Japan.
Oishi, Hirohisa, Nagoya-City, Japan.
Onozawa, Katsumi, Tokyo, Japan.
Osborne, Annie, Hong Kong.
Ozaki, Wakatsu, Kawanishi-City, Japan.
Pathak, Kit, Salford.
Pawson, Peter, Findon.
Probst, Nicholas J., Sarisbury Green, Hants.
Punshon, Clayton R., Regina, Canada.
Ranger, David E.A., St Albans.
Ratilal, Chandrakant, Northolt.
Rehak, Karel, Wakefield.
Richardson, Kay E., Mildenhall.
Roucan, Jean-Pierre, Le Vesinet, France.
Salahudeen, Mohamed F., Kelempong, Sri Lanka.
Saleh, Victor, Wembley.
Sanchez, Sabina, London.
Sato, Eisaku, Saitama-ken, Japan.
Semmes, Granville M., New Orleans, U.S.A.
Shams, Mohammad, Dubai.
Shand, Dolores M., Ontario, Canada.
Shima, Tatsuhito, Toyama-City, Japan.

Shimada, Masahiro, Kanazawa-City, Japan.
Shimaoka, Mitsuaki, Osaka-City, Japan.
Shimomura, Michiko, Tokyo, Japan.
Shum, Helen Y. S., Kowloon, Hong Kong.
Sibtsen, Johannes C., Heerjansdam, Holland.
Silverberg, Donald A., Fla, U.S.A.
Simkin, Michael B., Blackpool.
Singleton, Graham S., Cardigan.
Smith, Cyril R., Durban, S.Africa.
Stiever, Arthur J., Minn., U.S.A.
Sussman, Murray H., Ga, U.S.A.
Takahashi, Junko, Urawa City, Japan.
Takasu, Takitaro, Tokyo, Japan.
Taki, Chikako, Fuji-City, Japan.
Tamaya, Teruhisa, Tokyo, Japan.
Taoka, Hideki, Tokyo, Japan.
Taylor, Richard P., Liverpool.
Teramae, Kiyomi, Shibuya-ku, Tokyo, Japan.
Thelin, Jan, Umea, Sweden.
Thirumavukarasu, Velauthapillai, Colombo, Sri Lanka.
Tormino, Frederick J., N.J., U.S.A.
Tripp, Julia M., Hong Kong.
Tripp, Reginald U.G.H., Hong Kong.
Trowbridge, Rex A., Oreg., U.S.A.
Turner, Richard, Woking.
Ty Vicente, William, Manila, Philippines.
Uchida, Tatsuhiro, Nakakoma-District, Japan.
Van Baaren, Ralph, Zwijndrecht, Holland.
Vouilloux, Annie J., Kowloon, Hong Kong.
Vuyk-Welp, Walthera, Amersfoort, Holland.
Walker-Smith, Michael A., London.
Wills, Derek George, Swanage.
Wilson, Eunice K., Salisbury, Rhodesia.
Wong, Tak Chiu, Kowloon, Hong Kong.
Wood, Margo E., Vt, U.S.A.
Wood, Roger H., Bournemouth.
Wu, Jacob C.Y., Md, U.S.A.
Yano, Hajimu, Osaka, Japan.
Yokoo, Naoya, Tokyo, Japan.
Yoshinaga, Kyoichi, Tokyo, Japan.

GEM DIAMOND EXAMINATION 1977

Thirty-eight candidates entered for the Association's 1977 Gem Diamond Examination, of whom thirty-four qualified, four with distinction. The following is a list of successful candidates arranged alphabetically.

QUALIFIED WITH DISTINCTION

Collier, John M.B., Fordingbridge.
Prat Moya, Sagrado C., Barcelona, Spain.
Tarazona Almenar, Federico, Valencia, Spain.
Vilá Perales, Vicente, Barcelona, Spain.

QUALIFIED

Aloy, Richard N., Gillingham.
Aparici Miguel, Rafael, Valencia, Spain.
Blackley, Robert, Ilford.
Bratton, Timothy J., Sidcup.
Comin Vilajosana, Luis, Barcelona, Spain.
Davidner, Gail R., Wembley.
Fabregas Guardiola, Virginia, Barcelona, Spain.
Falomir Penarrocha, Amadeo, Liria, Spain.
Ferrandis Recatala, Juan V., Valencia, Spain.

Garcia Pilan, Alfonso, Albuixech, Spain.
Hudspith, James W., Leatherhead.
Jamieson, Vivienne, Southgate.
Leach, Jane, London.
Mills-Owens, Paul, London.
Moline Sala, Agustin, Barcelona, Spain.
Mollfulleda Buesa, Antonio, Barcelona, Spain.
Mora Carbonell, Antonio R., Valencia, Spain.
Obiols Mundet, Agustin, Barcelona, Spain.
Oria Albero, Isabel J., Valencia, Spain.
Oria Albero, Paz, Valencia, Spain.
Pons Gomez, Joaquin, Barcelona, Spain.
Ralston, Jonathan B., Stoke Newington.
Rappitt, Toby J., Maidenhead.
Ribes Cudinach, Emilio, Barcelona, Spain.
Rider, Stephen G., Chelmsford.
Ruiz Roca, José V., Valencia, Spain.
San Juan Ribes, Antonio, Valencia, Spain.
Statham, Patricia M., London.
Tilling, Julian G., Dunstable.
Vivo Ibanez, José, Valencia, Spain.

EXAMINATIONS IN GEMMOLOGY 1977

In the Association's 1977 Examinations in Gemmology, 691 candidates sat for the Preliminary Examination (370 passed), and 490 for the Diploma Examination (121 passed). Overseas centres were established again in many parts of the world.

In the opinion of the Examiners no candidate attained the standard required for the Tully Memorial Medal.

The Rayner Prize, in the Preliminary Examination, has been awarded to Mr Michael Allchin, of Altrincham, Cheshire.

The following are lists of successful candidates, arranged alphabetically.

DIPLOMA EXAMINATION

QUALIFIED WITH DISTINCTION

Canas Carballido, Miguel, Madrid, Spain.
Havlik, Jan C., London.

QUALIFIED

Abeyratna, Nayana S.S.K., Colombo, Sri Lanka.
Abril Sirvent, Inmaculada, Mataro, Spain.
Arla Pont, Antonio, Barcelona, Spain.
Ayres, Thomas D., Farnham.
Baldock, Edward J., Wirral.
Bapat, Suresh B., Bombay, India.
Beard, Paul, Nottingham.
Bennett, Lise C., Rochester.
Bhaskaran, Gopalan, Bombay, India.
Bienert Albaladejo, Rosario, Barcelona, Spain.
Borgen, Jennifer A., Fredrikstad, Norway.
Brewer, Peter C., Scarborough.
Bruce, James T., Salisbury, Rhodesia.
Campos De Quevedo, Juan N., Madrid, Spain.
Castanera Rodriguez, Luis, Barcelona, Spain.
Cavey, Christopher R., Ealing.
Chadderton, Yvonne E., Oldham.

Clarke, Kathleen D., London.
Clayton, Keith M., Alford.
Clements, Jennifer M., London.
Conrad, Donald B., East Islip, N.Y., U.S.A.
Cooper, Dorothy A., Stockport.
Cooper, Roy, Disley.
Dantanarayana, Malinie, Colombo, Sri Lanka.
Dave, Mayur, London.
De Silva, Nirmali P., Ambalangoda, Sri Lanka.
De Waele, Carine G., Ghent, Belgium.
Diaz Valcarcel, Teresa, Barcelona, Spain.
Dominguez Mondelo, Segundo, Oviedo, Spain.
Duroc-Danner, Jean M., Geneva, Switzerland.
Elkington, Mary, Solihull.
French, Anthony J., Brockenhurst.
Gade, Fredrik G., Skjetten, Norway.
Ghaswala, Sudhir R., Bombay, India.
Gill, Stephen H., East Horsley.
Goonawarna, Carl L.W.P., Ratnapura, Sri Lanka.
Gotch, Takeshi, Amsterdam, Holland.
Grater, Jane, Salisbury.
Grimbly, Margaret S., Plymouth.
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Henocq, Rosemary S., South Croydon.
Henrich, Francis J., Lower Hutt, N.Z.
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Horn, David E., Ripon.
Hughes, Steven B., Manchester.
Innala, Harri T., Hämeenlinna, Finland.
Kandiah, Asokavathy P., Colombo, Sri Lanka.
Kapukotuwa, Senerath L.B., Rajagiriya, Sri Lanka.
Kaye, Ian D., London.
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Kizawa, Masakatsu, Ibaraki-ken, Japan.
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Kortenaar, François L., Schagen, Holland.
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Meintjes, Arthur H., Stellenbosch, S. Africa.
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Murga Chivite, Miguel A., Barcelona, Spain.
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Nachimson-Palacci, Rosy, Troinex, Switzerland.
Narros Martin, Gabriel, Madrid, Spain.

Ng, Kevin K.F., Singapore.
Nootenboom, Poppy Z.L.-B., Kowloon, Hong Kong.
Norström, Stig E., Skärholmen, Sweden.
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Sepp, Arne, Cape Town, S. Africa.
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Stonebanks, Judith M., Maidenhead.
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Walz, Sylvia E., Langerhagen, W. Germany.
White, Paul T., Seattle, Wash., U.S.A.
Woodhall, Jon. W., Home Hill, Qld, Australia.
Yamaya, Sachiko, Tokyo, Japan.

PRELIMINARY EXAMINATION

RAYNER PRIZE

Allchin, Michael, Altrincham.

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Ali, Syed J.A., London.
Alltree, Derek D., Manchester.
A'Logann, Charles, San Francisco, Ca, U.S.A.
Alos Vidal, Elena, Barcelona, Spain.
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Arla Matas, Esteban, Barcelona, Spain.
Ashra, Harish B., London.
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Aznar Molla, del Dulce N., Valencia, Spain.
Bantekoe, Marijke, Steenwijk, Holland.

Barcham, Kathryn L., Peak, Hong Kong.
Barker, Cyril Henry, Nieder Sachsen, W. Germany.
Barot, Nandkishor R., Nairobi, Kenya.
Barthe Arias, Antonio-R., Oviedo, Spain.
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Beg, Mirza Z., Woking.
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Boles, Julian D., London.
Bou Castillo, Angel D., Barcelona, Spain.
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Britton, Stephen J., Crawley.
Bromwich, Graham S., Reigate.
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Budding, Peter J., Guildford.
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Catteau, Michel, Sens, France.
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Clark, Keith D., Ipswich.
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Davies, Garry, Hyde.
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Emslie, Iain A., Walsall.
Ergis, Aflal M., Hamburg, W. Germany.

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Evans, Hilary M.A., Wirral.
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Fernando, Marie C.H., Colombo, Sri Lanka.
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Kaleel, Ameena, Colombo, Sri Lanka.
Kalgutkar, Ranchandra S., Bombay, India.
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Leach, David T., Nairobi, Kenya.
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Lee, Robert J., Georgetown, Guyana.
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Levy, David W.P., Wimbledon.
Litchfield, Jeane, Albuquerque, N. Mex., U.S.A.
Litjens, Rosalia C., Leiden, Holland.
Liu, Kin-Shun, Hong Kong.
Lloveras Bech, Conrado, Gerona, Spain.
Loh, Swee K., Singapore.
Long, Gabrielle E.M., Swanage.
Lopez Paga, Francisca, Barcelona, Spain.
Lopez Garcia, Marisa, Barcelona, Spain.
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Manley, Frank R., Lymm.
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Marsh, Charles E., Dunedin, Fla, U.S.A.
Martin, William J., Nairobi, Kenya.
Masuda, Hideyo, Shizuoka-Shi, Japan.
McCready, Ann, Nairobi, Kenya.
Midgley, Ronald C., Leeds.
Miller, Harry T., Rio de Janeiro, Brazil.
Miller, Neil, London.
Moller Duran, Rodolfo, Barcelona, Spain.
Monclus Aspero, del Carmen, Barcelona, Spain.

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Proctor, Sarah-Jane L., London.
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Puig-Doria Pala, José, Barcelona, Spain.
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Pulle, Bernard T.B., London.
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Rajaratnam, Evelyne V., Ratnapura, Sri Lanka.
Rajivan, Sathyanandan, Colombo, Sri Lanka.
Rakke, Brit, Oslo, Norway.
Rance Jordana, Francisco, Barcelona, Spain.
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Rastall, Mark P., Halifax.
Rastall, Philip, London.
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Roberts, Ian P., Northampton.
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Ryan, Thomas G., Limbe, Malawi.
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Saito, Andrea L., Santa Monica, Ca, U.S.A.

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Shackley, Ian W., New Brighton, Christchurch, N.Z.
Shah, Nikunj V., Bombay, India.
Shiek, Swun K., Colombo, Sri Lanka.
Sideras, Chris S., London.
Sierstorpff, John v.Francken, Rheinbrohl, W. Germany.
Simpson, Carol A., London.
Skeate, Claire M., Johannesburg, S. Africa.
Snowden, Robert F., San Marino, Ca, U.S.A.
Soler Moradell, Nieves, Barcelona, Spain.
Solves Llorens, Vicente, Valencia, Spain.
Sosna, Boris, Wembley Park.
Soteras Torrella, Emilia, Barcelona, Spain.
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Sunde, Elisabeth M.H., Oslo, Norway.
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Swan, David G., London.
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Tamarit Garcia, Pedro A., Valencia, Spain.
Tan, Chow-Ng, London.
Tate, Julia F., Hong Kong.
Tattersall, Simon R., Radlett.
Taylor, Ernest B., Warrington.
Taylor, John B., Brisbane, Qld, Australia.
Taylor, Richard P., Liverpool.
Thompson, Hugh D.R., Mount Royal, Que., Canada.
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Tindall, Anthony P., Otley.
Tolley, Ian P., Brisbane, Qld, Australia.
Törnroos, Gunilla A.V., Helsinki, Finland.
Towler, Eric A., Kowloon, Hong Kong.
Townsend, Nigel D., Wakefield.
Truman, Raymond H., Ilford.
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Turtiainen, Arja A., Eura, Finland.
Teraura, S., Osaka, Japan.
Uchihara, Ichiro, Tokyo, Japan.
Ueta, Kouji, Osaka, Japan.
Vale, Shelagh V., Limuru, Kenya.
Valero Martinez, José F., Barcelona, Spain.
Valonen, Anne I., Kalhonkylä, Finland.
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Van Koppen, Maria E.C.T., Rotterdam, Holland.
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Visser - Bonnmann, Maria I.A., Delft, Holland.
Vollom, Paul A., Eugene, Oreg., U.S.A.
Wagenaar, Elke, Nairobi, Kenya.
Waller, John R., Thornhill, Ont., Canada.
Walter, Laetitia, Dordrecht, Holland.
Walz, Sylvia E., Idar-Oberstein, W. Germany.
Watson, Catherine H., Bulawayo, Rhodesia.
Watson, John L., Bulawayo, Rhodesia.
Webster, Pamela R., Middlesbrough.
Weerasekera, Vasantha, Nugegoda, Sri Lanka.
Wellcome, Clare R., Southampton.
Wieman, Jacob, Amsterdam, Holland.
Wijesuriya, Mutukuda A.N., Minuwangoda, Sri Lanka.
Wills, Derek G., Swanage.
Wills, Stuart S., Ayr, Qld, Australia.
Winter, Julie, Leatherhead.
Wise, Midori, London.
Wong, Tak C., Kowloon, Hong Kong.
Yamaguchi, Takashi, Osaka, Japan.
Yamagishi, Shoji, Kanagawa-Ken, Japan.
Yasuzawa, Tomiko, London.
Yim, Wyss Wai-Shu, Hong Kong.
Yoshikawa, Kazuhiko, Gobo - City, Japan.
Ypya, Teuvo H., Kemi, Finland.
Zaragueta Arce, Gaspar, Barcelona, Spain.
Zaveri, Bharat G., Bombay, India.

GIFTS TO THE ASSOCIATION

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

The Gemmological Association of All Japan for a large framed collage depicting a typical Japanese vase and floral arrangement. This picture is made up of opals, agates and sapphires.

Mr A. Hardy for calcite crystals from Eyam, Derbyshire.

Mr P.P.E. Paulin, B.Sc., F.G.A., Uppsala, Sweden, for a collection of hessonite garnet, small crystal groups and pieces of idocrase, some of which show a typical spectrum—all from Quebec Province, Canada.

Mr J.L. Slocum, Rochester, Mich., U.S.A., for an excellent collection of 'Slocum' stones—man-made material simulating opal. In the collection are four pieces of rough material and 36 cut and polished stones together with one doublet and two triplets.

Mr M. van Moppes, of Wessex Impex Ltd, for an excellent red agate and amethyst geode from Dulcote Mine, Somerset.

GEM CRAFT WORLD EXPO

An exhibition (organized by Gem Craft Magazine) of 'gems, minerals, silvercraft, lapidary machinery, jewellery, enamelling, treasure-hunting and allied crafts' is to be held at Grosvenor House Hotel, Park Lane, London, W.1. on 25th, 26th and 27th March, 1978. (Open 10 a.m.–7 p.m. Admission adults 60p., children 30p.)

"GEMPRINT"

The Gemprint is an instrument, simple in principle, which provides a means of obtaining a permanent record of reflections from polished gemstones—a 'fingerprint' from which the individual gemstone can always be recognized (unless it is repolished or recut). It consists (see Fig. 1) of:

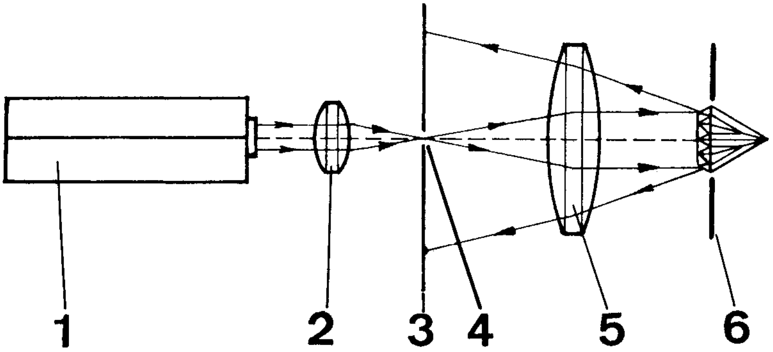

Fig. 1

(1) A laser beam light source
(2) Lens
(3) Polaroid film holder
(4) Holding screen with pin-hole in the centre
(5) A second lens
(6) Mobile holder to position the gem

In operation the laser beam from the light source (1) is focused by the lens (2) onto the screen plane and passes through the pin-hole (4). The second lens (5), which is placed at its focal length from the pin-hole, provides a parallel light beam. When the gemstone is placed in this beam, reflections of the polished surfaces return through the lens and focus on the screen (4). The gem is positioned in its holder (6) so that the reflections of the gem table are directed into the pin-hole. There is only one position in which the light reflected from the table of the gem can be brought to focus on the pin-hole. This provides an orientation point so that subsequent reflection patterns of the same gem will be identical with the original. When the gemstone is positioned in its exact location, recording of the reflection is than made on film at the screen plane.

Shown in Fig. 2 is a pattern of light spots produced by a particular diamond. There is only one position where this diamond will reflect light back from its table through the pin-hole so that subsequent Gemprints of the same stone will be identical, though when comparing negatives or prints it may be necessary to revolve them in order to match the patterns.

The Gemprint will accommodate stones of almost any size when unmounted

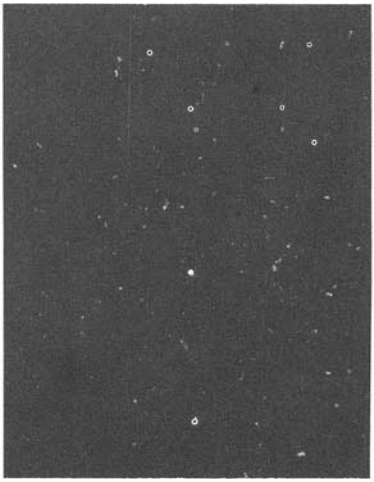

Fig. 2. Diamond.

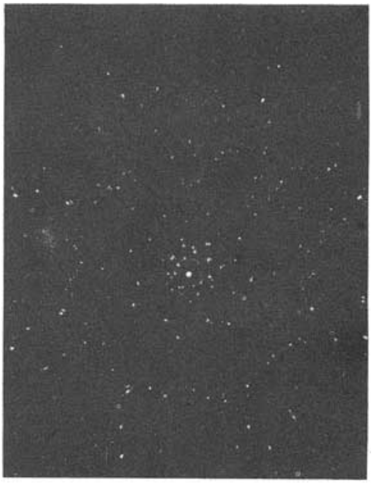

Fig. 3. Y.A.G.

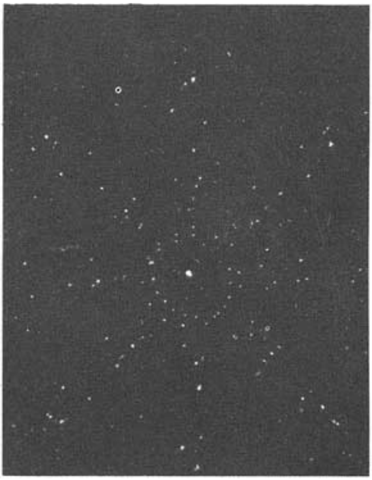

Fig. 4. G.G.G.

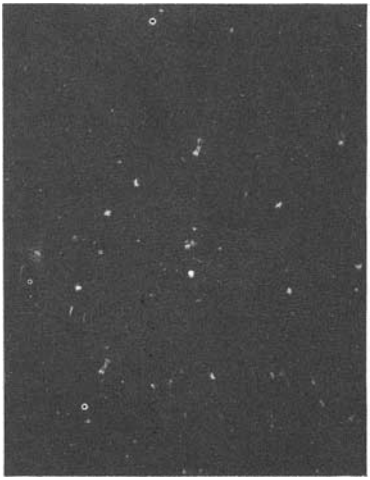

Fig. 5. Strontium titanate.

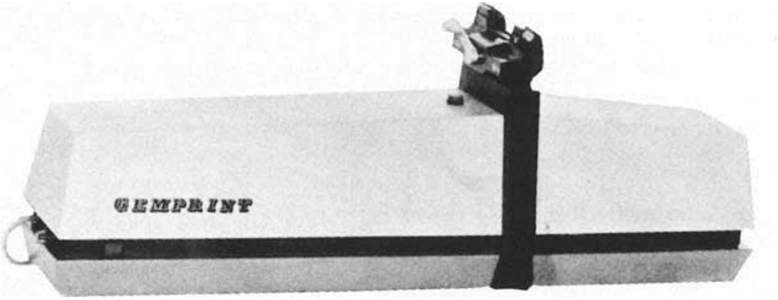

Fig. 6

and also many mounted stones as well. The prints are unique for each brilliant-cut diamond, provided it is not repolished.

The machine can also be used for brilliant-cut simulants of diamond (or indeed for any faceted stone with a flat table facet) because each individual gives a different pattern on the Polaroid film (see Figs 3, 4 and 5). When a stone is machine cut and polished as in the case of Y.A.G., G.G.G. and strontium titanate, shown in the illustrations, it will produce a more symmetrical pattern than a hand-cut stone.

The appearance of the instrument is shown in Fig. 6, and it was demonstrated by Mr A.E. Farn, F.G.A. to members of the Gemmological Association at a meeting in Goldsmith's Hall on 9th February, 1977.

The Gemprint would cost approximately £1,500 in the U.K. Further details are available from Gemmological Instruments Limited, Saint Dunstan's House, Carey Lane, London, EC2V 8AB (Tel. 01-606 5025).

FELLOWSHIP BADGE

In addition to the Association Tie there is now available a brooch with pin fitting suitable for female and male dress.

The brooch is oval (16×21 mm) and bears the Association Crest and Coat of Arms. The Coat of Arms is in red and white enamel and the motto at the bottom of the brooch is in red enamel.

The tie and the brooch are available only to Fellows of the Association.

Prices of the brooch are as follows:

Metal gilt and enamel

U.K. including postage and V.A.T. = £8.10 each
Overseas including airmail postage = £9.00 each

9 ct Gold (Hallmarked)

U.K. including postage and V.A.T. = £27.00 each
Overseas including airmail postage = £26.00 each

Please send payment with order and write name and address clearly: also state year in which diploma was obtained.

THE JOURNAL OF GEMMOLOGY

The Editor apologizes for the late appearance of this number of the *Journal* owing to unavoidable delays due to a change of the processes and typefaces used by the printers from letterpress to photolithography and from 'Baskerville' to 'Times' respectively.

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