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and

PROCEEDINGS OF THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

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GEMMOLOGY THEN

By R. KEITH MITCHELL, F.G.A. (Tully Medallist, 1934)

In 1932 a poster outside the Chelsea Polytechnic in London advertised a 'Course in Applied Mineralogy for Jewellers'. This was Gemmology, and it was in those days, limited to the Trade. Only some years later did the L.C.C. open all classes to all comers.

At that time I had spent four poorly paid years in the basement buying-department of a well-known Jewellers in Oxford Street, handling silver, enamel, leather goods, ivory, tortoiseshell, china, glass and many other sundries outside the elite jewellery section of the firm. With a keen interest in geology, awakened by visits as a schoolboy to the Mineral Gallery of the Natural History Museum and to the Geological Survey Museum, I felt that this Course might further my intent to take out in experience what I was unlikely to get from my employers in salary. I joined the class and on one evening a week a new world opened for me.

The instructor was Mr Irvine G. Jardine, a somewhat pedestrian schoolmaster, who was assisted by Thorold G. Jones, an instantly likeable young man of considerable enthusiasm, from the Geological Survey Museum which was then in a marvellously evocative building in Jermyn Street, on the site now occupied by Simpson's of Piccadilly.

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The class was perhaps twenty strong and mostly from firms where they were already handling gems in their daily work. In this they had the advantage of me. Some names were to become well known in Trade and wider circles in later years, among them A. Ross Popley, J. G. Shenton, W. Flower and Robert Webster.

Our textbook was the quite elementary 6th edition of Dr G. F. Herbert Smith's 'Gemstones', which still treated the trigonal or rhombohedral system as a sub-division of the hexagonal system and even used the old-fashioned three equal and inclined axes of reference for that division. Our class notes updated the axes but kept the system as a sub-division—an out-dated practice which survives in American textbooks even today, although x-ray crystallography has shown us that the two systems differ basically in their symmetry.

Our most successful refractometer was a tiny instrument invented and perfected by Dr Herbert Smith some years before. Its minute scale gave comparatively sharp readings but, without a cover to exclude top light, using it was something of a juggling feat, one hand manipulating the stone and holding or steadying the instrument while the other shielded the stone from extraneous light.

A much larger and quite heavy table instrument, inspired by the late B. J. Tully, was much in demand, for it had a rotating hemisphere of optically dense glass which made double refraction easy to measure. But, lacking a ball-bearing race, this soon showed signs of wear and became inaccurate. For both instruments we had only a 1.785 liquid, made by dissolving sulphur in methylene iodide. This was barely adequate for sapphires and rubies, and quite useless to test the higher red garnets which could in those days be tested only by a hydrostatic weighing.

The 1.81 liquid, the spinel, blende and diamond refractometers, Clerici solution and polaroid were all in the future and quite unknown to us, as were the Chelsea Filter, crossed filter tests, fluorescence tests, and absorption spectra, so far as gemmology was concerned.

The only commercial synthetics were Verneuil sapphires, rubies and blue or white spinels. They were simply made and comparatively easy to detect, for the modern furnace with its computerized feed-back temperature control was unknown. Hydrothermal and flux-diffusion synthetics were also unknown to us, although the Germans had made the first synthetic emeralds.

Commercial production of these and of the many other clever synthetics of today was then a very long way in the future. Many of the latter were to be the result of research into other substances, especially in the laser field, which did not begin until 1960.

Thorold Jones constructed some clever little wooden stands for the Smith refractometer which not only stabilized the instrument but also screened the truncated hemisphere from top light. This was probably the major advance in that year of 1932/33, so far as Chelsea Polytechnic was concerned.

Towards the end of the Summer Term in 1933 we learned that Jardine was moving to higher things in the education world, and rumour suggested that Thorold Jones was taking over as instructor. But we were left in the dark until the first evening of the Autumn Term when the class-room door opened and admitted the tall athletic figure of Mr B. W. Anderson who was, in those days, blessed with a fine head of fair curly hair. An instant rapport was established, for Anderson had, and indeed still has, an enviable ability to talk and write on his subject with great clarity and most infectious enthusiasm. Under his inspired teaching the 1933/34 class blossomed remarkably.

Almost at once we had 1.81 refractometer liquid, Clerici solution and the little gadget which eventually became known as the Chelsea Filter.

Personally I achieved a move into my employers' jewellery department and began to handle some exceptionally fine gems. I lived gemmology.

Each day, at lunch time, I would snatch a brief snack at a tea shop and them make my way rapidly through the deserted back streets (Carnaby Street is one which has since achieved a crowded fame) to the Geological Museum, in Jermyn Street. This wonderful old building, later to be lamented by John Betjeman, the son of a well-known supplier to my old department, had a domed roof which, in all the years that I knew it, was supported by an impressively massive shoring of square timbers which passed right up from the basement floor through the centre of the oval shaped display galleries. Here I would spend a precious forty minutes, gazing at gems and crystals in glass display cases until their essential appearance was firmly impressed on my memory. Then with exactly seven minutes in hand I would make the return dash to work. Weekends were spent in similar visits to the Mineral Gallery of the Natural History Museum and the Jewellery Department of the Victoria and Albert Museum.

At this time Anderson's 'Gem Testing for Jewellers' (later 'Gem Testing' and to run to nine editions), Webster's 'Gemmologist's (Pocket) Compendium' and 'Practical Gemmology' (at first little more than an expanded version of our class notes) were all to be written. The study of gem inclusions was still in its infancy and Edward Gübelin's life work on this subject scarcely started. Webster's 'Gems', which was in truth based on the work of the London Laboratory as a team, the author to some extent acting as resident scribe and collating the vast store of information for publication, was also some thirty years away.

Yet in these primitive conditions we still found much to interest us and classes were enjoyed to the full. In many ways one can look back at those far simpler days with a certain nostalgia. Life was less exacting and gemmology a great deal less complex than it is today.

[*Manuscript received 6th June, 1981.*]

ZAMBIAN TOURMALINE

By ARTHUR E. THOMAS, F.G.A.

Johannesburg

In the past tourmaline from sources in Zambia has tended to be too dark to be of anything other than academic interest. The tourmaline associated with the emerald occurrence at the Miku Mine was such a dark red that it required strong sunlight to distinguish it from the schorl which is abundant in that area. A very dark green material was found in the pegmatites near the bridge

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which carries the great east road over the Luangwa river. Finds in other areas were equally uninspiring. In recent months however an interesting range of Zambian tourmaline has come onto the market. This material is alleged to originate from sources near Lundazi in the eastern province. Pegmatites mined in that area a number of years ago did show indication of gem material. The Aries mine in particular produced a quantity of light aquamarine and dark tourmaline.

The first parcels of commercial quality material to arrive in Johannesburg were a rather pleasing green but showed either smoky or dark olive green parallel to the *c* axis. The next consignment contained samples of material described by the miners as 'khaki' tourmaline. This was a very apt description for the dull greeny brown; however, several pieces looked a more interesting cognac colour under the tungsten desk light. Illuminated by a daylight lamp a number of these specimens revealed an attractive rose pink colour. While in other pieces the colour change from cognac to a shade of salmon pink was less dramatic, it was still considerably more marked than the familiar minor variations in hue seen in Moçambique material.

Fourteen stones have been cut from this material to date, ranging in size from slightly under one carat to twelve and one half carats. The largest stone is a rectangular step cut which is bi-colour in addition to showing a very distinct colour change.

The dichroscope reveals a wide range of colour combinations even in material of a superficially similar colour.

Chartreuse	—	Russet Brown
Peach	—	Rose Pink
Very Pale Pink	—	Cerise
Eau de Nil	—	Dusky Pink
Oil Green	—	Russet Red

Examined through the Chelsea colour filter, in tungsten light the cognac coloured stones assume a dull green hue, while under a daylight lamp the pink becomes a very light green. The spectrum revealed a broad hazy absorption in the region of the blue-green from 4900Å—5300Å.

RI	1.619	—	1.639
SG range	3.022	—	3.029

This material is unlikely to reach the market in its natural state, since heat treatment removes the brown coloration and leaves an attractive and far more saleable pink.

[*Manuscript received 17th October, 1981.*]

THE PURIFICATION OF BROMOFORM

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ABSTRACT

A simple technique for the purification of bromoform is described which requires no complex laboratory facilities. It is particularly suited to the purification of aged and discoloured samples, and batches which have been diluted with low b.p. solvents.

INTRODUCTION

Heavy liquids are frequently used by the gemmologist and jeweller for rapid density determination by a 'sink-or-float' comparison technique. One oft-used is bromoform, which has a density of 2.89 g cm^{-3}.

The author was prompted to find a simple purification technique for bromoform for a number of reasons:

1. A commercial sample (Fisons SLR) contained 4% ethanol stabilizer and had a density of 2.56 g cm^{-3}; as such it was incapable of floating quartz. Workers should be warned that samples stabilized in this way may not be assumed to have the density of pure bromoform.
2. Gemmologists often accumulate quantities of bromoform residues of low density which have been diluted with other liquids; these can only have their densities raised by addition of large quantities of heavy liquids or by separation of the valuable dense component.

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3. Bromoform may become badly discoloured with age.
4. Many workers may not have the facilities for the usual distillation techniques of separation.

With these factors in mind the technique described below was developed. It is based on the fact that bromoform, having a freezing point of 8.3 °C, will crystallize out of many mixtures in a pure form when cooled in ice.

METHOD

The bromoform sample or residue is placed in a suitable container (e.g. a conical flask which it should approximately half-fill; a jam jar will suffice in an emergency) which should be securely stoppered and preferably taped to prevent the ingress of water. It is then placed in a bucket of ice-water slurry until the bromoform has crystallized out (up to two hours depending on quantities). The flask may then be removed from the slurry, opened, and the unfrozen liquid poured back into the bromoform residues bottle. The solid, when melted, consists of nearly pure ($\sim$98%) bromoform.

RESULTS

Two samples of bromoform were purified by this method; the first sample (Fisons A.R.) containing 4% ethanol with a density of 2.56 g cm^{-3}; from 100 ml of sample, 83 ml of bromoform with density 2.84 g cm^{-3} was recovered.

The second was a sample which had been diluted to a density of 2.65 g cm^{-3} for quartz flotation purposes; 100 ml yielded 52 ml bromoform of density 2.83 g cm^{-3}.

DISCUSSION

This method of purification relies upon the crystallization of bromoform, with a melting point above those likely for other components in the mixture, when cooled to just above 0 °C.

However, it should be noted that many substances that may well be present have melting points only slightly below that of bromoform. In particular benzene (m.p. 5.5 °C) and methylene iodide (m.p. 6.1 °C) may be present, and these will not be eliminated if the freezing is carried too far. The answer here is to introduce a thermometer through the bung of the vessel into the bromoform; while it indicates 8 °C bromoform is crystallizing, but when it falls below this temperature the freezing process should be stopped or other materials may crystallize. In such cases fractional distillation is a superior technique, but this method will yield acceptable results.

Finally, I have been informed that bromoform of density 2.60 g cm^{-3} is available for pharmaceutical purposes. This is presumably the ethanol-stabilized material, and it may prove cheaper, for anyone needing bromoform in quantity, to purchase this material and purify it than to buy the expensive pure liquid.

It is hoped that the technique described will prove useful to anyone who uses heavy liquids. With care, it may prove useful in the purification of other substances, providing that an appropriate freezing mixture is chosen and no high melting point impurities are present.

[*Manuscript received 17th June, 1981.*]

HORNBILL IVORY

By G. BROWN, Dip.D.T., F.G.A., F.G.A.A. and
A. J. MOULE, Ph.D., F.G.A., F.G.A.A.

Hornbill ivory, one of the world's rarest organic gem materials, has been carved and traded within the south-east Asian region for the last two thousand years. The material is obtained from the casque (a dense ivory-like protuberance located above the beak on the frontal aspect of the bird's cranium) of a single species of hornbill—the *Rhinoplax vigil.* This large, ungainly bird lives in a tree-top habitat that is restricted geographically to lower Burma, southern Thailand, peninsular Malaysia, Sumatra and Borneo.

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The *Rhinoplax vigil* or Helmeted Hornbill (Figure 1) is one of forty-six species belonging to the family *Bucerotidae.*⁽¹⁾ It is the only species from this family which possesses a casque that is suitable for carving into decorative objects and objects of art.

Helmeted hornbills are large birds,⁽²⁾ often 2 m in length. They have a rather dull plumage with a characteristic distribution of colours. Its black crested head contrasts spectacularly with chestnut eye covers and a carmine-coloured casque which extends onto the lateral surface of the bird's skull. A black, featherless neck

FIG. 1 Drawing of the Rhinoplax vigil or Helmeted Hornbill. The casque from which hornbill ivory is obtained is arrowed.

joins this attractively patterned head to the bird's body. Wings and its upper body are covered with reddish brown feathers, while the bird's lower body and upper legs are covered by whitish feathers. Two long tail feathers protrude beyond the normal tail feathers, giving the bird an elongated appearance.

The helmeted hornbill's flight is noisy, as the base of its flight feathers are uncovered. One of the unique characteristics of this bird is its call—a series of toks, increasing in intensity and frequency until the call resembles an insane laugh. The uniqueness of this call has led the Malays to dub the bird the 'kill your mother-in-law bird'.

The much prized casque (Figure 2) of the helmeted hornbill is formed from a dense ivory-like mass (5 × 5 × 4 cm) located on the frontal and antero-lateral aspect of the bird's cranium. Its top and sides are covered by a thin adherent carmine-coloured sheath of casque material, while the frontal surface and body of the casque is formed from yellowish-brown material. With age, the carmine-coloured sheath of the casque tends to wrinkle and crack, so becoming less valuable for carving purposes.

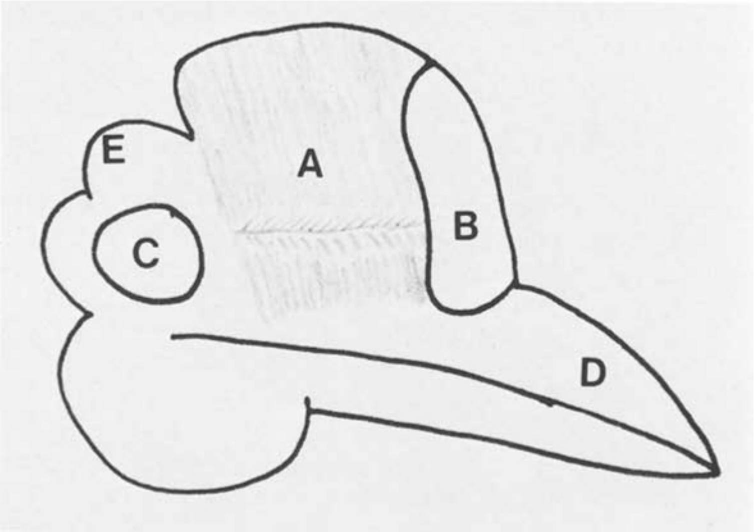

FIG. 2 Diagramatic representation of the skull of the Helmeted Hornbill indicating: A. The ridged carmine coloured outer sheath of the casque. B. The anterior yellowish-brown surface of the casque. C. Orbit. D. Beak. E. Cranium.

Why the *Rhinoplax vigil* possesses such a dense casque, and what the chemical nature of the material that forms the casque is, is not known. However, Robinson (1928)(3) offered a possible explanation for the existence of casques on all hornbills. '. . . it has been suggested that the bird uses its head to compact the gum with which it closes the nesting hole of its mate. The frontal plate is extremely hard and dense, like vegetable ivory; about one third of an inch thick, but behind it the casque is composed of loose spongy cancellous tissue, which no doubt prevents the shock being transmitted to the brain'. Unfortunately, Robinson's explanation may only be applied to the helmeted hornbill with some caution, as this bird has a totally dense casque.

DERIVATION OF TERMS

Hornbill ivory is known by a variety of names, including: *Calao Ivory, Hoting,* and *Hōden.*(4) All these terms, including that of hornbill ivory, are apparent misnomers.

Best available evidence seems to suggest that the word, commonly used to describe hornbill ivory, was invented by Malay-speaking Chinese traders who first discovered the material. They transliterated the Malay word for ivory *(gading)* into Chinese, and so the term *ho-ting* evolved. It has been suggested that the first written account of this new trade material was found in the trading records of the Ming Dynasty. In these accounts the words *ho-ting* and *ho-ting hung* first appear. Literally, these words can be translated to mean *crane's crest* and *crane's crest red* respectively. It would appear that the early Chinese scholars were under the misapprehension that this new material was the product of the crane. It was not until the early part of the Ch'ing Dynasty that the helmeted hornbill was verified as the source of *ho-ting.* By this time, the terminology was so well established that *ho-ting* became a word of every day use.

With the spread of appreciation of the value of hornbill ivory to other parts of the world, other terms soon evolved. The Japanese coined the word *hōden* to describe the hornbill ivory used in the manufacture of netsuke, inro and ojime, while the European export market used such terms as *Calao ivory* and *crane's crest ivory* to describe the material from which hornbill ivory export wares were made.

A BRIEF HISTORY OF THE USE OF HORNBILL IVORY

It is believed the original users of hornbill ivory were the native inhabitants of Sumatra and Borneo. Dyak artefacts, manufactured from hornbill ivory, have been discovered at archaeological sites in Borneo. Within their culture Dyaks used hornbill ivory to manufacture decorative sword-hilts, carved toggles for sword-belts, decorative ear-ornaments, and the much sought after tiger's-tooth ornaments.

Hornbill ivory was first brought to the Ming Court by the fifteenth-century Chinese traders, who traded with Malay intermediaries. Soon, within China, hornbill ivory became the prized possession of the ruling classes, with most value being given to *ho-ting hung*—the thin carmine-coloured outer sheath of the hornbill casque. From this material, Ming artisans produced ceremonial belt-buckles and ornate combs for the court.

It was soon discovered that the relatively small casque of the helmeted hornbill was thermoplastic; so it could be heated and pressed to produce flattened masses of larger size, greater strength, and superior translucency, than exist naturally. Initially, only the carmine outer sheath was stripped from the casque, steamed(?) and pressed, to produce the large homogeneous masses from which the decorative objects of the Ming Dynasty were manufactured. Later, it appears, techniques were evolved to reconstruct thick layers of both carmine-coloured and yellowish-brown casque material and then fuse them together. Details of these reconstructive techniques are still trade secrets; however, it would seem reasonable to assume that the reconstructive process would be relatively similar to that used to reconstruct and mould tortoiseshell or horn.

By the time the Ch'ing Dynasty was established, the Manchus possessed all the necessary technology for producing a range of decorative items from hornbill ivory. Ceremonial belt-buckles, plume-holders for hats, and archers thumb-rings, were some of the aesthetically pleasing objects produced during this dynasty. Once the tobacco habit was introduced into China from the West, the Manchus and their Chinese subjects quickly adopted the habit of taking snuff. As a consequence, the snuff bottle—originally a functional item—rapidly became an object of art. Hornbill ivory was one of the valuable materials used in the manufacture of these bottles.

Use of hornbill ivory spread to Japan during the Tokugawa Period; during which time the Shoguns and the aristocracy commissioned the making of some superb netsuke carved from hornbill ivory. Subsequent loosening of the harsh Japanese trade laws allowed the Japanese artists and craftsmen to manufacture and decorate a range of hornbill ivory netsuke and inro.

It was not until the nineteenth century that Europeans first became familiar with hornbill ivory. Since that time, Chinese artisans have manufactured a range of jewellery items, snuff bottles, decorative spoons and cuff links, especially for the export trade. Today, some hornbill ivory is still being carved in Singapore and Hong Kong. No details seem available concerning today's trade in hornbill ivory.

PROPERTIES OF HORNBILL IVORY

Although some of the properties of hornbill ivory have been previously published in the gemmological literature,(5,6) more information is required to assist the discrimination of natural hornbill ivory from its possible imitations and simulants.

A search of the gemmological and related literature has indicated that it is possible for hornbill ivory to exist in one of two forms: in its natural state, and in a reconstructed form. The only details that could be located concerning the reconstructive process are contained in Cammann's classic monograph,(4) *The Story of Hornbill Ivory.* He noted that reconstructed hornbill ivory possessed improved properties of:

Firmer adhesion between the carmine outer sheath and the yellowish-brown core;
More uniform texture;
A glistening, luminous surface lustre.

As the authors of this paper were unable to obtain samples of reconstructed hornbill ivory for examination, this investigation is restricted to a study of the gemmological properties and microscopic appearance of naturally occurring hornbill ivory.

GEMMOLOGICAL PROPERTIES

The physical properties for hornbill ivory, found in this study, are illustrated in Table 1. These properties differ slightly from those previously reported by Webster(5) (Hardness—2½;

Density—1.28 to 1.29; Refractive Index—about 1.55; Ultraviolet Light Fluorescence—greenish to bluish-white; Hot Point Test—smell of burning hair).

TABLE 1
The physical properties of Hornbill Ivory

Property	*Carmine Casque*	*Yellowish Casque*
Colour	Carmine	Yellowish-brown
Diaphany	Translucent	Translucent
Lustre	Resinous	Resinous
Hardness	3 Mohs	3 Mohs
Sectility	Easily pared	Easily pared
Fracture	Hackly	Hackly
Specific Gravity	1.30	1.30
Refractive Index	1.53	1.52
UV Fluorescence		
Long Wave	Greenish	Greenish-white
Short Wave	Whitish superficial	Inert
Hot Point Test	Smell—burning hair	Smell—burning hair
Thermoplastic Temperature	110 to 125 °C	110 to 125 °C

LIGHT MICROSCOPY

Little useful information has been published concerning the microscopic appearance of hornbill ivory. Munsuri (1973)(6) describes the microscopic characteristics as:

'fibres—but irregular ones—which have a tendency to come together and separate like whirlwinds'.

Unfortunately Munsuri's description and one black-and-white photomicrograph which accompanied this otherwise excellent paper were of little use for discrimination. In contrast, Wang Tso(7)—a Ming Dynasty writer—offers a relatively similar description:

'This is true ho-ting . . . On the surface of the material are fine wavy lines; examples without which are counterfeit.'

It would seem that Munsuri was describing the external surface of hornbill ivory—not its internal microscopic structure.

For this investigation, the block of hornbill ivory was sectioned in three directions at right angles: vertically along the long axis of the beak (longitudinal section); vertically across the beak (cross section); and horizontally.

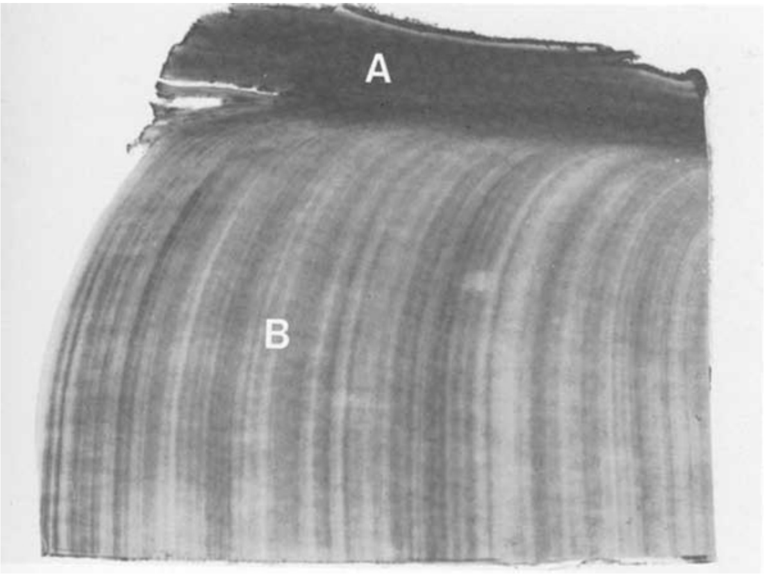

FIG. 3 Longitudinal section through the middle of the casque of the Helmeted Hornbill showing the upper carmine layers (A) which show a striated structure roughly at right angles to the curved striations of the yellowish-brown cassque material which makes up the bulk of the casque (B). (Unstained. × 10 magnification).

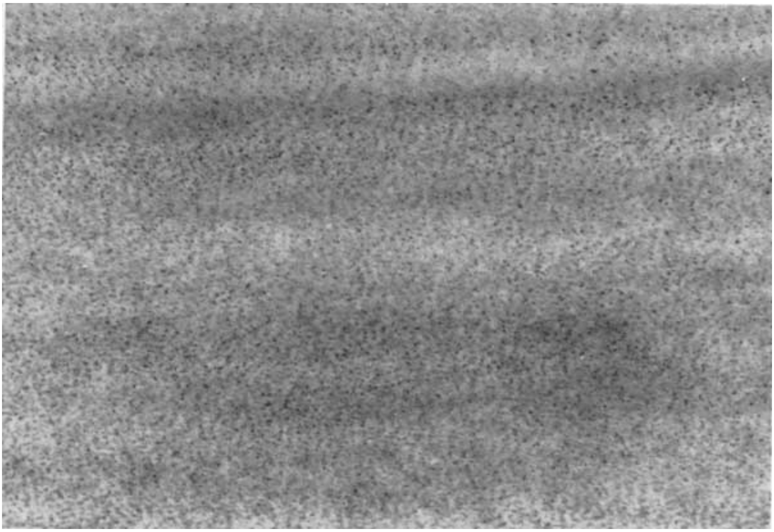

FIG. 4 Photomicrograph of the upper outer carmine-coloured sheath of Hornbill casque showing the light and dark bands interspersed within and between which were small particles of material resembling pigment granules. (unstained. × 40 magnification).

Macroscopically, in longitudinal section (Figure 3), the two different parts of the hornbill casque are readily discernible. The thin sheath was carmine-coloured and appeared to be formed from a series of layers producing a striated structure. These laminations ran antero-posteriorly, roughly at right angles to the curved striations in the yellowish-brown material which made up the bulk of the mass of the casque.

Microscopically (Figure 4), the thin sheath was composed of light and dark bands of carmine-coloured casque material within which were interspersed many small particles of darker material. These small particles have the morphology of pigment granules. It

FIG. 5 Photomicrograph of the junction between the outer layer (A) and inner layer (B) of the Hornbill casque. The junctional zone between the two layers is rich in granules; some of which are cell size. (Unstained. ×40 magnification).

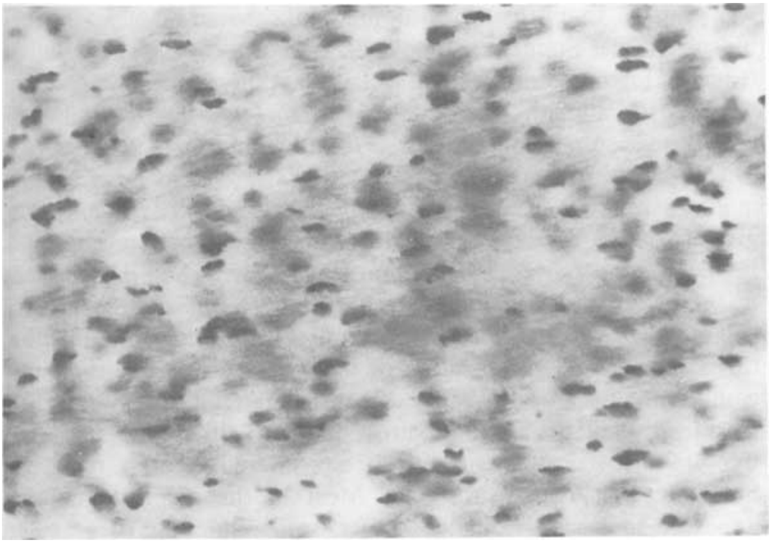

FIG. 6. High power photomicrograph of the junctional zone between the two layers of Hornbill casque showing the appearance of the pigment granules in the area. (Unstained. × 100 magnification).

FIG. 7. Photomicrograph of a vertical section of the inner layer of Hornbill casque, showing the parallel light and dark bands within this material. The granules are arranged in rows parallel to the light and dark bands. (Unstained. × 40 magnification).

was noted that the sheath material shared many of the morphological characteristics of buffalo horn.⁽⁸⁾ Pigment granules (Figure 5) were very numerous at the junction of the inner and the outer portions of the casque. Some of these granules were larger than others; some being of cell size (Figure 6).

In both longitudinal and horizontal section, the inner casque material was banded and yellowish in colour. Lines of pigment granules were present parallel to the banded pattern, but the pigment granules were smaller and less frequent than those found in the external sheath of the casque (Figure 7). In cross section (Figure 8), the banded pattern was not evident, indicating that the three dimensional visualization of the inner portion of the casque could represent parallel planes of casque material running roughly parallel to the cross sectional direction. Within these cross sections the granules of pigment appeared scattered over a relatively homogeneous ground-substance. Most of the pigment granules appeared to be individual; however, some clumping of granules was also a feature of this direction of sectioning.

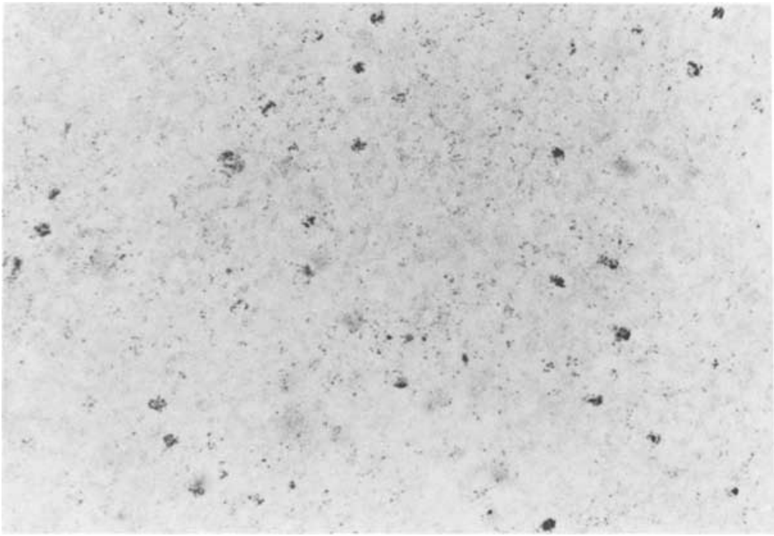

FIG. 8. Photomicrograph of a section of the inner layer of Hornbill casque in a plane parallel to the direction of the banding, showing scattered granules between which are interspersed large clumps of granular material. (Unstained. × 40 magnification).

CONCLUSIONS

This investigation has provided a description of the major physical properties of interest, and the microscopic appearance of natural hornbill ivory. Its identification should be relatively simple for the practising gemmologist. If its characteristic appearance, specific gravity of 1.30, and refractive index of about 1.52 is not sufficient to ensure positive identification, then a thin peeling, examined by low power light transmission microscopy, will readily display the layered structure, with oriented pigment granules, which should facilitate identification.

ACKNOWLEDGEMENTS

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FERROAXINITE—ANOTHER NEW GEM FROM SRI LANKA

By HENRY A. HÄNNI, Ph.D., F.G.A.,

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INTRODUCTION

Foreign visitors from Fa-Hien in the fifth century A.D. to Robert Knox in the seventeenth century through Arabian Nights to contemporary science-fiction author, Arthur C. Clarke, have referred to the abundance of gemstones in Sri Lanka. As one of the productive localities of valuable gemstones its collection extends to many of the rarer minerals. There is every reason to expect still more new findings in this South-East Asian locality.

During his visit to Sri Lanka in October 1980, one of the authors (M.G.) was shown a parcel of rough stones by courtesy of the firm Many Gems, of Colombo, Sri Lanka. The distinct trichroic effect and the preliminary refractive index determination suggested it to be axinite.

Axinite is known as a mineral typically formed under pneumatolytic conditions. Although it has not yet been reported from Sri Lanka, axinite occurs in the Swiss Alps, Dauphiné in France, in the Ural mountain range of U.S.S.R., in Australia, U.S.A. and Tanzania. Since axinite is easily confused with kornerupine, an x-ray powder diffraction photograph was taken to confirm its authenticity. The lines and intensities were similar to the data published by J.C.P.D.S. (1974). Mineralogical and chemical analyses were carried out and the comparison was done in order to introduce this new finding to the gemmological literature. Three axinites from other origins were selected for comparison (Table 1).

TABLE 1

List of axinites referred to in this paper

1	Ferroaxinite, Thissamaharama, Sri Lanka, present work.
2	Ferroaxinite, Bourg d'Oisons, Dauphiné, France, Jobbins *et al.* (1975).
3	Magnesioaxinite, iron-rich, New South Wales, Australia, Vallance, (1966).
4	Magnesioaxinite, Tanzania, Jobbins *et al.* (1975).

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TABLE 2

Chemical analyses of axinites

Oxides in wt-%

	1	2	3	4
SiO_2	42.70	42.20	42.39	44.00
TiO_2	nt.fd.	0.03	n.d.	0.03
B_2O_3	nt.fd.	**	5.52	**
Al_2O_3	18.31	17.50	17.10	17.90
Cr_2O_3	nt.fd.	nt.fd.	n.d.	nt.fd.
V_2O_3	nt.fd.	nt.fd.	n.d.	0.13
Fe_2O_3	*	*	1.68	nt.fd.
FeO	10.40	6.10	5.18	nt.fd.
MnO	0.38	3.30	1.38	0.40
MgO	1.40	1.60	4.20	6.90
CaO	19.35	20.10	20.31	21.70
ZnO	nt.fd.	nt.fd.	n.d.	0.06
CoO	nt.fd.	nt.fd.	n.d.	nt.fd.
Na_2O	nt.fd.	0.04	0.06	nt.fd.
K_2O	0.01	0.02	0.03	0.01
$H_2O > 105°$	n.d.	n.d.	1.67	n.d.
$H_2O < 105°$	n.d.	n.d.	0.31	n.d.
totals	92.55	90.89	99.83	91.13

* the total iron is calculated as FeO

** the presence of boron was confirmed by chemical tests

nt.fd. = not found, n.d. = not detected

Number of ions on the basis of 28 (O)

	1		2		3		4	
B	—		—		1.772		—	
Si	7.997		8.025		7.885		8.012	
Al	4.042	4.042	3.923	3.927	3.634	3.869	3.842	3.865
Fe^{3+}	—		—		0.235		—	
Ti	—		0.004		—		0.004	
V	—		—		—		0.019	
Mg	0.380	5.949	0.454	6.070	1.165	6.265	1.872	6.177
Fe^{2+}	1.621		0.970		0.806		—	
Mn	0.060		0.531		0.217		0.061	
Zn	—		—		—		0.008	
Ca	3.883		4.095		4.049		4.234	
Na	—		0.015		0.021		—	
K	0.005		0.005		0.007		0.002	
Fe-Mn-Mg-ratio	79:3:18		50:27:23		37:10:53		0:3:97	
Authors	1. this paper		2. Jobbins *et al.*, (1975)		3. Vallance, (1966)		4. Jobbins *et al.*, (1975)	

CHEMISTRY

The name axinite is derived from the Greek word *axine* (ἀξίνη), meaning 'axe', in allusion to its acute edged form of triclinic symmetry. It is rather a complex calcium aluminium borosilicate containing ferrous iron, manganese, magnesium and a considerable amount of water. The chemical composition can be formulated as:

$$(Ca, Fe^{2+}, Mn, Mg)_3\, Al_2\, BO_3\, (Si_4O_{12})\, OH$$

The proportions of CaO, FeO, MnO and MgO may vary in different axinites. Three end-member compositions are stated, namely *ferroaxinite* (Ca, Fe), *manganoaxinite* (Ca, Mn), and *magnesioaxinite* (Ca, Mg).

The sample from Sri Lanka was analysed by an ARL electron microprobe. Light elements as B, OH could not be detected by this method. The results of this partial analysis are listed in Table 2 together with literature analyses of the comparative stones from Table 1. The total iron is expressed as FeO and the number of ions is calculated on the basis of 28 (O).

The iron content of the Sri Lanka axinite is fairly high compared to the analyses shown by Deer *et al.* (1962) and Jobbins *et al.* (1975). The Fe-Mn-Mg ratios are 78.6 : 2.9 : 18.4—thus the name ferroaxinite is correct.

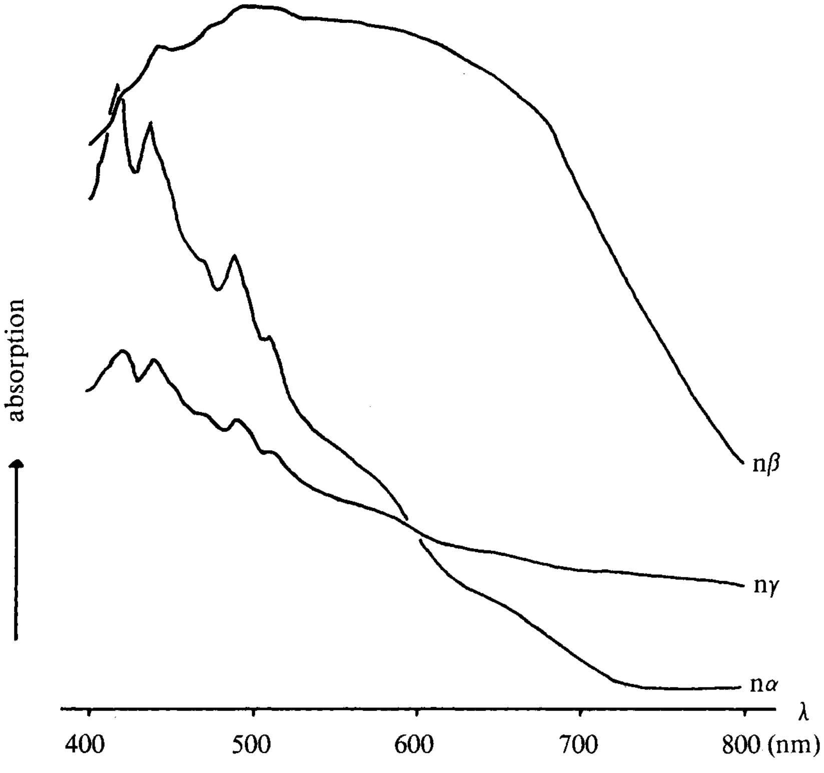
PROPERTIES

The colour of the present Sri Lanka stone and of other pieces of the same origin visually inspected by one author (M.G.) were all of cinnamon brown with differently coloured internal reflections due to pleochroism. The colour is directionally obscured by the strong pleochroism. The strong trichroic colours are: n_α reddish-brown, n_β dark violet, n_γ colourless-yellowish. In magnesioaxinite and manganoaxinite colours like blue and green respectively are reported.

The refractive indices determinations were carried out by using a Krüss ER 60 critical angle refractometer with Na_D light. The angle between the optical axes was measured in immersion on a spindle stage (Steck, 1968). For recording the absorption spectra a Pye-Unicam SP-8 100 spectrophotometer with polarization filter was used. The spectrum is shown in Figure 1.

Specific gravity determination was done by hydrostatic weighing in ethylene dibromide as an immersion liquid. The results of the optical and physical determinations are presented in Table 3,

FIG. 1. *Absorption spectrum of ferroaxinite*



The absorption curves were recorded on a Pye-Unicam SP8-100 spectrophotometer with polarization filter. The unpolarized curve beyond 400 nm shows an absorption band at 376 nm and general absorption in the ultraviolet region below 340 nm.

TABLE 3

Physical constants of axinites

Refractive indices	1	2	3	4
$n\alpha$	1.675	1.672	1.659	1.656
$n\beta$	1.681	1.679	1.665	1.660
$n\gamma$	1.685	1.682	1.668	1.668
Birefringence	0.010	0.010	0.009	0.012
Optical character	Bi−	Bi−	Bi−	Bi+
Axial angle* 2Vx	69.5°	—	—	—
Specific gravity	3.314	3.288	3.190	3.178

*Determination of axial angle in immersion on a universal spindle stage (Steck *et al.*, 1968).

Absorption spectrum of sample 1

$n\alpha$: 580, 510, **488, 470**, 450, **436, 416** nm

$n\beta$: **540** (broad band), 472, 438, 416

$n\gamma$: 584, 512, 489, 474, **438, 418**

FIG. 2. Two-phase fillings in axinite from Sri Lanka. *(Photo: M. Gunawardene. 60×.)*

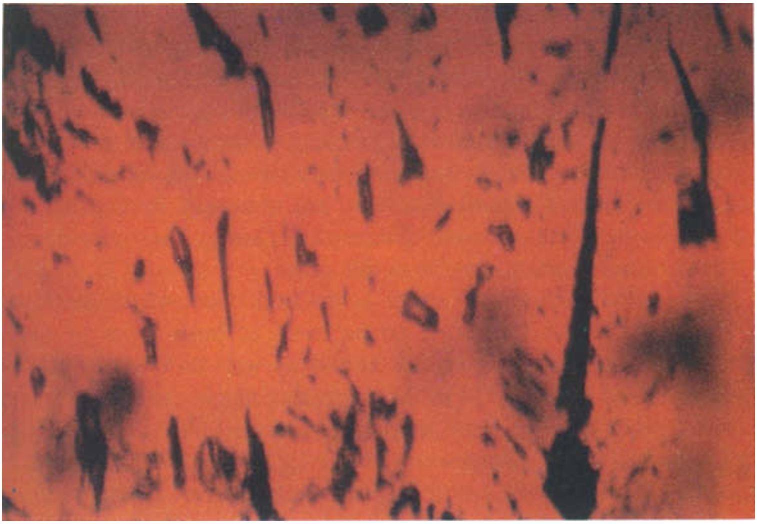


FIG. 3. Two-phase fillings in axinite from Brazil. *(Photo: M. Gunawardene. 60×.)*

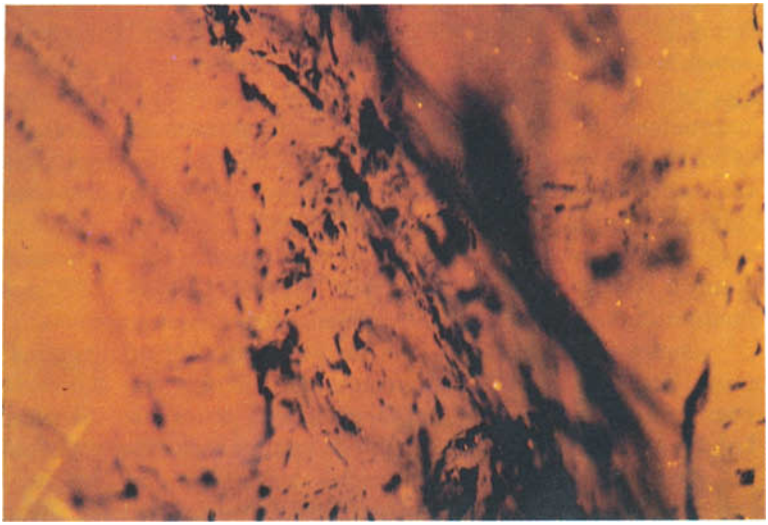


FIG. 4. Black feathers, probably healed fissures in Sri Lanka axinite. *(Photo: M. Gunawardene. 60×.)*

together with comparative literature values. The optical character of magnesioaxinite (Table 1, no. 4) is not reported as positive by mistake. The explanation is given by the substitution of Mg for Fe. With increasing Mg content n_β gets small more quickly than n_α and n_γ; in the meantime the axial angle $2V_x$ grows and the optical character turns from negative to positive. It should be stressed (Gübelin, private communication) that apparent discrepancies in gemmological textbooks frequently have their cause in isomorphous replacement, as in this case.

A visual inspection under long- and short-wave ultraviolet radiation showed the stone to be inert in both types of light. Inclusions in axinite from Sri Lanka as well as from Brazil are illustrated in Figures 2 to 4. The aspect of the inclusions is similar from both localities. They mainly consisted of liquid feathers with two-phase fillings reminiscent of the inclusions in tourmaline or topaz. The exact nature of those inclusions was not determined.

OCCURRENCE

Different geological units may be distinguished in the southern part of Sri Lanka. The precambrian Khondalite system (archaic metasediments), the Vijaya gneiss series and their alluvial cover are important with respect to the occurrence of gemstones. These rocks sometimes are intruded by dolerite dykes and pegmatites. Pegmatites frequently bear gemstone quality zircon, beryl, tourmaline, etc. The pegmatite formation (pneumatolytic phase) is often followed by a hydrothermal phase. Under both circumstances the conditions for an axinite formation are physically given. Axinite is formed in contact metamorphic calcareous sediments and less commonly in altered basic rocks, too. The geological frame (Gübelin, 1968; Herath, 1980) allows different interpretations of the type of the present axinite occurrence.

Our stone is reported from the southern part of the island, most probably from Tissamaharama district. In this area pegmatites intruded into the Vijaya gneiss series. On the other hand, the Khondalite complex with its various rock types is not too far away with a possible parent rock. The production of axinite is rather common now and even well developed crystals are found (Gübelin, private communication).

CONCLUSION

With x-ray powder diffraction we confirmed the suspicion of a new member in Sri Lanka's list of gemstones. The physical properties agree with the range of data in gemmological literature, but the high SG value requires an extension of the recorded range since our sample exceeds the noted upper value for axinite. The reason is most probably the very high iron content of the stone which was confirmed by a microprobe analysis. According to Sanero & Gottardi (1968) this mineral has to be named a Ferroaxinite.

ACKNOWLEDGEMENTS

Our sincere thanks are due to Dr G. Lenzen, of Deutsche Gemmologische Gesellschaft, and Prof. H. Schwander, Mineralogical Institute, University of Basel, who helped us in realizing this work. Finally we thank the firm Many Gems, of Colombo, Sri Lanka, who kindly allowed us to investigate their material and so to introduce gem axinite to the Isle of gems—Sri Lanka.

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THE USE OF A STEREOMICROSCOPE BRIGHTFIELD/DARKFIELD ILLUMINATOR IN CONJUNCTION WITH THE ZEISS PHOTOMICROSCOPE II FOR THE EXAMINATION AND PHOTOGRAPHY OF GEMSTONE INCLUSIONS

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INTRODUCTION

The use of the microscope is firmly established as an essential part of the testing procedure necessary for the examination and identification of gemstones. The microscope can help the gemmologist in many ways but is most frequently used for the investigation of gemstone inclusions. One of the difficulties confronting the would-be student of inclusions is the provision of adequate illumination for the gems he wishes to examine with the microscope. If the illumination of the specimen is unsatisfactory the observer will inevitably miss features within a gemstone which may be significant or even diagnostic. Many modern microscopes allow a choice of two illumination techniques. One is called 'brightfield' and the other 'darkfield' illumination.

Brightfield illumination is achieved when the microscope is set up in the conventional manner for observations in transmitted light. Ideally light from a substage illuminator follows a 'straight line' path through the gemstone, objective and eyepiece to the observer. With 'dry' faceted gemstones this technique is rarely satisfactory because much light is lost by reflection and refraction at the surface of the stone. A closer approach to ideal brightfield illumination conditions can be achieved if the gemstone is immersed in a liquid of high refractive index. Monobromonaphthalene (RI = 1.66) is a familiar example of a widely used immersion liquid. Under good brightfield conditions inclusions appear as relatively dark objects against the light background of the host gemstone.

In darkfield illumination the gemstone lies at the apex of a 'hollow' cone of light again produced by a substage illuminator.

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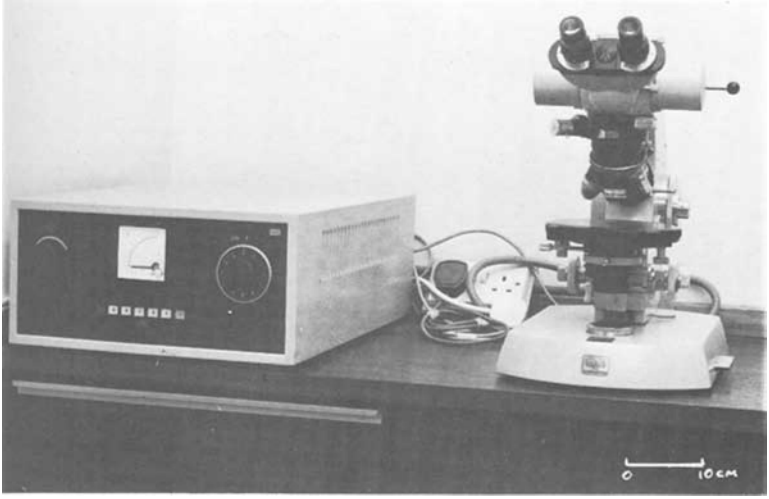

FIG. 1. The Zeiss Photomicroscope II (right) and control unit (left).

With this technique all light enters the stone obliquely from the sides; consequently no light can follow a 'straight line' path from the illuminator, through the stone and into the microscope objective. The image which the observer actually sees is produced mainly by scattered light which is reflected from the surface of the stone or from inclusions within it. Under these circumstances inclusions appear brightly illuminated against a predominantly dark background. Most gemstones, particularly those of high RI, may be studied dry when using darkfield illumination. In some instances, however, the darkfield effect may be considerably enhanced if the stone under examination is, once again, immersed in a suitable liquid.

A fuller account of both types of illumination, and the various means by which they may be produced, is given in the standard books on gem testing.

THE ZEISS PHOTOMICROSCOPE II

Some years ago the Mining Department at Sunderland Polytechnic acquired a Zeiss (polarizing) Photomicroscope II (Figure 1). The optical performance of this remarkable instrument

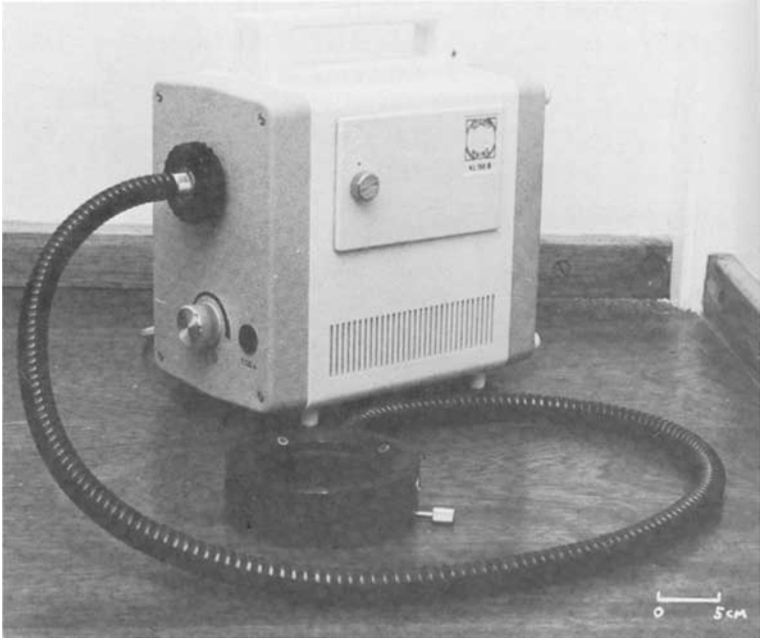

FIG. 2. The Schott four-point circular lamp, flexible fibre optic light guide and 15 V 150 W cold-light source.

is quite outstanding. A built-in camera, coupled to an automatic exposure control unit, is fitted as standard. A wide range of accessories, capable of considerably extending the versatility of the microscope, are readily available and easily fitted.

Although designed primarily for thin-section work, it soon became apparent that the Photomicroscope could be easily adapted for the study of inclusions in unmounted, transparent gemstones. In nearly all cases gemstones to be examined are covered in a highly refractive liquid contained in a glass immersion cell. The cell is placed directly on the microscope stage beneath the objective in use. The presence of an immersion cell necessitates the use of low power objectives (up to 10×)—only these objectives have sufficiently long working distances to allow thorough examination of the interior of a gemstone whilst normally avoiding any risk of a collision occurring between the objective and cell during focusing.

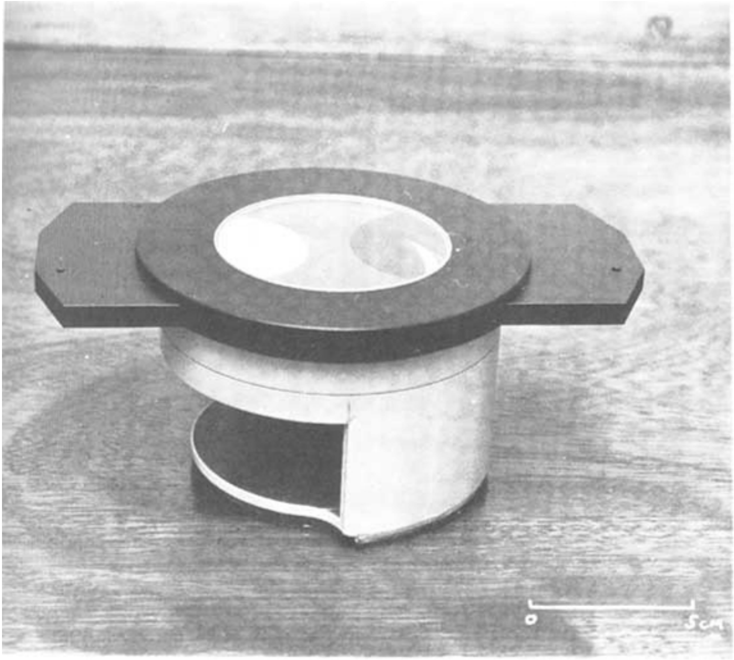

FIG. 3. The Zeiss HD (brightfield-darkfield) transilluminator.

The limitation imposed by the use of low magnification objectives can be partially overcome if the Photomicroscope is fitted with an Optovar system. This device is a stepped magnification changer which allows the magnification to be increased by up to a factor of 2 without changing the objective. It is broadly comparable with the 'zoom' system found on many modern stereomicroscopes. The Optovar system is operated by a knurled ring located in the microscope body tube between the objective and eyepieces. In practice, however, the system is rarely required, because high magnification is not often necessary in gemstone work.

Over the past two years the technique outlined above has been successfully employed in the examination and photography of gemstone inclusions with the Photomicroscope. With few exceptions, this work was carried out using brightfield illumination.

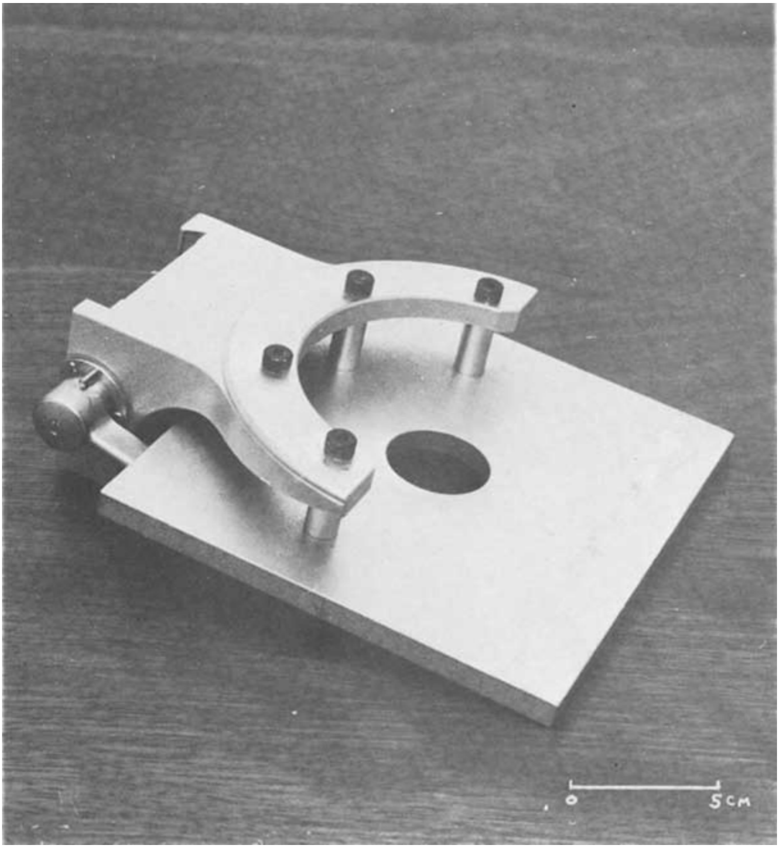

FIG. 4. The modified Photomicroscope stage-carrier showing the mild steel plate bolted to the underside of the carrier.

DARKFIELD ILLUMINATION WITH THE PHOTOMICROSCOPE

Some months ago the writer was asked to comment on the inclusions in a number of emeralds and garnets. After initial inspection under brightfield conditions it became apparent that the investigation would benefit from the use of darkfield illumination. It was therefore decided to explore the possibility of adapting the Photomicroscope for darkfield work. It appeared that the acquisition of a Zeiss darkfield condenser, which could be easily fitted beneath the microscope stage, would provide the necessary oblique illumination. Enquiries revealed, however, that Zeiss do

FIG. 5. The modified stage carrier and steel plate assembly fitted to the microscope.

not manufacture a suitable condenser which is optically matched to the low power objectives which would be used for gemstone study. After some preliminary set-backs the problem was finally solved by adapting a relatively new type of stereomicroscope illuminator for use with the Photomicroscope.

The illuminator selected is manufactured by the German firm of Schott. It consists of a four-point circular lamp which is connected by a flexible fibre optic light guide to a powerful 15 V 150 W halogen light source (Figure 2). The circular lamp is housed

FIG. 6. The apparatus ready for use.

in a special unit of Zeiss manufacture known as the HD (brightfield-darkfield) transilluminator (Figure 3). The HD transilluminator incorporates a large hemispherical lens, the central portion of which is blacked out. The Schott four-point circular lamp fits beneath this lens. A sliding device, which allows the microscope operator to change from darkfield to brightfield illumination at will, is fitted to the top of the transilluminator. Above the sliding device is a fixed glass plate on which the specimen rests. Unfortunately the overall height of the HD transilluminator prevents it being used directly on the normal Photomicroscope stage. If this is attempted the stage simply cannot be lowered far enough to allow a specimen to be focused. (N.B. On the Photomicroscope focusing is achieved by up and down movement of the microscope *stage*). This difficulty was overcome by modifying an ordinary Photomicroscope stage carrier. A mild steel plate measuring 127 mm × 114 mm × 6 mm thick was bolted to the *underside* of a spare stage carrier (Figure 4). This steel plate functions as a new microscope stage. Having first removed the conventional stage and substage condenser assembly from the Photomicroscope, the modified stage carrier was then *inverted* (so that the mild steel stage plate was uppermost) and attached to the

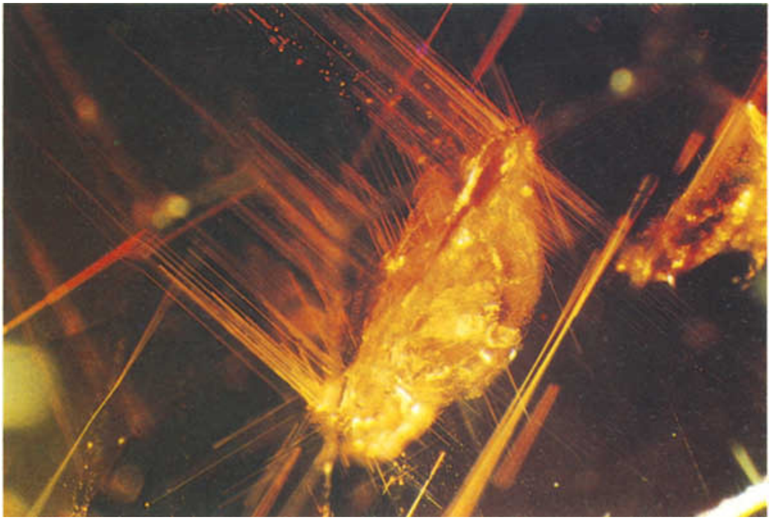

FIG. 7. Rutile needles in almandine. Darkfield 6.3 ×.

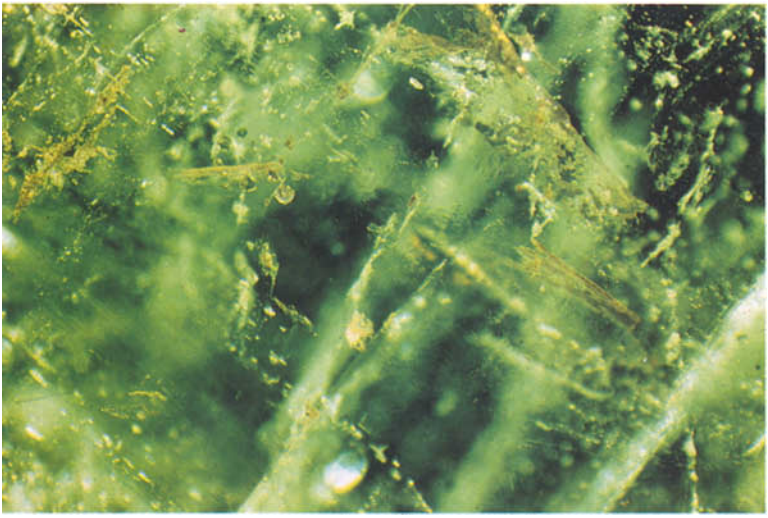

FIG. 8. Liquid and solid inclusions in Indian emerald. Darkfield 6.3 ×.

microscope body in the usual way (Figure 5). Inversion of the stage carrier results in the location of the new stage at a much lower level than the conventional stage. This simple modification ensures that the HD transilluminator housing (containing the Schott circular lamp) can be placed directly on the new stage plate while allowing ample room for focusing of a specimen beneath the objectives. To facilitate centring of the illumination a thin strip of magnetized rubber was cut to size and stuck (using araldite) to the underside of the transilluminator housing. The magnetized rubber holds the housing securely on the stage plate in any desired position, and yet allows it to be easily moved when pressure is applied by the hand. Figure 6 shows the HD transilluminator set up on the Photomicroscope ready for use.

The modification to the Photomicroscope outlined above can be easily carried out by anyone with the necessary facilities. Using this technique excellent darkfield illumination can be obtained. The chief advantage of the system is that it allows a very high quality stereomicroscope illuminator to be used in conjunction with the superb optical performance of the Photomicroscope. Preliminary results have proved most encouraging. Two of the photographs obtained, using the apparatus described, are reproduced in Figures 7 and 8.

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COLOUR CENTRES IN DIAMOND

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1. INTRODUCTION

Diamond is, of course, the most prized of gemstones. Its high refractive index, its hardness and the natural occurrence of stones which are, from the gemmological point of view, almost perfect, place it in a class of its own. Diamond is also a material of considerable interest to the solid-state physicist. Carbon is the first element in group IV of the periodic table, which also contains the industrially important semiconductors silicon and germanium (both of which have the diamond crystal structure). The physical properties of these three substances are greatly influenced by 'point defects' and an enormous amount of research work has been carried out to determine how these point defects may be introduced into crystals (either naturally or artificially in the case of diamond) and how they may be studied.

When point defects give rise to optical absorption in the visible spectral region for a material that would otherwise be transparent they are often referred to as 'colour centres'. It is natural that such centres should be studied using optical spectroscopy. The use of the hand spectroscope in the examination of gem diamonds was pioneered by Anderson(1) and an enormous amount of valuable information has been obtained from the use of this instrument in

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gem testing laboratories world-wide. Detailed spectroscopic examinations of diamonds by physicists have also been in progress for more than 40 years (see, for example, Nayar(2), Mani(3) and Clark *et al.*(4,5)), but it is only recently that the origin of some of the absorption bands has become understood. Even so, there is still much to learn. Many, many different absorption and luminescence bands are observed in diamond; some occur naturally and others may be produced artificially by 'treatment'.

1.1 *Absorption Systems in Diamond*

For the newcomer to the spectroscopy of diamond the list of absorption lines is truly bewildering. Some have a 'name' based on a particular author's classification system while others are known by the wavelength or the energy at which the line is observed. We have, as typical examples, GR1, N2, 3H, H4, 4152Å, 595 nm, 1.945 eV, as well as descriptive terms such as Cape and canary; there are well over 100 others! In this article I propose to discuss only those colour centres which have gemmological significance and to refer the interested reader to articles which review more fully the optical properties of diamond (see for example Davies(6) and Walker(7)). In treating the subject in a highly selective way from my own viewpoint I am aware that there may be important omissions from the article. However I hope that the information I do give may cast some new light on a familiar subject and will prove generally useful in the field of diamond gem testing.

The diamond classification scheme used, and the models described for some of the colour centres, are those generally accepted in the West but differ in some cases from those used by Russian workers.

1.2 *Units*

Most people regard the visible spectrum as covering the wavelength region 4000Å in the violet to 7000Å in the red (or, in S.I. units, from 400 to 700 nm). Visible radiation, as we know, may be considered to be a stream of photons, and the physicist normally considers the energy, rather than the wavelength, of the photon. If the energy E is expressed in electron-volts (eV) the wavelength λ in angstroms is given by

$$\lambda = 12398/E \qquad (1)$$

It is important to realize that the wavelength thus calculated is the wavelength *in vacuo*. If high accuracy measurements are being undertaken, the refractive index of air (approximately 1.00028 in the visible region) must be taken into account and we have

$$\lambda_{air} = 12395/E \qquad (2)$$

Equation (2) is normally most appropriate, and we see that, for example, the 1.945 eV transition is the familiar 6372Å line observed in treated pink diamonds (see section 6.7). This transition is at 6372Å when the diamond is cooled to liquid nitrogen temperature; at room temperature the line is at about 6380Å.

In the infrared part of the spectrum wavenumbers and microns (or, more correctly, micro-metres) are generally used. The wavenumber is just the reciprocal of the wavelength, where the wavelength is expressed in cm. The inter-relation between these units is as follows:

$$1 \text{ micro-metre } (\mu m) = 1000 \text{ nm} = 10\,000\text{Å} \qquad (3)$$

$$1 \text{ wavenumber } (cm^{-1}) = 10^{8}/\lambda(\text{Å}) \qquad (4)$$

Equations (2), (3) and (4) allow us to write, for example, that $7.3\ \mu m \equiv 1370\ cm^{-1} \equiv 0.1698$ eV

1.3 *Absorption Coefficient*

In some cases, as we shall see, in order to decide whether a diamond has been artificially coloured it is not enough merely to determine whether certain absorption lines are present in the spectrum—we must determine *how strongly* the diamond is absorbing at these wavelengths. The reason, quite simply, is that many of the absorption lines produced when a diamond is artificially coloured may be created *to some extent* by natural processes.(8) Ideally, then, we need to know the concentration of colour centres in the diamond under investigation, and to decide whether this concentration is significantly higher than may be observed in untreated diamonds. The hand spectroscope must then be abandoned and a spectrophotometer employed which produces a graph of absorption coefficient (or absorbence) plotted against wavelength. The spectrophotometer has the further advantage that broad, featureless absorption bands are shown up that are often not observed by eye, since the eye only responds to sharp changes in transmission levels. The range of measurement may also be extended into the infrared or ultraviolet, if required.

Consider in Figure 1 the ideal case of light with intensity I_o at a certain wavelength falling on a parallel-sided sample of thickness t and with absorption coefficient α. The intensity I_t of the

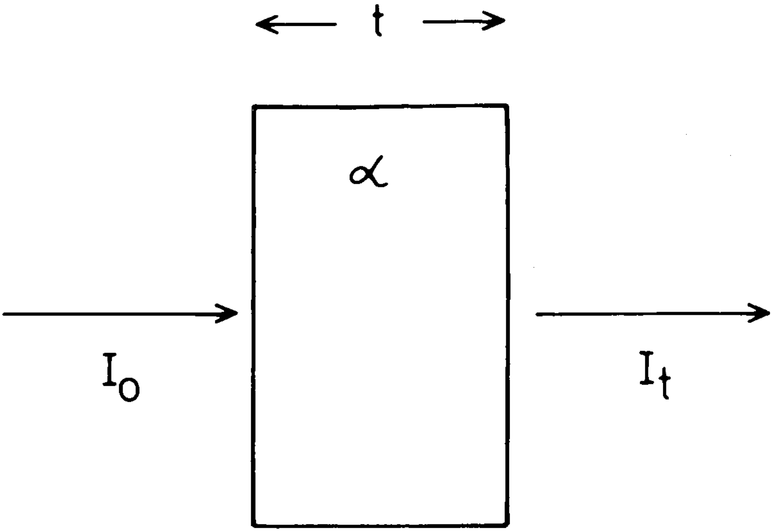

FIG. 1. Transmission of light through a parallel slab of thickness t and absorption coefficient α.

transmitted light depends on the product of α and t, and α is proportional to the concentration of colour centres (assuming the absorption is due to only one type of colour centre). At the risk of stating the obvious, the *transmission spectrum* of a thin, strongly absorbing, diamond can be virtually identical with that for a thick, weakly absorbing, diamond. It is easy to jump to the conclusion, when examining a large diamond with a hand spectroscope, that the colour is due to treatment, whereas when the absorption coefficient is actually measured on a spectrophotometer it is found to be well within the range encountered in diamonds coloured by natural processes (see Figure 19 for example).

To a reasonably good approximation

$$\alpha t = \log_e(I_o/I_t) \text{—constant} \qquad (5)$$

For the parallel slab shown in Figure 1 the value of the constant is about 0.34, due simply to reflective losses at the front and back surfaces. By increasing the gain of the measuring instrument when the sample is inserted it is possible to compensate for these reflective losses, and to set $\alpha t = 0$ at a wavelength where the absorption is known to be zero. In the non-ideal case—for example a rough diamond or a faceted diamond—some of the light will be scattered or internally reflected, less light will emerge from the stone than in the case of a parallel-sided sample and the constant in equation (5) will be greater than 0.34. However, provided the same procedure is followed, increasing the gain of the instrument to correctly set the zero, the absorption coefficient is given, with an error not exceeding 6% by

$$\alpha = \frac{1}{t} \log_e(I_o/I_t) \qquad (6)$$

Normally t is measured in cm and the units of α are cm^{-1}.

On a commercial spectrophotometer the data can be output as *absorbance* which is given by $A = \log_{10} I_o/I_t$. The *absorption coefficient* in this case is given by $\alpha = 2.3\ A/t$, and this can be calculated quite easily from the spectrum.

Because of the nature of the log function it does not matter if the zero-absorption condition is not correctly set—the effect is merely to move the spectrum up or down the absorbance axis, but the shape of the spectrum remains unchanged.

2. INSTRUMENTATION

A diamond gemstone, particularly a brilliant cut, is designed to totally internally reflect most of the light incident on the front surface. To obtain an absorption spectrum, therefore, the beam of light is best focused through one of the pavilion facets and out of an opposite facet, and the fraction of the incident light that emerges, even for a colourless stone, is often very small. We shall see in Section 5 that the absorption spectra of diamond are very much sharper if the stone is cooled to about 100 K, at which temperature the lines may be only 1 or 2Å wide.

When setting up the equipment to be described I was not aware of any commercial spectrophotometer which would handle the low throughput of light for cut gemstones (or natural diamonds with rough faces), would accept a 'cold-cell' to cool the diamond to 100 K and would record spectra with the required resolution (better than 1Å). My own system is therefore based on a high resolution grating monochromator and an on-line micro-computer. Recent developments in spectrophotometers may well mean that machines of adequate performance are now available.

Figure 2 illustrates the external optical system. The image of the filament of a tungsten strip lamp is focused (with an image reduction of about 3:1) onto the diamond by lens L1, and the light emerging from the diamond is focused onto the entrance slit of the monochromator by a symmetrically positioned lens L2. Both the lenses are glass achromats. A yellow filter F is used for measurements at wavelengths longer than 625 nm to prevent overlapping orders.* The diamond is mounted in a glass cell similar to that described by Scarratt⁽⁹⁾ through which cold nitrogen gas is flowing.

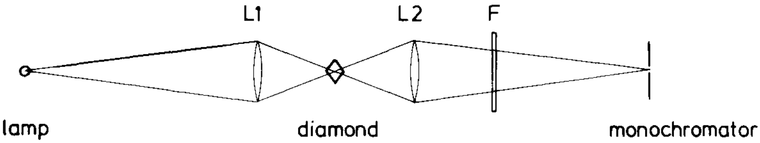

FIG. 2. Optical system used to focus light through a small area of a diamond.

Basically this optical arrangement produces an image of the lamp filament on the entrance slit of the monochromator, having passed the light through a pair of opposite facets of the diamond. Even with strongly luminescing diamonds, the intensity of the transmitted light is much greater than the intensity of the luminescence collected by L2, and no interference is experienced. By contrast, when the diamond is diffusely illuminated and then most of the light emerging from the diamond is collected and fed into the spectrometer using a system of parabolic reflectors, brightly luminescing diamonds can give problems (V. Manson, personal communication). If multiple reflections prove troublesome in the arrangement described, those facets which are not used can be blacked out with a dilute solution of 'dag' in alcohol, but this is rarely necessary.

We have seen in Section 1.3 that the quantity required is

$$\alpha = \frac{1}{t}\log_e I_0/I_t$$

plotted against photon energy or wavelength. In the author's system this is achieved by carrying out an initial scan from 750 to 380 nm with no sample in position, scanning at 25 nm/min. The output from the photomultiplier amplifier is digitized to an accuracy of 1 part in 4096 four times every second and stored in the computer. This is the I_0 spectrum with more than 3500 points

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*When a grating monochromator is set to pass a wavelength λ, wavelengths of $\lambda/2$, $\lambda/3$ . . . . will also be passed. These 'overlapping orders' must be removed by a suitable filter. In the system described the glass lenses filter out the unwanted orders when λ is less than 625 nm.

spaced just over 1Å apart. The diamond is then inserted and the gain of the photomultiplier amplifier increased as necessary. The thickness of the sample is entered into the computer, the monochromator is again scanned from 750 to 380 nm and the signal digitized and stored as before. This is the I_t spectrum, and the computer evaluates α at each point and plots the result on an X-Y recorder. If required, any region of the spectrum can subsequently be expanded and replotted from the computer's memory.

By using a very stable lamp and electronics* the same stored I_0 spectrum can be used for all subsequent runs, so that spectra can be obtained from two or three diamonds per hour. In addition to the copy of the final spectrum produced, the digital data may be stored on punched paper tape, magnetic tape or floppy disk for archiving or more detailed analysis.

Similar equipment is used to record luminescence spectra. In this case the tungsten lamp is not used, but the diamond is illuminated from the side using a mercury lamp with an appropriate filter, or a laser. Obtaining luminescence spectra is a more difficult exercise than recording absorption spectra, and is rarely required in gemmological applications. A detailed description of the apparatus and experimental techniques would therefore be out of place in this article.

3. PURE DIAMOND

Diamond is a covalently bonded material. An isolated carbon atom has four outer electrons and in the diamond structure each carbon atom bonds with four neighbouring carbon atoms to produce a very stable structure in which each atom is surrounded by eight electrons. This is shown schematically in two dimensions in Figure 3a. In three dimensions the carbon atoms are at the centre and the corners of a regular tetrahedron. The energy required to remove an electron from one of the bonds is about 5.5 eV; this corresponds to a wavelength of 225 nm in the ultraviolet and is the longest wavelength at which absorption involving electrons can occur in a pure diamond. At shorter wavelengths all diamonds are strongly absorbing. Diamond also absorbs energy at wavelengths which will set the atoms into *vibration.* This gives rise to absorption in the infrared between about 2.6 and 7.2 μm (3800 to 1380 cm^{-1}).

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*i.e. the intensity of the lamp and the response of the light-measuring system do not change with time.

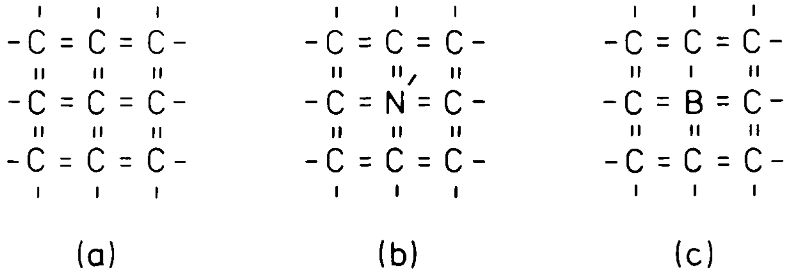

FIG. 3. Two-dimensional representation of the atoms and electron-bonds for (a) a pure diamond, (b) single substitutional nitrogen in diamond and (c) substitutional boron in diamond.

There is, however, no absorption in the visible region and a pure diamond is therefore completely colourless.

4. DONORS AND ACCEPTORS

For silicon and germanium the group V and group III impurities give rise to donor and acceptor centres respectively, and these dramatically affect the electrical properties of the host material. As far as is known nitrogen and boron are the only elements which will substitute for carbon atoms in the diamond crystal and the properties of these centres are described below. In contrast with earlier work, aluminium is *not* now believed to be electrically or optically active in diamond.

4.1 *Nitrogen*

In Figure 3b we represent schematically a single-nitrogen atom that has substituted for a carbon atom. Nitrogen is in group V of the periodic table and has five outer electrons; four of these are required for bonding to the surrounding carbon atoms. The fifth electron is relatively weakly bound and requires only about 2 eV to dislodge it, compared with the 5.5 eV required to remove an electron from a carbon-carbon bond. Diamonds which contain significant concentrations of single-nitrogen atoms (say 30 parts per million) show appreciable absorption for photon energies greater than 2.2 eV (wavelengths less than 560 nm) and appear yellow in colour. Diamonds like this are classed as Type Ib, and a typical absorption spectrum is shown in Figure 4a. The colour of such a stone is often referred to as 'canary yellow' although this description is normally reserved for Type Ib diamonds which exhibit yellow or orange luminescence when excited with a long

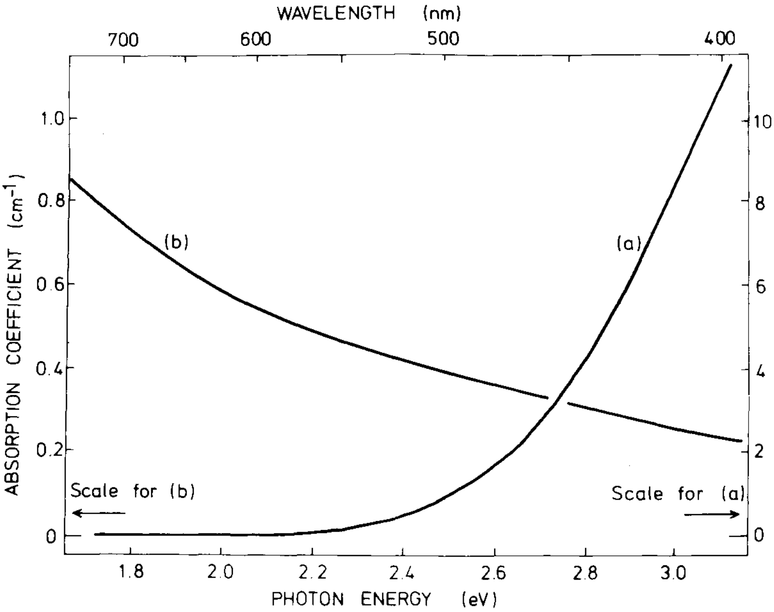

FIG. 4. Absorption curves for (a) a Type Ib diamond and (b) a Type IIb diamond.

wave ultraviolet lamp.(10,11) Type Ib diamonds are rare in nature because the long period of time spent by most diamonds in the Earth's crust at elevated temperatures favoured the almost complete transformation to aggregated forms of nitrogen. Diamonds containing aggregated nitrogen are classified as Type Ia, and about 95% of all diamonds fall into this category. I have summarized the properties of nitrogen in diamond in a previous issue of this *Journal*(11) and will not reiterate them here, except to mention that neither the A-aggregate nor the B-aggregate of nitrogen gives rise directly to any absorption in the visible spectral region, and that most colourless gem quality diamonds contain substantial concentrations (typically 0.1 to 0.3%) of aggregated nitrogen. The three different major forms of nitrogen in diamond give rise to characteristic absorption bands in the infrared spectral region between about 7 and 12 μm (1400 to 800 cm^{-1}) from which the concentrations of nitrogen in the different forms can be determined. (See, for example, the spectra given by Davies(6)). When the nitrogen concentration is too small to detect by conventional infrared absorption spectroscopy the diamond is classified as Type II.

4.2 *Boron*

Boron from group III of the periodic table has only three valence electrons and so there is a missing electron, or hole state, when boron substitutes for carbon in the diamond structure, as indicated in Figure 3c. It turns out that only 0.37 eV is required to transfer an electron from a neighbouring bond into this hole state, and so the diamond absorbs radiation for wavelengths shorter than 3.35 μm. The 'tail' of this absorption band extends into the red end of the visible spectrum, as shown in Figure 4b, giving the diamonds a pale blue colour.

In semiconductor terminology single-nitrogen in diamond is a donor and boron is an acceptor. At room temperature the thermal energy available from the surrounding atoms (about 1/40 eV) is insufficient to ionize (i.e. release electrons from) a significant fraction of nitrogen donors, and a Type Ib diamond is a very poor conductor of electricity. It is even more difficult to ionize the aggregated nitrogen centres in Type Ia diamonds, requiring an energy of at least 3.7 eV, and such diamonds are therefore excellent insulators. However, a small fraction of the boron acceptors *can* be ionized at room temperature, and diamonds containing boron as the major impurity will conduct electricity to a certain extent. The electrical current is said to be carried by positive holes, and the electrical conductivity increases as the temperature is increased. This behaviour is entirely characteristic of a p-type semiconductor, and such diamonds are classed as Type IIb. The electrical conductivity of Type IIb diamonds enables them to be distinguished easily from diamonds that have been coloured blue by irradiation with high energy electrons (see Section 6.8.1). Diamonds with immeasurably small nitrogen concentrations, but which are not semiconducting, are classed as Type IIa.

When nitrogen and boron are present simultaneously in a diamond the properties are determined by the major impurity. Boron is only ever present as a trace impurity with a concentration around 1 ppm in natural diamonds; the nitrogen concentration in Type IIb diamonds must therefore be less than 1 ppm and these specimens represent the purest form of naturally occurring diamond.

5. VIBRONIC CENTRES—DESCRIPTION

The word 'vibronic' is a contraction of vibrational-electronic and is used to describe absorption and luminescence bands which arise when the *electron* in an optical centre is excited (i.e. given energy) and at the same time *vibrational* energy is transferred to the crystal. Vibronic bands are so common in diamond—all but one of the remaining colour centres to be described in this article are vibronic centres—that it is worthwhile trying to obtain a general understanding of the processes involved and of the nomenclature often employed in describing the spectra.

I shall try to explain some of the underlying principles by means of an analogy. As with all analogies, it cannot be pushed too far and indeed the picture I present here is not even accurate since it separates the electronic and vibrational terms in a way which is not valid. Nevertheless I believe that some useful insights may emerge from this approach.

Imagine that we have a snooker table as shown in Figure 5 and that the legs at the top have been propped up slightly so that there is a gentle uphill slope from bottom to top. Near the top of the table we have a pack of three balls, each interconnected by a spring and each anchored to the table by another spring. The ball E shown shaded has a layer of glue on it; this glue has rather special properties which we shall describe later.

Consider now striking the cue ball from the point Q on the bottom cushion. The cue ball has its lowest possible energy here, and the bottom cushion represents the 'ground state' of the system. There is assumed to be no friction between the cue ball and the table, and there are three cases that we can consider:

(i) The cue ball is hit gently so that it rolls part way up the table then rolls back to the lower cushion. In this case no net energy has been gained by the cue ball, and this corresponds to the situation in a crystal where the energy of the light is too small (i.e. the wavelength is too long) for absorption to occur at the optical centre.

(ii) The cue ball is hit very precisely so that it just reaches E and sticks to it. The cue ball is now in an 'excited state' and this corresponds to the *electronic transition* at a colour centre in a crystal.

(iii) If the cue ball is hit somewhat harder than it was in case (ii) then the cue ball will stick to E and also set the pack of balls

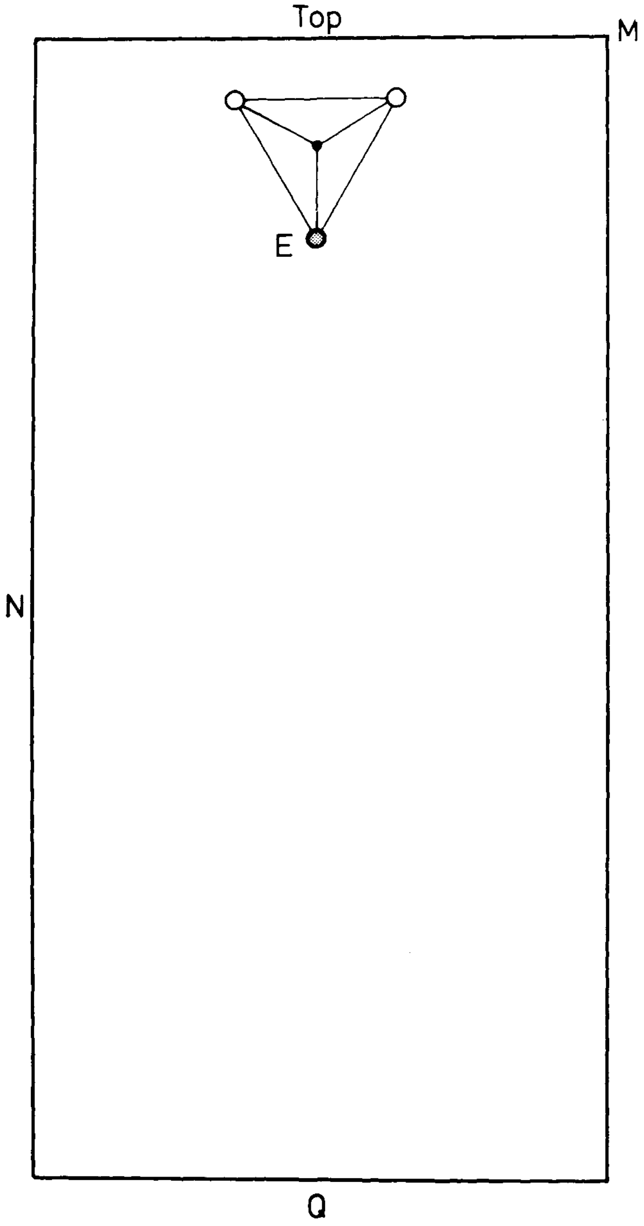

FIG. 5. Snooker table and balls used in analogy to represent vibronic interactions in diamond. The lines interconnecting the three balls, and between each ball and the anchoring point at the centre of the triangle, represent springs.

into vibration. The frequency of the vibration will be determined by the mass of the balls and the strength of the springs. In a real crystal the atoms of the colour centre are bonded to the diamond lattice and the vibrating atoms in the centre force the surrounding carbon atoms into motion and the vibrational energy spreads out into the diamond. The vibrational waves which propagate through the crystal are referred to as PHONONS, which have a characteristic frequency or energy.

Our simple model does not allow us to predict the shape of the absorption band, but calculation based on a simple theoretical model which assumes there is only one characteristic phonon energy yields a typical band shape like that shown in Figure 6a. The essential features are a sharp line marked O corresponding to the electronic transition, and a broad band at higher energy which shows peaks 1, 2, 3 . . . . whose spacings from O are multiples of the phonon energy. These peaks become more diffuse at higher energies. The line O is referred to as the phononless, no-phonon or zero-phonon line (the latter term being most generally used in the diamond literature) and the peaks 1, 2, 3 . . . . as the first, second, third . . . . phonon replica (or sideband). In a real situation the

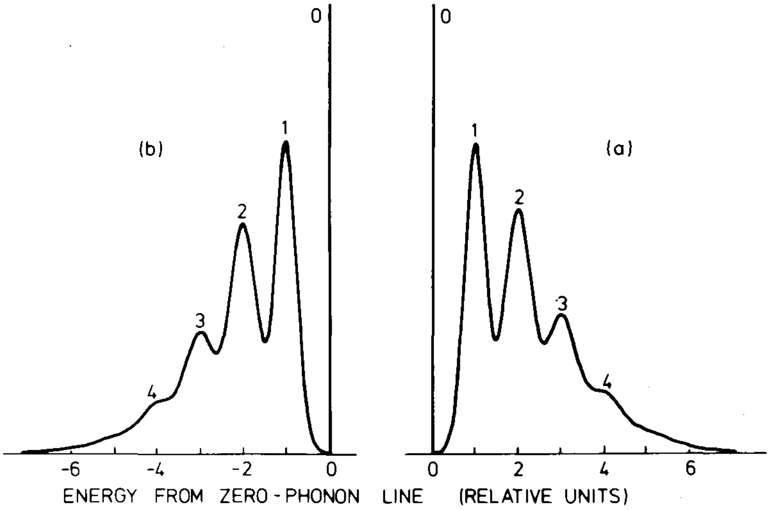

FIG. 6. Theoretical spectra representing (a) the absorption spectrum and (b) the luminescence spectrum associated with an ideal vibronic centre. In each case 0 represents the zero-phonon line and 1, 2, 3 . . . are the first, second, third . . . phonon sidebands.

electronic transition may couple to more than one phonon energy so that the spectrum is more complicated than that shown in Figure 6a, but often there is one dominant feature which repeats at equal energies. For just a few bands in diamond the coupling between the electronic and vibrational terms is so strong that the zero-phonon line is too weak in intensity to be detected, and the phonon replicas are broadened out into a single band. The transitions which give rise to the amber yellow (Section 6.2) and natural pink (Section 6.6) colours are believed to be of this type.

5.1 *Temperature dependence*

In our snooker table analogy we have assumed that the pack of balls near the top of the table is absolutely stationary. In a real crystal the atoms are continuously vibrating at random, unless the temperature is reduced to absolute zero. Furthermore the higher the temperature of the crystal the larger is the amplitude of vibration. If the balls in our model are allowed to vibrate to represent a finite temperature the ball E will sometimes be nearer to, and sometimes farther from, the bottom of the table than it would be when absolutely stationary, and this means that there is no longer a single precise energy at which the electronic transition takes place, but that there is a spread of energies. This means that the zero-phonon line in the absorption spectrum, and the features in the vibronic band, become broader as the temperature is increased. There are two further temperature effects which emerge from detailed theoretical analyses of vibronic bands.(12) The intensity of the zero-phonon line, relative to the vibronic band, decreases as the temperature is raised and the line moves to lower energy (longer wavelengths). For most optical centres in diamond there is very little change in the width, intensity or position of the zero-phonon line for temperatures up to 100 K, but between 100 K and room temperature (~ 300 K) the effect of temperature is quite considerable. For example the width of the N3 zero-phonon line increases typically by a factor of 3, its intensity decreases by a factor of 2 and its position changes from 415.2 to 415.6 nm.(12) (The N3 centre is discussed in Section 6.1). When an absorption spectrum is plotted as absorption coefficient versus energy the *area* under the zero-phonon line is a measure of its intensity. As a rough approximation we may regard the zero-phonon line as being triangular in shape, and its area is then ½ × width × height. Since the intensity decreases, and the width increases, with increasing temperature, the *height* of the line on the absorption spectrum drops off very considerably at higher temperatures. Many zero-phonon lines vary with temperature more rapidly than the N3 line and are difficult, if not impossible, to measure at room temperature.

From what has been said so far it would seem that the width of a zero-phonon line should be close to zero at low temperatures. In reality this is not so—the lines are typically a few Å wide, although occasionally line-widths less than 1Å may be observed. The origin of this residual line-width is strain broadening.(12) Diamond crystals are not perfect; they contain impurities and have often experienced plastic deformation resulting in a high concentration of dislocations. Dislocations and impurities produce random elastic strains in the crystal which slightly alter the energy of the electronic transition at a particular centre. A cubic millimetre of diamond may contain 10^{14} optical centres of a particular type. On our snooker table analogy the effect of the random strain is to squeeze some colour centres a little nearer to the top of the table and squeeze others a little further away, resulting in a spread of energies for the electronic transition, even at low temperature. As we have seen, nitrogen is the dominant impurity in diamond, and it has been shown that the width of the H3 zero-phonon line increases as the nitrogen content increases,(13) because of the increasing strain.

5.2 *Luminescence*

Thus far in our discussion of vibronic centres we have considered only absorption processes. Suppose that after a time t_1 the glue on ball E in Figure 5 ceases to be sticky and releases the cue ball. The ball will roll back to the bottom cushion releasing energy equal to the electronic excitation energy. This is equivalent to the production of a zero-phonon line in emission (i.e. luminescence) and the time t_1 is called the lifetime of the centre. Suppose now that the glue does not always release cleanly but behaves like some of the 'stringy' adhesives the handyman encounters from time to time. Then as the cue ball rolls back down the table it will occasionally tug on the pack of balls, setting them into vibration, and will be slowed down in the process so that it arrives at the bottom cushion (the ground state) with *less* than the zero-phonon energy. Again this simple picture does not allow us to visualize the exact details of the luminescence band, but the shape of this can be calculated, using the same assumptions as were used to calculate the absorption band. A typical theoretical luminescence band is shown in Figure 6b, and we notice that it is a mirror image of the absorption band.

The effects of temperature and strain-broadening are virtually the same for the absorption and luminescence bands, and because of coupling to more than one phonon energy the absorption and luminescence spectra will, in general, be more complicated than shown in the simple example in Figure 6. Furthermore, because of a phenomenon called the Jahn-Teller effect, the absorption and luminescence spectra are not usually exact mirror images, and for some optical centres (for example GR1(14)) the departure from mirror symmetry may be considerable.

5.3 *Radiationless Transitions*

In our model described so far each optical centre that has been excited decays after time t_1, giving out luminescence. In practice there are ways in which a centre can decay without producing luminescence. We can envisage this on our snooker table (and here the analogy becomes exceedingly strained) if we suppose that from point M balls are fired off at random, with an average time between successive balls of t_2, with a trajectory such that if the cue ball is in an 'excited state' (i.e. stuck to E) it will be knocked off into the centre pocket at N. From here it must be collected by hand and returned to the bottom cushion; we can define this to be a radiationless transition or non-radiative process (i.e. one that does not produce luminescence). If t_2 is very long compared with t_1, very few cue balls will be knocked into the pocket. For a colour centre in a crystal this would correspond to the situation where most of the energy *absorbed* is re-emitted as luminescence, a process which is described as having high quantum efficiency. If $t_2 = t_1$ the luminescence quantum efficiency would be about 50% and if t_2 is very short compared with t_1 the quantum efficiency would be very low.

Research work on the H3 and N3 centres(13,15) has shown that the smaller the separation between the colour centre and an A-aggregate of nitrogen the smaller is the value of t_2 which determines the probability of non-radiative decay. Increasing concentrations of A-nitrogen in diamond therefore quench the luminescence from these centres. It is probable, although it has yet to be demonstrated experimentally, that this quenching mechanism operates for all colour centres in diamond.

6. VIBRONIC CENTRES—EXAMPLES

In this section I shall discuss some of the gemmologically important vibronic centres in diamond, working through the visible spectrum from violet to red.

6.1 *The N3 centre*

The N3 centre is the most common naturally occurring point defect in diamond, and is responsible for the coloration of the vast majority of yellow diamonds. The centre has been investigated for at least 90 years and Davies *et al.*(16) list some of the earlier work although they do not include the important contribution made by Anderson.(17) The absorption spectrum is shown in Figure 7a and the luminescence spectrum is given in Figure 7b and we see that they are classic examples of vibronic spectra, being almost mirror images about the zero-phonon line at 2.985 eV (415.2 nm). On the low energy side of the absorption line there is a weaker series of lines, shown on an expanded scale in Figure 7c, with the most prominent feature at 2.593 eV (478 nm). This is the N2 peak, which correlates in intensity with the N3 band.(16) The N2 line is not, however, a zero-phonon line, and there is no corresponding N2 luminescence.(16) The absorption spectrum in Figure 7 is characteristic of Cape yellow diamonds, and most of the perceived colour is due to the N2 band since the eye is very insensitive at wavelengths less than 400 nm. It has been noted by K. Scarratt and also by G. Bosshart (personal communications) that when strongly absorbing Cape yellow diamonds are examined at low temperature (around 100 K) a series of sharp absorption lines is observed at wavelengths between 420 and 440 nm. Bosshart has determined the wavelength of these lines as 424, 429, 432, 434, 437 and 439 nm.

The currently accepted model for the N3 centre is a triangle of three nearest-neighbour nitrogen atoms, bonded to a common carbon atom.(16) Thus the conditions in nature which favoured the creation of larger nitrogen aggregates in diamond would be expected to have favoured the production of the N3 centre, and there is certainly a tendency for the N3 absorption to be strong in diamonds which have a high concentration of B-nitrogen.(18)

When Cape yellow diamonds are illuminated by a longwave ultraviolet lamp (365 nm) many exhibit bright blue luminescence (the spectrum in Figure 7b was recorded for such a stone). However, as was originally noted by Anderson,(17) there is no relation between the strength of the luminescence and the strength of the absorption band, and the present writer has observed many

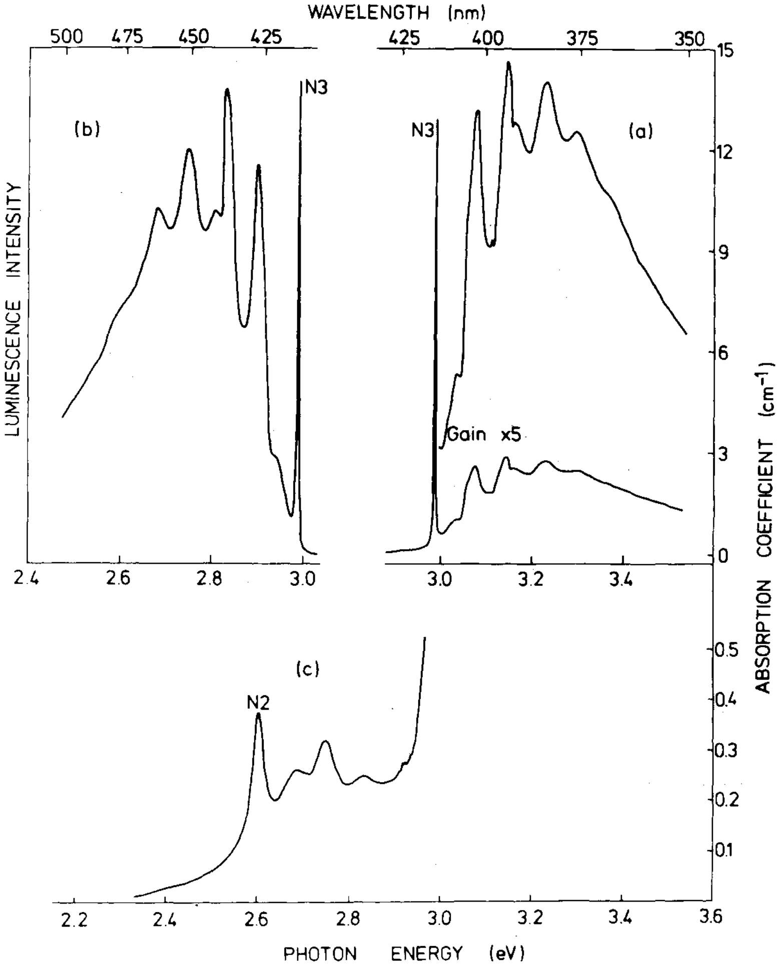

FIG. 7. (a) Absorption spectrum measured for a Cape yellow diamond. (b) Luminescence spectrum for the same diamond. The N3 zero-phonon line in (a) and (b) is indicated. (c) Absorption spectrum in the region of the N2 peak, shown on a vertically expanded scale. All the spectra were recorded at a temperature around 100 K.

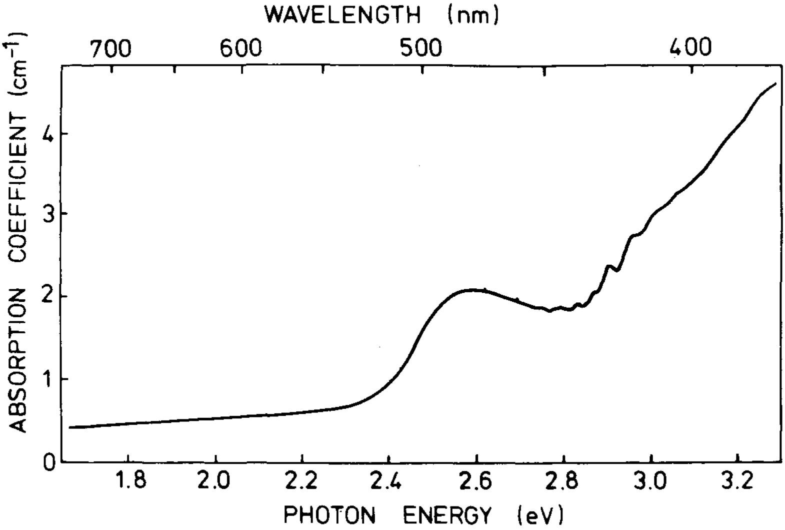

FIG. 8. The 2.6 eV absorption band observed in diamonds which exhibit bright yellow luminescence in long wave ultraviolet.

yellow diamonds which are, to the eye, non-luminescent. An explanation of this phenomenon, already mentioned in Section 5.3, has been given recently by Davies and Thomaz.(15) Luminescence from N3 centres (and probably from all colour centres in diamond) is quenched by high concentrations of A-nitrogen. If two diamonds have the same concentration of N3 centres, with one sample having no nitrogen present in the A-aggregate form and the second having 0.3% A-nitrogen, then Figure 8 from Reference 15 indicates that the luminescence intensity from the first stone will be about 30 times greater than that from the second.

Non-luminescent samples are normally selected for the production of treated yellow diamonds. The resulting yellow colour in this case is predominantly associated with the H3 and H4 bands (Section 6.3), and the green luminescence which would be excited by daylight in strongly luminescing diamonds gives the stones an undesirable appearance (F. Pough, personal communication).

6.2 *The 2.6 eV band*

Some diamonds exhibit bright yellow luminescence when excited with long wave ultraviolet. All such stones examined in the author's laboratory have an absorption spectrum like that shown in

Figure 8. This shows a featureless band, with a peak near 2.6 eV (477 nm) together with an underlying absorption, characteristic of Type Ib diamond (see Figure 4a). Infrared measurements show that the total nitrogen concentration is relatively low (and so the luminescence efficiency is high). Detailed investigations(19) show that the 2.6 eV peak is indeed a vibronic band, but because the coupling between the electronic and vibrational terms is very strong the zero-phonon line cannot be observed, and there are no features on the absorption band. The 2.6 eV band is not, in fact, responsible for the yellow luminescence; absorption of light in the 2.6 eV band produces red luminescence, the emission spectrum being approximately a mirror image of the absorption band.(19) The yellow luminescence appears to be associated with a vibronic band which is too weak to detect by conventional absorption spectroscopy, and which always occurs with the 2.6 eV band.

In white light diamonds with well developed 2.6 eV bands are an attractive amber colour.

6.3 *The H3 and H4 Centres*

When a Type Ia diamond is subjected to radiation damage and then annealed at typically 800 °C we obtain a treated yellow specimen, and the colour is due to absorption in the H3 and/or H4 bands. The H3 centre has a zero-phonon line at 2.463 eV (503.2 nm) and the zero-phonon line of the H4 centre is at 2.499 eV (496.0 nm). Davies has shown that the H3 centre is a vacancy trapped at an A-aggregate of nitrogen and the H4 centre is a vacancy trapped at a B-aggregate.(20) (We shall encounter the vacancy in Section 6.8) Thus in treated diamonds we find H3/H4 = A/B where H3, H4, A and B represent the concentrations of the corresponding defects, as estimated from the absorption spectra. (This relationship has been established using high energy electrons to create the initial radiation damage).

The H3 line is also found naturally-occurring in some diamonds, particularly brown stones, and there is some evidence that naturally-occurring H4 absorption may be observed, but in the author's experience this is very rare. Furthermore the relationship given in the previous paragraph generally does not apply, but instead H3/H4 is very much greater than A/B.(21, 22) If artificially irradiated and annealed diamonds containing predominantly H4 centres are heated to 1500 °C the intensity of the H4 absorption

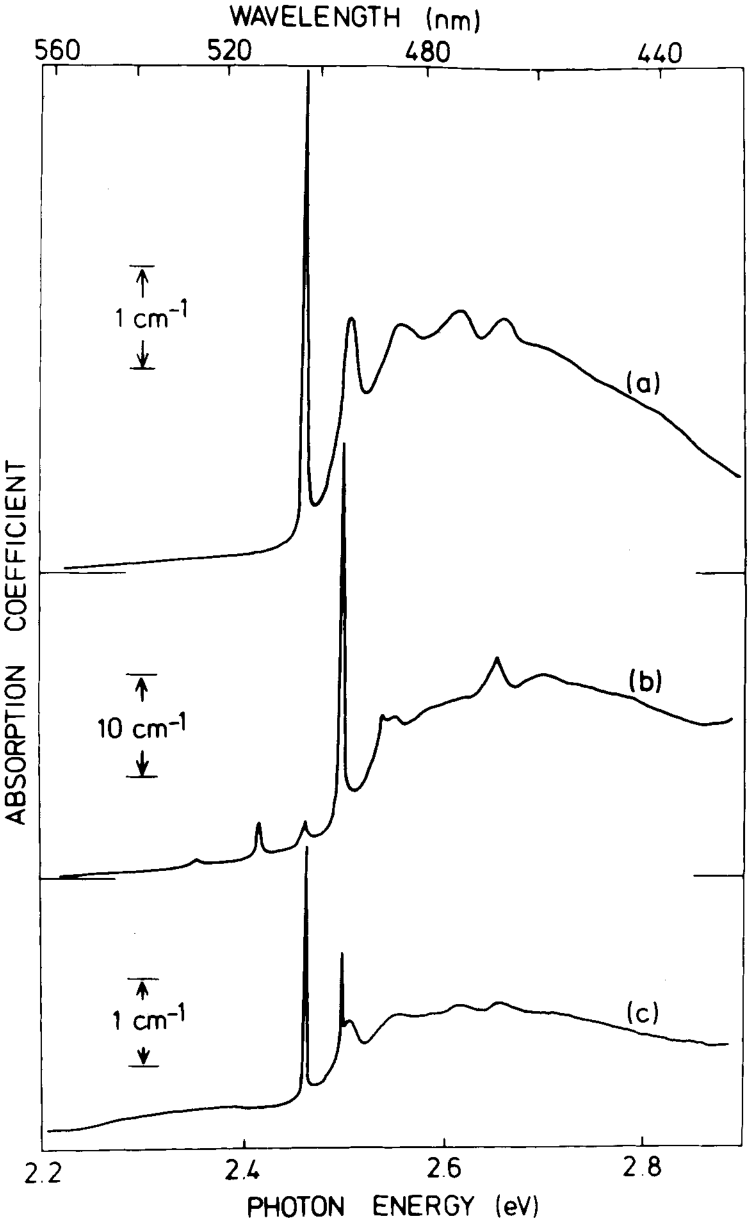

FIG. 9. Absorption spectra recorded at about 100 K for (a) a diamond with naturally-occurring H3 (503 nm) absorption, (b) a treated diamond showing predominantly H4 (496 nm) absorption and (c) a diamond with H3 and H4 absorption—believed to be naturally-occurring.

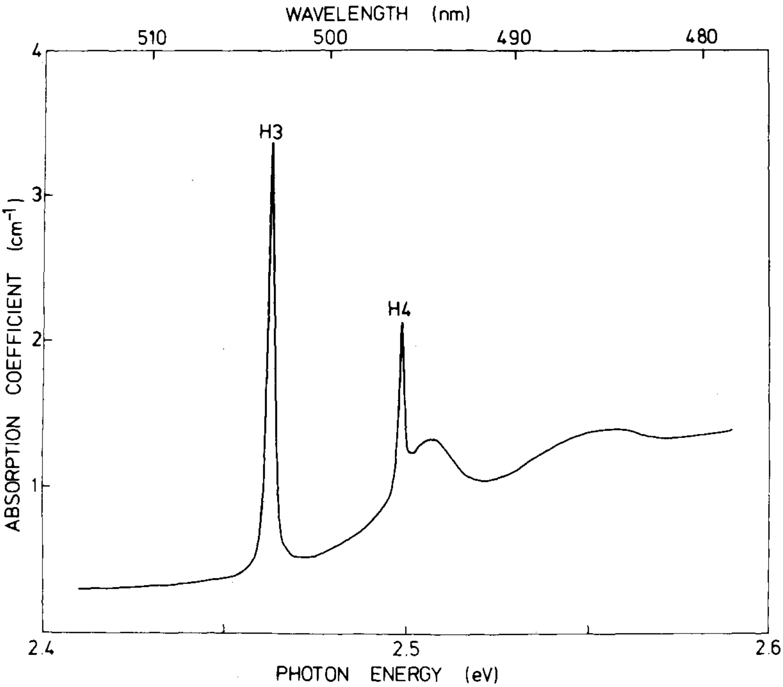

FIG. 10. Absorption spectrum recorded at about 100 K for a diamond with H3 and H4 absorption, shown on an expanded plot. The H3 and H4 zero-phonon lines are labelled, and the latter is seen to be superimposed on the first phonon replica in the H3 band.

decreases and that of the H3 increases to produce a situation more nearly like that observed in nature.(23) Although this observation casts some light on the processes of natural H3 and H4 formation, the heating of valuable gem-quality diamonds to 1500 °C is an exceedingly risky business and it is most unlikely that diamonds treated in this way are currently being used in the gem trade.

In Figure 9 we show the absorption spectra of *(a)* a diamond with a naturally-occurring H3 system, *(b)* a treated diamond showing predominantly the H4 band and *(c)* a stone containing both H3 and H4 centres. Diagrams *(a)* and *(b)* show that the H3 and H4 systems are further examples of typical vibronic bands and we notice from diagram *(c)* that when H3 and H4 centres are present simultaneously in a diamond the H4 zero-phonon line is very close to the peak of the first phonon sideband of the H3 centre. There is unfortunately a considerable amount of misleading

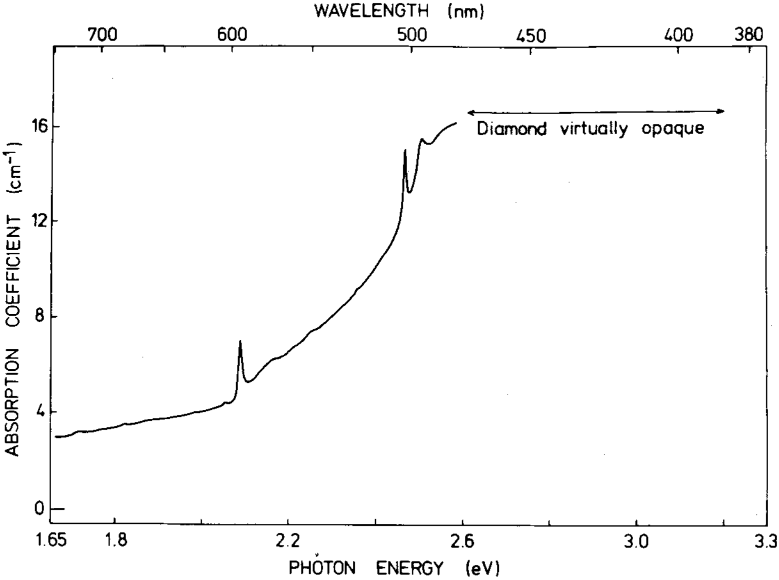

FIG. 11. Absorption spectrum recorded at about 100 K of a heavily irradiated diamond that has been annealed. The stone is virtually opaque at wavelengths less than 490 nm and appears orange in colour. A strong 595 nm (2.086 eV) line is also observed.

information in the gemmological literature about the relative intensities of the 503.2 and 496.0 nm peaks, from which incorrect conclusions have been drawn about the relative H3 and H4 concentrations. It is essential before making such comparisons that the stones are cooled to make the zero-phonon lines as sharp as possible, and that the absorption coefficient is recorded with an instrument capable of fully resolving the narrow lines. Part of Figure 9c is shown expanded in Figure 10 to make this point more clearly.

The diamond for Figure 9a is interesting in that, although it shows only the H3 system, virtually all the nitrogen is in the B-aggregate form. There is therefore very little luminescence quenching by A-nitrogen and the stone exhibits bright green luminescence in white light. The combination of absorption and luminescence gives the sample a 'Vaseline-like' appearance. The diamond for Figure 9c is a particularly important specimen. It was loaned to the author by Basil Anderson who is confident that the stone has not been artificially coloured. We will deal with this specimen again in Section 7.

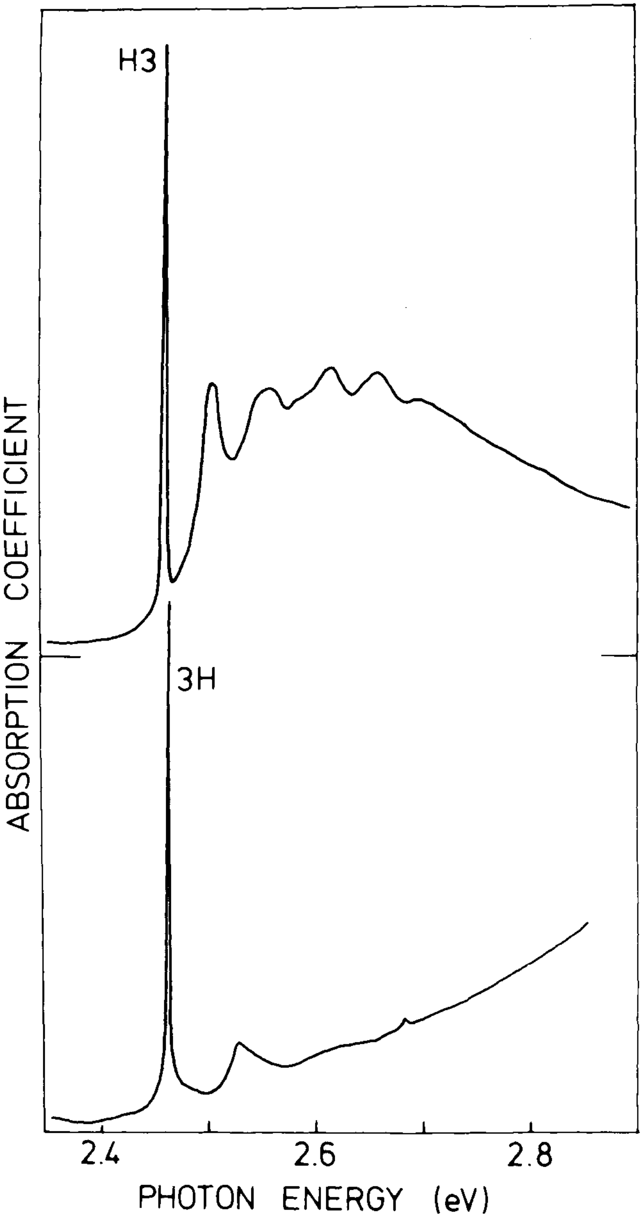

FIG. 12. Comparison of the H3 and 3H absorption spectra recorded about 100 K. Although the zero-phonon lines are at almost the same energy the band shapes are quite different.

When a diamond is very heavily irradiated and then annealed the absorption in the H3 and H4 bands is intense and the stone becomes virtually opaque at wavelengths shorter than about 500 nm. The diamond then acquires an orange colour unlike any naturally-occurring stone (in the author's experience). A typical absorption spectrum is shown in Figure 11.

6.4 *The 3H Centre*

In his pioneering paper on the effects of neutron-radiation damage and annealing Dugdale(24) found that when bombarded stones were heated at 350-400 °C an absorption line at 504 nm appeared in considerable strength, sometimes accompanied by a band at 492 nm (the spectra were measured with the sample at room temperature). After heating to 425 °C these bands vanished completely. However, when the annealing temperature was raised to 700-1000 °C, a line at 504 nm was again observed, sometimes accompanied by a companion line at 497 nm.

We now recognize that the 504 and 497 nm lines obtained after annealing at above 700 °C are the zero-phonon lines of the H3 and H4 bands discussed in the previous section. Davies(25) has shown that the 504 nm line obtained at lower annealing temperatures is the zero-phonon line of a quite different optical centre. Because of the closeness of the two zero-phonon lines it has been suggested that the description 3H should be used for this centre. High resolution spectroscopy shows that the lines occur at slightly different wavelengths (503.2 nm and 503.6 nm for the H3 and 3H lines respectively measured at 77 K) and as shown in Figure 12 the band shapes are quite different.

6.5 *The 595 nm Centre*

When Type Ia diamonds are irradiated and annealed at about 800 °C to produce treated yellow or orange stones (Section 6.3) an absorption band with a zero-phonon line at 595 nm (2.086 eV) is always produced, together with a related line at 425 nm (2.916 eV). These lines are indicated in the absorption spectrum shown in Figure 13. It is only very rarely that the 595 nm line is observed naturally in diamond, and it had been thought that it is never observed in an untreated diamond once it has been cut and polished (B. W. Anderson, personal communication), but see Section 7. Until recently the presence of the 595 nm line in the absorption

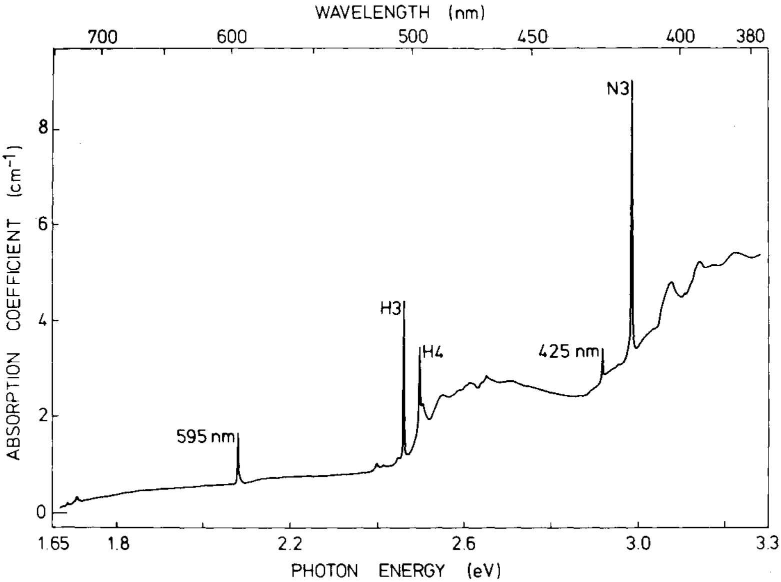

FIG. 13. Absorption spectrum recorded at about 100 K for an irradiated and annealed diamond. The 595 nm (2.086 eV) and related 425 nm (2.916 eV) lines are labelled.

spectrum of a coloured stone was considered as positive proof that the colour was associated with treatment, and, by implication, that if this line were absent then the colour was natural. However, work by the author(26) has shown that if a treated yellow diamond is heated to 1000 °C the 595 nm line is destroyed, without significantly changing the colour of the stone. It is probable that this result has been known for some time by those operators who try to pass off treated diamonds as being naturally coloured. The implications of this in the field of gem testing are considered in Section 7.

6.6 *Natural Pink and Mauve Diamonds*

Raal(27) discovered a broad, featureless absorption band with a peak near 2.2 eV (563 nm) in all natural pink and mauve diamonds, and some brown ones. The pink diamonds have additional peaks at 3.13 and 3.18 eV (396 and 390 nm), and the absorption spectrum of such a stone is shown in Figure 14. Some preliminary work in the author's laboratory has shown that the 2.2 eV peak is a vibronic band. Absorption of light in the high energy part of the band produces red luminescence, and the band

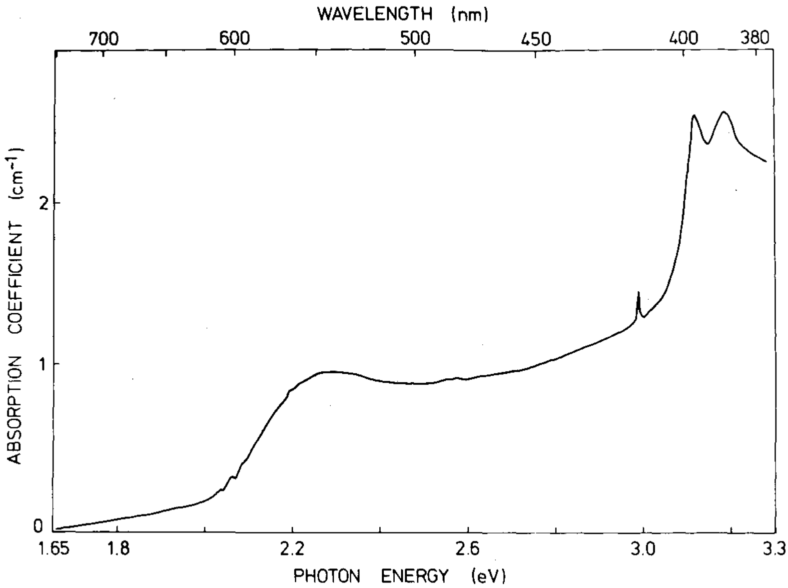

FIG. 14. Absorption spectrum of a natural pink diamond recorded at 77 K.

shape of the luminescence spectrum is approximately a mirror image of the absorption band.

Relatively little is known about the colour centres responsible for the pink and mauve coloration. Diamonds classified as pink are usually Type IIa, while the mauve diamonds contain substantial concentrations of nitrogen and often show N3 absorption features in addition to the broad band at 2.2 eV.(28) The earlier suggestion(27) that the colour is associated with the presence of manganese has been shown to be incorrect.(28, 29)

6.7 *Treated pink diamonds*

If a Type Ib diamond is subjected to radiation damage and then annealed at 700-800 °C an absorption spectrum like that shown in Figure 15 is produced.(28) This is a completely typical vibronic band with a zero-phonon line at 1.945 eV (637 nm). Various other weak zero-phonon lines may also be superimposed on the band, in particular at 2.086, 2.156 and 2.463 eV (595, 575 and 503 nm)—the latter being the H3 line. The relative strength of the 2.156 eV line appears to depend on the annealing conditions.(30) Davies and Hamer(30) have shown that the 1.945 eV

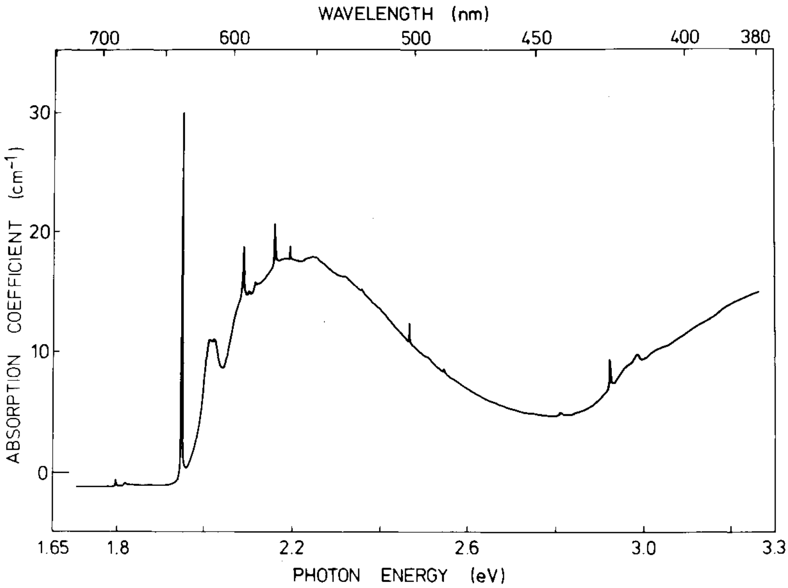

FIG. 15. Absorption spectrum of a 'treated pink' (irradiated and annealed Type Ib) diamond recorded at about 100 K. The zero-phonon line is at 637 nm (1.945 eV).

centre is a vacancy trapped at an isolated substitutional nitrogen atom.

The final colour of the treated stone will depend on the strength of the yellow colour before irradiation and on how heavy an irradiation is used. A pale yellow diamond given a short irradiation produces a pink colour, whilst a longer irradiation gives a mauve colour. The similarity of these colours to the natural pinks and mauves is because the vibronic band of the 1.945 eV centre reaches a maximum near 2.2 eV (compare with Figure 14).

Occasionally naturally-occurring 1.945 eV absorption is observed in Type Ib diamonds. This is not surprising in view of the frequency with which Type Ia diamonds with naturally-occurring H3 absorption are found. In the author's experience, however, the 1.945 eV absorption produced in nature is very weak and makes no significant contribution to the colour of the diamond. A stone which has a good fancy-yellow colour, with the typical Type Ib absorption shown in Figure 4a, can safely be certified as 'not treated' even if there is a weak zero-phonon line at 637 nm in the low temperature spectrum.

6.8 *The GR1 Centre*

The GR1 zero-phonon line at 1.673 eV (741 nm) is the first (i.e. lowest energy) transition produced by the *G*eneral *R*adiation of diamond; it is produced in all types of diamond by all types of radiation damage (neutrons, 1 MeV γ-rays, α-particles and high energy particles—e.g., 2 MeV electrons). Other transitions at the centre give rise to the GR2—8 lines between 2.881 and 3.007 eV (430-412 nm). The effect of the radiation damage is to knock some of the carbon atoms away from their normal lattice position leaving a vacancy. The displaced carbon atoms are pushed into spaces (interstitial positions) in the regular framework of atoms. Although the radiation damage produces equal numbers of vacancies and interstitials, virtually nothing is known about what happens to the interstitial. The GR defect, however, has been positively identified with the vacancy.(31)

The colour of the diamond following irradiation and the detail in the absorption spectra are dependent on the diamond type and the method of irradiation. Some of the important variations are given below.

6.8.1 Electron Irradiation

In Figure 16a we show the absorption spectrum of a Type IIb diamond which has been irradiated with 2 MeV electrons at low temperature, such that during the irradiation the temperature of the sample did not rise above −25 °C. The GR1 vibronic band is very clearly defined, and the GR2—8 transitions at higher energy are well resolved. Most of the absorption is at the red end of the visible spectrum and the sample has a blue coloration.

Figure 16b shows the absorption spectrum of a Type Ia diamond which has also been irradiated with 2 MeV electrons at low temperature. This diamond contains a high concentration of nitrogen in the A-aggregate form, and the effect of this is to broaden all the sharp features in the spectrum. If the diamond is carefully annealed, some sharpening of the structure is observed after heating to 275 °C and after heating to 400 °C the features in the spectrum are almost as well resolved as in Figure 16a. This annealing also causes a reduction in the total band strength.

Diamonds to be coloured commercially are not normally irradiated at low temperature, but the effective temperature during

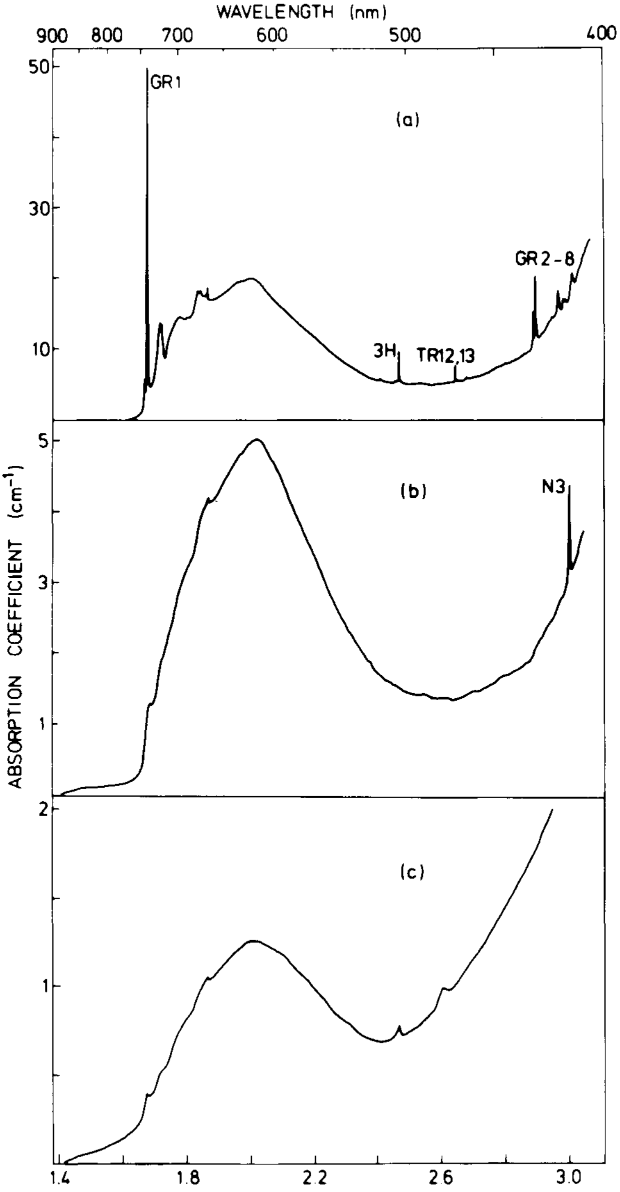

FIG. 16. Absorption spectra recorded at about 100 K for (a) a Type IIb diamond irradiated with 2 MeV electrons at low temperature; (b) a Type IaA diamond irradiated with 2 MeV electrons at low temperature; (c) a Type IaA diamond that has been neutron-irradiated (without cooling). The TR12 and TR13 lines shown in (a) are produced by radiation damage only in Type II stones, and will not normally be observed in gem diamonds.

the irradiation is rarely as high as 400 °C. The absorption spectrum of a treated blue is therefore usually somewhere in between the two extreme cases shown in Figure 16a and 16b. It is also not unusual for some absorption to be present in the 3H band (see Section 6.4).

If a colourless Type Ia diamond is irradiated with electrons the colour obtained is normally blue. However, as it is only off-white (Cape yellow) diamonds that are usually chosen for treatment, the combination of GR absorption with the substantial N2 and N3 absorption results in a blue-green colour.

The penetration depth of 2 MeV electrons in diamond is about 2 mm. Thus although a large diamond might not be coloured all the way through, it is not practicable to polish off the irradiated region.

6.8.2 γ-ray Irradiation

γ-rays of energy around 1 MeV will colour a diamond uniformly throughout, but even with the most powerful radioactive sources available the process is very slow, taking several months. The effective temperature during the irradiation is only slightly above room temperature, and the absorption spectrum of a Type Ia diamond is very similar to Figure 16b.(5) Once again, annealing to about 450 °C results in a sharpening of the features in the spectrum, and a reduction in the total absorption.(5)

6.8.3 Neutron Irradiation

Figure 16c shows the spectrum of a diamond that has been irradiated with fast neutrons in a nuclear reactor. Again we have an almost featureless GR1 band, but there is in addition a continuously increasing background absorption (scanning from low to high photon energies). The total absorption gives the diamond a distinctive green colour, which is uniform throughout the whole diamond. In this case also, annealing to 450 °C results in sharper absorption lines and a reduction in the total absorption in the GR1 band.(5)

Neutrons are almost 2000 times heavier than electrons, and in addition to creating vacancies it is believed that regions of complete disorder are formed as the neutrons tear through the diamond lattice. The continuous background absorption is thought to be associated with the multiply-damaged regions of the diamond.(5)

6.8.4 α-particle Irradiation

The earliest irradiation of diamonds by α-particles was carried out by Crookes(32) who placed diamonds in close contact with radium salts for several months. In addition to colouring the stones green this process imparts a substantial radioactivity to the diamond which persists for at least 50 years.(8) The absorption spectrum of diamonds irradiated in this way is similar to that for neutron-irradiated stones (Figure 16c), because the relatively heavy α-particle creates multiple damage as well as vacancies. The penetration depth of α-particles is, however, only a few μm and the coloured (and radioactive) region of the diamond is easily polished off.

Radiation of diamonds by α-particles is not used commercially because of the unacceptable risk associated with the resulting radioactive diamond. It is interesting, however, that α-particle damage is not uncommon in natural diamond. This may produce a uniform surface-coloration in cases where the stone has been surrounded by an aqueous solution of a radioactive salt, or results in small green spots when the diamond has been in contact with a speck of radioactive ore. Spectroscopic measurements show that the green tinge exhibited by these diamonds is indeed due to the GR1 band. Sometimes the zero-phonon line is well defined whilst in other stones it is virtually impossible to detect. Presumably this is because the diamonds have experienced natural annealing for different times and at different temperatures. Often the radiation spots are brown, rather than green, indicating that such diamonds have been subjected to temperatures above 500 °C after (or simultaneously with) the α-particle damage (see Section 6.8.6). In all cases the colour is only skin deep and is easily polished off.

6.8.5 Natural Green Diamonds

In addition to the 'green-skinned' diamonds described in the previous section, diamonds are occasionally found which have a *uniform* bottle-green coloration.(33) There are no spectra described in the literature for such diamonds, and the writer has not had the opportunity to examine any stones of this type. In view of the fact that diamonds with uniform absorption caused by H3 centres are found from time to time (Section 6.3, Figure 9a) it is possible that diamonds with uniform, natural, GR1 absorption exist, and these would have a green colour. It would be of considerable help in the understanding of naturally-occurring colour centres if absorption spectra could be obtained for green diamonds of the type described.

6.8.6 Annealing of Radiation Damage

The way in which radiation damage anneals depends to some extent on the diamond type. Temperatures quoted are therefore only examples. At about 500 °C some of the vacancies become mobile and are trapped by one or more of the forms of nitrogen to form H3, H4 or 1.945 eV centres (Sections 6.3 and 6.7). As the temperature is increased from 500 to 800 °C the strength of the GR1 band continuously decreases to zero, and the strength of the H3, H4 or 1.945 eV absorption continuously increases to reach a maximum value. (See, for example, Figure 1 of Reference 26). During this annealing the colour of the diamond changes from blue or green to yellow, brown, orange, pink or mauve depending on the end product and on how strongly the diamond is absorbing. During the production of a treated diamond the annealing need not necessarily be taken to completion, and, for example, the GR lines and the H3 and H4 lines may be present simultaneously.

6.9 *Brown Diamonds*

Some diamonds have a featureless absorption spectrum which continuously increases in strength from the red end to the blue end of the visible spectrum. Such diamonds are often, though not necessarily, Type IIa. The absorption gives the diamond a brown colour. X-ray measurements show that these diamonds have been subjected to severe plastic deformation(33) but it is not clear how this is related to the absorption observed. Many brown diamonds exhibit, in addition, some absorption in the 2.2 eV band characteristic of natural pink/mauve stones (Section 6.6) and some brown Type I diamonds have naturally-occurring H3 absorption, sometimes in considerable strength.

6.10 *Miscellaneous Absorption Lines*

In addition to the major colour centres already described in this article numerous other lines may be observed from time to time in spectroscopic tests on diamonds, although none is normally present in sufficient strength to appreciably affect the colour of a stone. A significant number of brown diamonds luminesce pink in

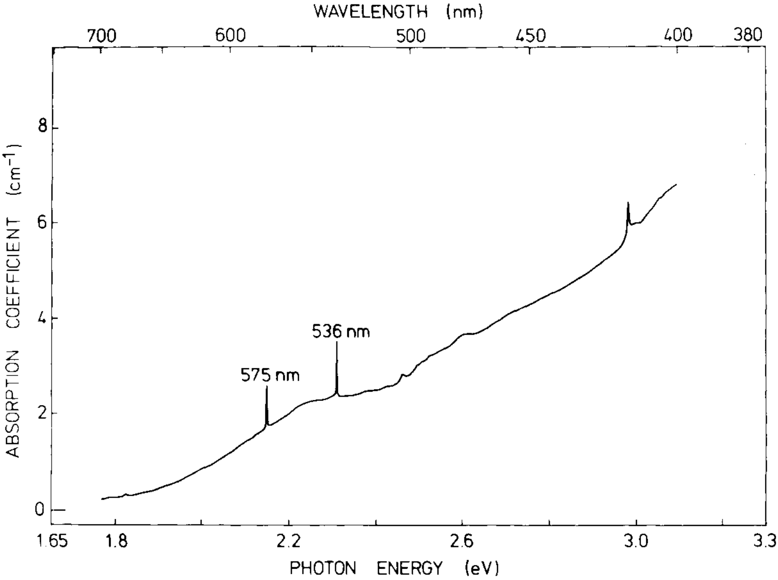

FIG. 17. Absorption spectrum recorded at about 100 K for a brown diamond with absorption lines at 575 and 536 nm. (2.156 and 2.312 eV). This stone showed pink luminescence in long-wave ultraviolet.

long-wave ultraviolet. The pink colour is often caused by emission in the band associated with the zero-phonon line at 575 nm (2.156 eV), and in some diamonds this line may be seen in absorption. A typical absorption spectrum is shown in Figure 17, and this illustrates our observation, on a limited number of samples, that when naturally-occurring absorption at 575 nm is detected a line at 536 nm is frequently present as well. This latter absorption line is also observed in some brown diamonds which have naturally-occurring H3 absorption,(34) and Anderson has previously noted that diamonds showing 575 nm luminescence may also display an emission line at 536 nm.(34) The only report in the literature regarding formation in the laboratory of the colour centre which gives rise to the 536 nm absorption line suggests that very high temperatures (around 1500 °C) are required.(23) In nature, more modest temperatures for much longer time periods would also be effective.

Finally it is worth recording that in a recent survey of rough diamonds we have observed weak absorption lines at 432, 440, 473 and 561 nm (measured at about 100 K) in several diamonds, and a

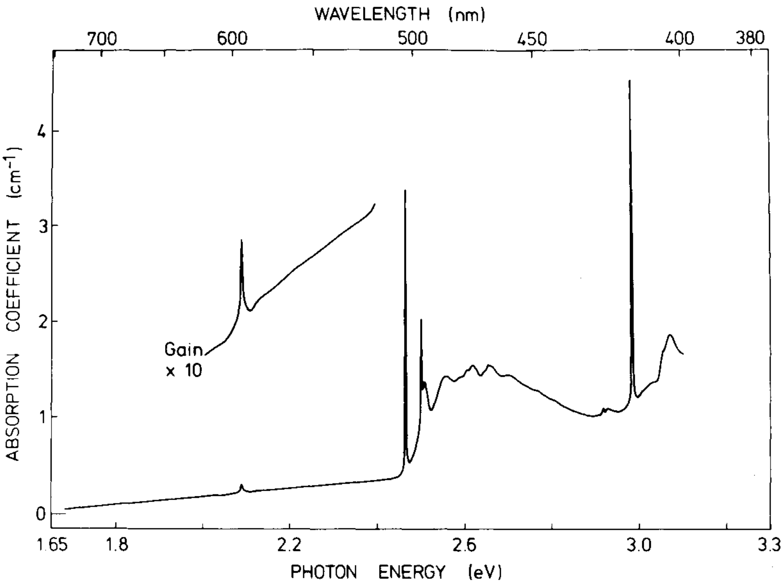

FIG. 18. Absorption spectrum recorded at about 100 K, shown over the whole visible spectral region, for a diamond believed to be naturally coloured.

number of other sharp lines have been noted just once. Other laboratories can no doubt add to the list of miscellaneous absorption lines. Many more sharp lines may be observed using luminescence techniques, but these have little significance in the field of gem testing.

7. THE FUTURE OF DIAMOND GEM-TESTING

Gem testing laboratories are frequently required to determine whether a particular diamond owes its colour to treatment. In many cases the diamond in question will be yellow or brown, and it is here that the situation is most confused.

In Figure 18 we show the full absorption spectrum for an old-cut yellow-green diamond which was loaned to the author by Basil Anderson. The H3 and H4 lines are both present (see Figures 9(c) and 10 for detail) as well as the 595 nm (2.086 eV) line characteristic of treatment (Section 6.5). This is one of few gem diamonds for which measurement in the 7-10 μm infrared region is possible, and this shows that the A/B ratio is the same as the H3/H4 ratio (see Section 6.3). The absorption spectra of this stone, then, are *entirely characteristic* of a Cape yellow diamond that has been artificially coloured. However, Anderson's records show that the diamond was purchased in 1948, many years before artificial colouring of gem diamonds became fashionable. The colour is a body colour, and there is no radioactivity, so there is no question of this being a diamond artificially coloured by α-particles. Furthermore, part of the girdle on this stone has not been polished—it is still the original diamond surface—and this shows the brown markings characteristic of natural radiation damage. Similar surface markings are present on a number of uncut stones in the author's possession in which the natural H3 absorption is comparable in strength with that shown in Figure 17.

The only respect in which this diamond differs from a conventional treated diamond is that, because the A-nitrogen concentration is low, the diamond is strongly green fluorescent in daylight. As noted in Section 6.1 fluorescent diamonds are not nowadays selected for treatment.

Diamonds with moderately strong, naturally occurring, absorption in the H3 and H4 bands present a puzzle to physicists and a dilemma to gemmologists. Although the formation of a 'green skin' on diamonds due to α-particle damage is well understood (Section 6.8.4), the bulk coloration of a diamond by natural radiation damage seems improbable because of the very high flux of energetic (i.e. 1 MeV or greater) γ-rays that would be required. And yet, as already noted, many samples show the small brown circular patches on the surface that are usually attributed to natural radiation damage.

Anderson's diamond is the only polished stone in which I have observed naturally-occurring H4 absorption (Figures 9(c) and 10) and 595 nm absorption (Figure 18), although these two lines have been found together in two rough diamonds examined in this laboratory. The absorption in these rough diamonds was much less intense than in Anderson's stone, but if, as the records indicate, that specimen is naturally coloured, how does the gemmologist assess another diamond with a similar absorption spectrum? Take, for example, the spectrum of the diamond shown in Figure 19(a). This is plotted as percentage transmission and shows 'very strong' absorption in the H3 and H4 bands. This particular stone weighed almost 40 carats, and the path length of the light in the diamond was 11.55 mm; if the spectrum is plotted properly as absorption

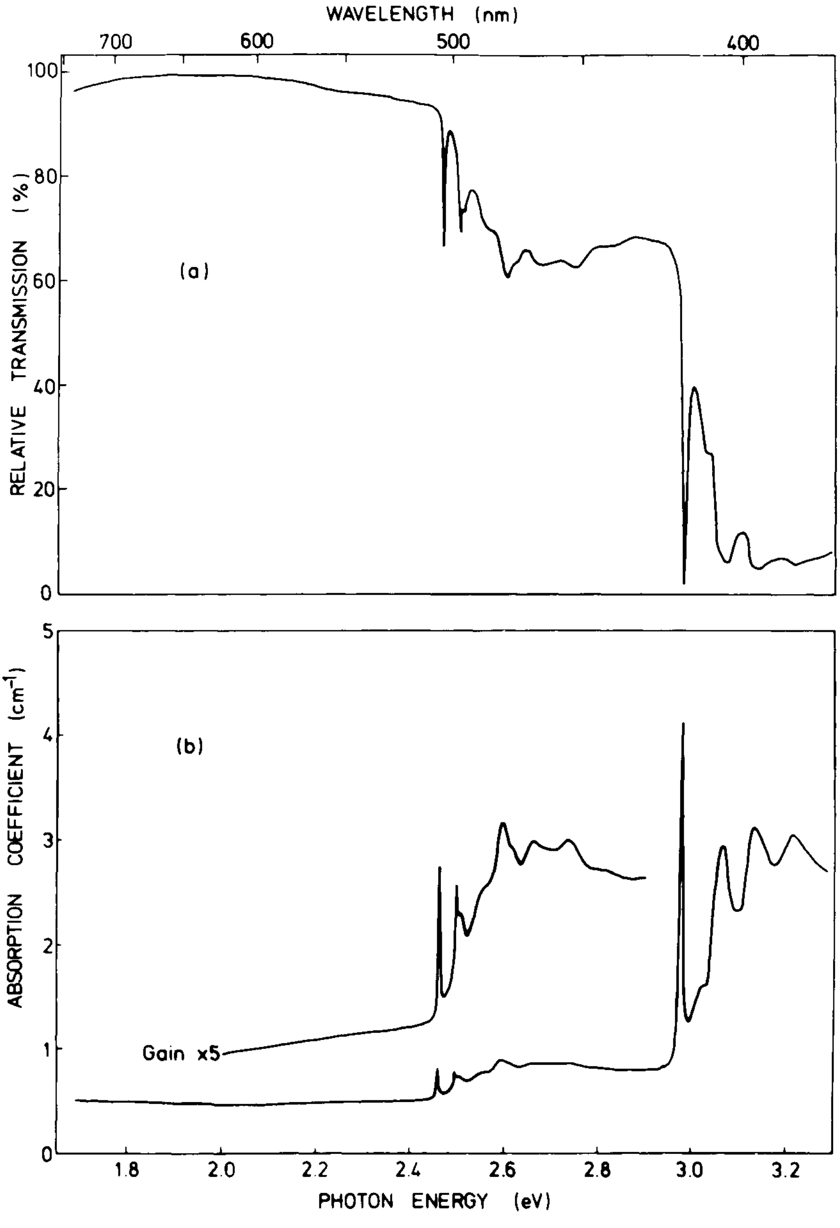

FIG. 19. Spectra recorded for a 40 carat diamond cooled to about 100 K plotted as (a) percentage transmission and (b) absorption coefficient. The path length of the light in the diamond was 11.55 mm.

coefficient (Figure 19(b)) then we see that the H3 and H4 bands are, in fact, considerably weaker than in Anderson's stone. Furthermore, there is no hint of an absorption peak at 595 nm, and so if the colour is indeed due to treatment, whoever carried it out must have heated the stone to at least 1000 °C (see Section 6.5). With such a valuable diamond this would have required very considerable courage. Unfortunately the diamond was far too large to obtain any data about the A to B nitrogen ratio in the 7-10 μm infrared spectral region.

I am inclined to believe that this particular diamond is naturally coloured, but what emerges from this article is that, with the present state of knowledge, no one can decide with certainty from the spectroscopic tests described whether such a diamond is treated.

8. SUMMARY

I have described the prominent absorption bands responsible for the colours of many natural and treated diamonds, but there will doubtless be some stones whose colour is not accounted for. I have presented a picturesque treatment of the band shapes and explained why it is necessary to make measurements at high spectroscopic resolution with the diamond at low temperature. I have emphasized that sensible conclusions about whether a diamond has been treated can only be reached by measuring the absorption coefficient, rather than the percentage transmission, and that even then there will be cases where doubt remains. Some of the puzzles about naturally coloured stones may be resolved by further detailed spectroscopic study, particularly of uniformly green diamonds and those with strong H3 and H4 (503 and 496 nm) bands.

ACKNOWLEDGEMENTS

I am grateful to Mr Basil Anderson and Mr Roy Huddlestone for the loan of coloured diamonds and to Mr Khalid Mohammed for obtaining the data for Figures 8 & 14 and carrying out the calculations for Figure 6. I have had interesting discussions on the topic of coloured diamonds with Mr Kenneth Scarratt and Mr George Bosshart, and I am grateful to them and Mr Anderson for their comments on the first draft of this paper.

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[*Manuscript received 25th June, 1981.*]

GEMMOLOGICAL ABSTRACTS

ANDERSON (B. W.). *The development of synthetic emeralds.* Gem World, **8**, 4, 38-42, 1981.

A review of synthetic emerald is given with notes of some recent productions. (Article first appeared in Retail Jeweller, date not given.) M.O'D.

ANDERSON (C. O.), HUTTON (D. R.), TROUP (G. J.). *Magnetic resonance distinction between synthetic and natural blue sapphire.* Aust. Gemmol., **14**, 5, 87-9, 3 figs, 1981.

An attempt to identify blue sapphire by a complex test. Depends on Cr^{3+} being added in small quantities to synthetic production to aid nucleation of iron and Ti^{4+} impurities which give the colour. This is detectable in magnetic resonance spectra but is fallible if Cr^{3+} is present in the natural stone. 'Forbidden' lines seen when tested parallel to trigonal axis seem to be more conclusive. R.K.M.

BADZIAN (A. R.), KLOKOCKI (A.). *On the catalytic growth of synthetic diamonds.* Journal of Crystal Growth, **52**, 843-7, 2 figs, 1981.

Diamond crystals grown with cobalt and nickel were studied by x-ray diffraction methods. Inclusions of metastable cobalt or nickel carbides were the commonest inclusions. It is thought that the metal atoms are located in the octahedral holes of the structure, which suggests that they play a part in nucleation and crystallization. M.O'D.

BANK (H.). *Erzminerale als Edelsteine.* (Ore minerals as gemstones.) Z.Dt.Gemmol.Ges., **30**, 2, 71-89, 36 colour photographs, extensive bibl., 1981.

Ore minerals are described which have become known as gemstones. Some are important gemstones, such as corundum, quartz, malachite and rhodonite, while others are collectors' items. The article is dedicated to Prof. Dr P. Ramdohr, who is celebrating his 90th birthday and on whose early work Dr Bank has based this work. The minerals are listed according to their chemical formula and include sulphides (sphalerite, marcasite, pyrites, proustite), halogenides (fluorite), oxides (cuprite, zincite, gahnite, magnetite, haematite, corundum, rutile, anatase, quartz), carbonates (siderite, rhodochrosite, smithsonite, witherite, cerussite, azurite, malachite), sulphates (anglesite and barytes), wolframite (scheelite), molybdate (wulfenite) and silicates (rhodonite, pyroxene mangite and willemite). E.S.

BANK (H.). *Gemmologische Untersuchungsmethoden und ihre sinnvolle Verwendung.* (Gemmological investigation methods and their intelligent use.) Z.Dt.Gemmol.Ges., **30**, 2, 90-4, 1 fig., 1981.

The different steps of a gemmological examination, which do not destroy the material to be investigated, are described, using polariscope, refractometer, microscope, spectroscope, UV lamp, colour filter. Most features which can be examined by the use of polariscope and microscope are listed. E.S.

BANK (H.). *Über die Lichtbrechung und Farbe von Topasen, speziell geschliffener Topase vom Schneckenstein, Sachsen.* (On the refractive index and colour of topaz, especially cut topaz from Schneckenstein in Saxony.) Z.Dt.Gemmol.Ges., **30,** 2, 98-100, 2 colour figs, bibl., 1981.

The well-known topazes from Schneckenstein in Saxony in the Democratic Republic (East Germany) are mainly faintly yellow and possess higher refractive indices than generally mentioned for them and lower ones than given for yellow topaz from other localities. Besides colours, refractive indices and birefringence of topaz in general are listed. E.S.

BANK (H.). (a) *Avanturisierender Beryll aus Norwegen.* (Aventurine beryl from Norway.) Z.Dt.Gemmol.Ges., **30,** 2, 107-8, 1981; (b) *Irisierender Aragonit aus Kanada.* (Iridescent aragonite from Canada.) Id., 109-11, 3 figs in colour, 1981; (c) *Zur gemmologischen Diagnostik: Topas für Spinell gehalten.* (Gemmological diagnosis: topaz mistaken for spinel.) Id., 114-15, 1981; (d) *Mit synthetischem Smaragd überzogene Berylle für Dubletten angesehen—eine Nomenklaturfrage.* (Synthetic emerald coated beryl diagnosed as doublet: a question of nomenclature.) Id., 118-19, 1981.

(a) The aventurism in the beryl from Norway is caused by inclusions of haematite. The author also mentions star beryls which owe their asterism to inclusions of needle-like crystals. (b) The iridescent aragonites described are recovered from fossil upper cretaceous ammonites. Some doublets and triplets are made of this material. (c) Reports on a colourless topaz taken to be a colourless natural spinel and explains how dangerous it is to make a diagnosis without instruments and how easy it is to distinguish gemmologically between the two minerals. (d) A case where a coated beryl was diagnosed as a doublet since the synthetic material had been polished off and thus different RIs had been obtained from table and back. It is a question of nomenclature as to whether coated stones should be called doublets or triplets. E.S.

BANK (H.) and (F. H.). *Beim Erhitzen milchig-trüb gewordener Rosaturmalin mit ungewöhnlich niedriger Lichtbrechung.* (Rose-coloured tourmaline became milky-opaque when heat-treated, with unusually low refractive index.) Z.Dt.Gemmol.Ges., **30,** 2, 116-17, 1 fig. in colour, 1981.

Pink tourmalines heated to 900 °C became milky, less intense in colour, and showed RI as low as 1.605 for the extraordinary, 1.620 for the ordinary ray and 1.608 and 1.623 respectively. X-ray analysis proved that they were still tourmalines. E.S.

BANK (H.), BECKER (G.). *Synthetischer rosa-farbener Beryll.* (Synthetic pink beryl.) Z.Dt.Gemmol.Ges., **30,** 2, 112-13, 1 fig. in colour, 1981.

A new synthetic pink beryl is described, probably produced hydrothermally. E.S.

BROWN (G.). *An evaluation of the Snow pocket polariscope.* Aust. Gemmol., **14,** 5, 90-1, 2 figs, 1981.

Describes and assesses a useful folding self-illuminating polariscope. R.K.M.

BROWN (G.). *An evaluation of the Snow dichroscope.* Aust. Gemmol., **14**, 5, 97-9, 3 figs, 1981.

A new type of dichroscope employing polaroid and achieving two images of a single aperture by using a pentagonal prism combined with the cross-orientated polaroids to refract images to the viewing lens. Approved. R.K.M.

BROWN (G.). *Gemmology study club report: examination of a fossil pearl.* Aust. Gemmol., **14**, 6, 131-4, 5 figs,* 1981.

A report on a fossil Pinna from Cretaceous shales in Kansas. The optical nature of the pearl was found to be different from that of a present-day pinctada pearl. [After 150 million years this should not cause surprise.] R.K.M.

BROWN (G.), MAIN (P.), RICHARDS (P.), SNOW (J.), TAYLOR (B.). *An evaluation of the Gemlusta reflectometer. Part 1.* Aust. Gemmol., **14**, 6, 120-6, 7 figs,* 1981.

An evaluation of a rather complex dual-range infrared reflectometer giving an electronic LED numerical read-out. Trouble experienced with switch leading to disparate readings for the one stone. Usefulness of the lower range questioned. The imposition of an arbitrary scale which is the same for both ranges seems very confusing. [Lustre, whether of visible wavelengths or infrared is not usually numerically identified.] R.K.M.

BROWN (G.), SNOW (J.). *Examination of two Iimori imitations.* Aust. Gemmol., **14**, 5, 100-5, 4 figs, 1981.

Victoria-stone, a chatoyant nephrite-like imitation material, and Meta-Hisui, an imitation jade, were examined. Described as attractive partially devitrified glasses. SG 3.00 and 2.80, and RI 1.61 and 1.50 respectively; H 6 for both glasses. R.K.M.

BROWN (G.), SNOW (J.). *Examination of a prehnite cat's-eye.* Aust. Gemmol., **14**, 5, 93-4, 3 figs, 1981.

A 9.68 carat greenish-yellow cabochon of prehnite from Prospect, N.S.W., exhibited chatoyancy. H 6 to 7; SG 3.00; RI 1.62; no fluorescence or usable absorption spectrum. R.K.M.

BROWN (G.), SNOW (J.). *Some observations on goldstone.* Aust. Gemmol., **14**, 6, 139-40, 1 fig, 1981.

Observations, generally what one would expect of a crown glass, conclude that the many millions of copper particles in each specimen are 'prefabricated . . . machined and not crystalline'. [This is nonsense, on the score of cost, if no other.] R.K.M.

BUKIN (G. V.), MATROSOV (V. N.). *Growth of alexandrite crystals and investigation of their properties.* J. Crystal Growth, **52**, 537-41, 5 figs, 1981.

Crystals up to 120 mm long and 20 mm in diameter have been grown by the Czochralski method in an inert gas atmosphere in iridium crucibles. A narrow line at 645.5 nm was observed in both the absorption and excitation spectra. It is attributed

*Fig. 3 in these two papers is transposed.

to Cr^{3+} ions and may be due to the phonon-free electron transition in the U-band. This particular effect has not been previously noted from any other crystals doped with Cr^{3+} ions. M.O'D.

DAHANAYAKE (K.). *Modes of occurrence and provenance of gemstones of Sri Lanka.* Min. Deposita, **15,** 81-6, 2 figs, 1980.

The dominant gemstones mined in Sri Lanka are blue sapphires, ruby, and beryl, associated with eluvial, residual, and alluvial sediments. Source rocks are garnetiferous and cordierite gneisses, marbles, and pegmatites. L.G.L.

DRESCHHOFF (G. A. M.), ZELLER (E. J.). *Identification markings for gemstones.* U.K. Patent Application GB 2047215A, filed 18th April 1979, published 26th November, 1980.

The patent describes a new method for producing permanent identification markings within a gemstone by means of proton bombardment, such markings not being visible to the naked eye. A metal template or stencil mask is placed between the gemstone and the proton source to produce a pattern of radiation in the form of numbers or letters, and the gemstone is cooled to confine the resulting crystal lattice reaction to a closely defined plane and to a depth beneath the stone's surface which is a function of the proton beam energy level. The markings produced in this way are claimed to be stable, permanent and ineradicable. When used to print an identification code beneath the surface of a diamond, the irradiated areas are converted to amorphous carbon by the proton beam. In this application, the energy level of the proton beam is within the range of 0.25 MeV to 4 MeV, and the diamond is cooled to the temperature of liquid nitrogen during irradiation. P.G.R.

GÜBELIN (E.). *Die Eigenschaften der undurchsichtigen Schmucksteine und deren gemmologische Bestimmung.* (The properties of non-transparent gemstones and their gemmological determination.) Z.Dt.Gemmol.Ges., **30,** 1, 3-61, 1981.

The whole issue is devoted to Dr Gübelin's excellent survey of non-transparent gemstones. He first discusses colour, density and hardness, and follows this with detailed tabulated descriptions of streak colours. After mentioning acid spot tests, the author lists the most important absorption lines and goes on to dichroism, double refraction, luminescence and fluorescence (table). Microscopic examination is shortly touched on. Possibly the most helpful table lists the stones, their description, RI, density, hardness, peculiarities, occurrences and remarks, subdivided into white/black, yellow/brown, pink/red, blue/violet, and green groups with special sub-tables dealing with jade minerals, jade-like minerals (mainly green), and serpentine group stones.

Another interesting table lists turquoise and sixteen of its simulants, again with description, composition, RI, density, hardness, spectrum and helpful hints for each item. Finally there is a table ennumerating multi-coloured gemstones with their description and properties. E.S.

LIPINSKY (A.). *Archeogemmologia: proposta di una nuova scienzia sussidaria per l'archeologia e la storia dell'arte della gioielleria.* (Archeogemmology: a proposal for a new science subsidiary to archeology and the history of the jeweller's art.) La Gemmologia, **6**, 1/2, 7-40, 1980.

The argument is put forward that the study of gemstones can be a useful adjunct to the work of the archaeologist and the art historian. Numerous examples are given, with some liguistic notes, of the ways in which such a separate science might operate. M.O'D.

MANUTCHEHR-DANAI (M.). *Faustit in der Türkislagerstätte von Neyschabour (Iran) in Zusammenhang mit der Frage der Türkisbildung.* (Faustite in the turquoise occurrences in Nishapur in Iran in relation to the question of the formation of turquoise.) Z.Dt.Gemmol.Ges., **30**, 2, 95-7, bibl., 1981.

A description of turquoise-faustite isomorphic mixed crystals is presented together with a discussion of their formation as a weathering product (of vulcanic trachyte). X-ray investigation allows distinction from similar material. E.S.

NOTTES (G.). *Eine Reise zu den Smaragd-Gruben Kolumbiens.* (A journey to the Colombian emerald mines.) Aufschluss, **32**, 325-34, 7 figs (3 in colour), 1981.

The present state of emerald mining in Colombia is described with a map of the main working areas. M.O'D.

O'DONOGHUE (M.). *Alcuni sviluppi nella produzione di materiali di interesse gemmologico.* (Further developments in the production of gemmologically interesting materials.) La Gemmologia, **6**, 1/2, 41-4, 1980.

Recent developments in the field of man-made crystals are reviewed with particular reference to those of ornamental interest. (Author's abstract) M.O'D.

O'DONOGHUE (M. J.). *Man-made gems—what next.* Aust. Gemmol., **14**, 5, 106-8, 1981.

Discusses present synthetics and man-made materials and possible further developments in this field, rather optimistically. R.K.M.

O'DONOGHUE (M.). *Man-made crystals and the gemmologist: some recent developments.* British Association for Crystal Growth Newsletter, pp 3-4, April 1981.

Some of the more recent man-made gemstones are reviewed, including coloured varieties of beryl made in Japan, opal and cubic zirconia.

(Author's abstract) M.O'D.

PASTERNAK (L. B.), SEVASTYANOV (B. K.), OREKHOVA (V. P.), REMIGAILO (Yu L.). *Growth and light induced colour centres in crystals of yttrium aluminium garnet doped with Cr^{3+} ions.* J. Crystal Growth, **52**, 546-51, 6 figs, 1981.

The absorption spectrum of growth induced colour centred YAG:Cr shows bands at 285, 310, 335, and 446 nm. Annealing in a hydrogen atmosphere destroys those at 446 and 335 nm. In the absorption spectrum of light-induced colour centred YAG:Cr are bands at 380 and 480 nm. Both these and the bands in the GCC YAG crystals are removed on annealing in an oxidation atmosphere. M.O'D

PERNER (B.), KVAPIL (Ji.), KVAPIL (Jo.), PLESTIL (Z.). *The influence of protective atmosphere on the growth of ruby single crystals by Czochralski method.* J. Crystal Growth, **52,** 552-5, 4 figs, 1981.

The purity of an inert gas used to prevent chemical reactions between crucible and heater when ruby is grown by the Czochralski process must be at least 5N. Optical quality of crystals grown in He is higher than that of crystals grown in Ar.

M.O'D.

READ (P.). *Sri Lanka, island of gems.* Gems, **13,** 4, 22-5, 8 figs (7 in colour), 1981.

The gem mining industry of Sri Lanka is reviewed and the major gem species discussed. The construction of an irrigation reservoir may assist in the discovery of further gem material. M.O'D.

ROBERTSON (A. D.). *Chrysocolla 'a little known gemstone'.* Aust. Gemmol., **14,** 6, 127-9, 1981.

Author confirms known fact that this is a mineral variable in composition, water content, colour and constants. Colours generally due to copper but varied by many impurities. R.K.M.

SAHAMA (T. G.). *Growth structure of Ceylon zircon.* Bulletin de Minéralogie, **104,** 89-94, 7 figs, 1981.

Prismatic zircon crystals 1-2 cm long, from the gem-bearing gravels of the Ratnapura area, SW Sri Lanka, show concentric growth structures. These growth bands do not represent normal chemical zoning but reflect a variation in the degree of radiation damage. Detailed electron probe, optical, and density determinations on a polished {100} face gave an empirical equation: $D = 4.078 + (10.678 \times \text{birefringence})$. There is also a negative correlation between the UO_3 content and the birefringence. In some crystals the density decreases from core to margin, others show the opposite trend. The variation within a single crystal is due apparently to irregularity in the convective flow of the crystallizing medium.

R.A.H.

STEINERT (H.). *Die Einschlüsse der Granate Schwedens.* (Inclusions in garnets found in Sweden.) Z.Dt.Gemmol.Ges., **30,** 2, 101-6, 1981.

The inclusions in garnets from Swedish river sands were investigated for a further development of the sedimentiological methods of heavy mineral analysis. With the investigation of 60 samples from all the larger rivers, a general survey of inclusion types was developed. The wide variety of inclusions, which were found during these preliminary investigations, show also some inclusions new to garnet, such as zoisites, tremolites and tourmalines. Distinct new mineral associations of inclusions were found. Rutile was seen in numerous forms. E.S.

STOTT (C. R.). *How it works—the Stott dichroscope.* Aust. Gemmol., **14,** 5, 85-6, 5 figs, 1981.

Describes an ingenious dichroscope using two pieces of polaroid immediately behind a convex lens with a central section removed. This cut lens gives two images of the single aperture and obviates the need to compare two different parts of the specimen when testing for dichroism. R.K.M.

TAKAGI (K.), OI (T.), FUKAZAWA (T.). *Growth of high purity $ZnWO_4$ single crystals.* J. Crystal Growth, **52,** 580-3, 4 figs, 1981.

Zinc tungstate (the mineral sanmartinite) can be grown as transparent single crystals using the Czochralski technique. Easy cleavage limits a possible ornamental application. M.O'D.

THOMPSON (W. H.). *Determination of the maximum and minimum refractive indices of a gemstone.* Aust. Gemmol., **14,** 6, 142-3, 1981.

Part of a paper which appeared in the May 1980 issue but which was omitted. Appeals for specimens which do not yield their full birefringence when tested by refractometer on a single facet. And a note makes clear the fact that the refractometer tests a stone in a direction parallel to the tested surface and to the optical path of the instrument. R.K.M.

TOWNER (J. M.). *Sapphires and gold.* Lapidary Journal, **35,** 3, 640-4, 13 figs (9 in colour), 1981.

An account of working for sapphire in Montana. M.O'D.

TROUP (G. J.). *Letter to the Editor.* Aust. Gemmol., **14,** 6, 141, 1981.

Dr Troup records that synthetic alexandrite has highly desirable laser properties and predicts that this material will inevitably become more available to the gem market. Its absorption spectrum should give sharp chromium (Cr^{3+}) lines and no Fe^{3+} lines. Material should be very clean and will need microscope and other tests to identify it. [Transparency to UV light?] R.K.M.

ZECCHINI (P.), MÉRIGOUX (H.). *Étude de l'absorption infrarouge des quartz hyalin et colorés, naturels ou de synthèse: application à la gemmologie.* (Study of the infrared absorption of colourless and coloured quartz, natural or synthetic; application to gemmology.) C.R. Acad. Sci., Paris, **290,** ser. D, 291-4, 1980.

One may identify synthetic gem quartz by IR spectroscopy using the following data: synthetic rock crystal: thin band at 3585 cm^{-1}, no absorption at 3480 cm^{-1}. Synthetic amethyst: extra absorption bands in the range 3700-3300 cm^{-1}. Synthetic citrine: total absorption at wave numbers lower than 3600 cm^{-1}. J.C.T.

ZWAAN (P. C.), ARPS (C. E. S.). *Sphene, Sri Lanka's newest gemstone.* Scripta Geol., **58,** 11pp., 5 figs, 1980.

Three cut sphenes, originating from the Tissamaharama area of Sri Lanka, are comparable with gem-quality sphene from Capelinha, Brazil. Electron microprobe analyses are given for two sphenes from Sri Lanka and for three from Brazil. A yellowish green 4.60 ct stone from Sri Lanka gave SiO_2 30.4, TiO_2 38.6, Al_2O_3 1.11, Fe_2O_3 0.60, MnO 0.04, CaO 28.7, = 99.45; SG 3.5276 ± 0.0008, *a* 1.910. Indexed x-ray powder data are tabulated for Sri Lankan and Brazilian specimens, and fluid inclusions in sphenes from both areas are illustrated. The absorption spectra of brownish yellow stones show lines due to rare earths; these lines are less developed in the yellowish green stones. R.A.H.

Stones seen. Aust. Gemmol., **14,** 5, 86, 1981.

Describes a transparent kyanite crystal (with colour-change from sea-green to deep mauve purple) from the Harts Range, Northern Territory. J.R.H.C.

BOOK REVIEWS

BARNES (L. C.), *et al. Some semiprecious and ornamental stones of South Australia.* Geol. Surv. South Australia, 1980. pp.159, 40 figs, 73 pls. $5.00.

This handbook, prepared from a selection of reports, describes the location, geology, and mineralogy of some well-known 'semiprecious' stones in South Australia. 'Semiprecious' stones listed include jade, amazonite, amethyst, agate, chrysoprase, turquoise, scholzite, and chiastolite. W.A.F.

DESAUTELS (P. E.). *The gem collection.* Smithsonian Institution Press, Washington, D.C., 1979. pp.77. Illus. in colour. £4.95.

Although it is not stated to be such, it is clear that this most attractively presented work is intended as a successor to the various guides to the Smithsonian gemstone collections that have appeared in the past. Since the last of those guides was published, considerable additions have been made to the collections, particularly in the field of important jewellery, some of which is illustrated.

The guide does not only discuss the important and spectacular specimens to be seen in this cabinet; it outlines the properties of the major species and gives, with weights and provenance, a list of some of the more outstanding pieces. M.O'D.

GÜNTHER (B.). *Bestimmungstabellen für Edelsteine, synthetische Steine, Imitationen.* (Identification tables for gemstones, synthetic stones and imitations.) Elisabeth Lenzen, Kirschweiler, 1981. pp.168. Price on application.

This work consists entirely of tables in which all the necessary constants for identification are given. Species are listed in the main table in order of refractive index and the commoner ones are given a bolder type-face for greater clarity. Many absorption spectra are included in colour. A preliminary table, also arranged in order of refractive index, points to particular places in the main table once a starting position is arrived at.

As far as the tables go they seem perfectly workmanlike, though somewhat overloaded by species of little gem application, such as durangite, chondrodite and mimetite. There is a short bibliography, an index, and pages for supplementary material to be added by the reader. Presentation is attractive and clear; the book opens easily and lies flat—even today few working manuals are as well made as this.

M.O'D.

HIGGINS (R.). *Greek and Roman jewellery,* 2nd edn. Methuen, London, 1981. pp.xliii, 243. Illus. in black-and-white. £18.00.

The first edition of this standard work was published in 1961. Since then many new discoveries have been made, and this edition takes them into account both in the main text and in the first-class bibliography. 64 pages of plates are provided.

M.O'D.

HOFMANN (F.). *Schöne und seltene Mineralien.* (Beautiful and rare minerals.) Herder, Freiburg, 1981. pp.224. Illus. in black-and-white and in colour. Price on application.

This is another of the large format general descriptive mineral books consisting largely of good quality colour plates with the minimum of text. Many of the minerals depicted are not, in fact, rare but the quality of the photographic work is in general good. One good example is the colour plate of legrandite (the specimen itself is quite large). Scales are given with the illustrations; there is an index and a bibliography. Each mineral has a reasonable amount of descriptive text with it.

M.O'D.

LIDDICOAT (R. T.). *Handbook of gem identification,* 11th edn. G.I.A., Santa Monica, U.S.A., 1981. pp.xv, 450. $2.50.

Though this familiar classic still gives good value for a competitively low price, it now shows signs of hastiness and a need for a thorough revision. As expected, details of reflectivity meters, diamond pens and probes are given; new synthetics—Kashan ruby (recently restored to the market), Regency emerald, CZ (but not the coloured varieties)—are mentioned and the tables expanded to take them into account. There is a new section dealing with the alteration of stones. For the rest the book gives brief details of the major gem materials (though quite a lot of species could have been included, such as sogdianite) and of man-made products. Here there is no mention of the opal imitation made from monodisperse latex nor of the cat's-eye imitation manufactured by Cathay Corporation. The index with unaccustomed misprints and some bad errors (chrysoberyl is referred to the wrong pages) could do with expert revision; the lack of any useful bibliography is a detraction from the overall merits of the book.

Much of the material is given as before under the colours of the stones. These sections become harder to read the more they are expanded and consideration should now be given to opening them out, improving the style and omitting the considerable repetition. All classics need the occasional daylight. M.O'D.

READ (P. G.). *Gems, Questions and Answers.* Newnes Technical Books, London, 1981. pp.107. £1.95.

One of the *Questions and Answers* series, this book contains many of the problems likely to face the gemmology student. The treatment is basic and some degree of knowledge is expected of the reader, since terms are not explained; rather, the sections are intended to lead the reader on from stage to stage without the need for explanatory halts. Simple tables are given. This is a handy-sized book and should be useful for such onerous tasks as examination revision. M.O'D.

RÖSLER (H. J.). *Lehrbuch der Mineralogie.* (Text-book of mineralogy.) 2nd edn. VEB Deutscher Verlag für Grundstoffindustrie, Leipzig, E.Germany, 1981. pp.833. Illus. in black-and-white. 60M.

This is a large standard mineralogical text, well produced on good quality paper. With some resemblances to Klockmann's book of the same title, it is a useful addition to the ranks of German mineralogy texts. This edition includes minerals quite recently described such as liddicoatite, and the main part of the text is devoted to mineral descriptions; less space is given to techniques of mineral testing, though what there is is up-to-date. There is an excellent bibliography and an index. M.O'D.

SCHUBNEL (H.-J.). *Larousse des mineraux.* (The minerals' Larousse). Librairie Larousse, Paris, 1981. pp.363. Illus. in colour. Price on application.

After a brief skirmish with mineral chemistry, crystallography and an account of major mineral collections, this attractively produced book battles with the whole kingdom of minerals so far identified. These are arranged in alphabetical order and the more important ones have details of hardness, specific gravity, optical properties, as well as chemical composition and mode of occurrence, which are the only features given for the less significant species. There are a short glossary and a list of synonyms and recent discoveries.

Although well written, it is difficult to see clearly the potential readership for this book. It will not be possible for the beginner or even the adept to find more than brief accounts of species, and such descriptions are quite easily found elsewhere by those who would otherwise find the book useful. The pictures are very good and few have been published before; most, but not all, have the size given. There is neither index nor bibliography, two serious omissions. A useful addition to the sparse literature on mineralogy in French. M.O'D.

VOLLSTADT (H.), BAUMGARTEL (R.). *Edelsteine.* (Precious stones.) VEB Verlag für Grundstoffindustrie, Leipzig, E.Germany, 1979. pp.218. Illus. in black-and-white and in colour. 28M.

This is a book well produced from the scientific standpoint and is clearly aimed at student level. Especially interesting, on account of their rarity, are the illustrations of gemstones from German localities, such as topaz from Saxony. The rest of the book follows a pattern similar to that of other recently published gemmological books. There is a short bibliography and an index, with identification tables. M.O'D.

An exhibition of fine jade. Spink & Son Ltd, London, 1981. pp.28. Illus. in black-and-white and in colour. £5.

This is an exhibition catalogue in which each piece is illustrated. Measurements are given, and the pieces are dated. The whole is well produced and informative.

M.O'D.

ASSOCIATION NOTICES

GIFTS TO THE ASSOCIATION

The Council is indebted to the following for their gifts:

Mr Christopher Cavey, F.G.A., Greenford, Middlesex, for one particoloured (blue/white) euclase crystal group from Miami district, Zimbabwe.

Mr George K. L. Chan, F.G.A., Coober Pedy, Australia, for an opalized fossil shell from Coober Pedy opal field.

The Gemmological Association of Hong Kong for an ivory fan and a carved rosewood stand. The fan is the emblem of the Hong Kong Association.

Mr A. B. Jayasundera, F.G.A., Ratnapura, Sri Lanka, for a copy of the Ceylon National Museum's publication 'Some extinct elephants, their relatives and the two living species' by P. E. P. Deraniyagala, 1955.

The Norwegian Gemmological Association (Norges Gemmologiske Selskap) for a quartz crystal together with anatase from Hardangervidda, Norway.

Dr Marcio D. de Mendonca Porto, Minas Gerais, Brazil, for a collection of cut and polished topaz specimens, gold and yellow, golden brown, pink and blue, together with some topaz crystals.

Mr C. R. Smith, F.G.A., Kannesaw, Georgia, U.S.A., for a slice of lazulite containing kyanite, pyrite and quartzite.

Mrs Joyce Ward, F.G.A.A., West Perth, W. Australia, for a rare cut transparent petalite of 4.43 carats.

NEWS OF FELLOWS

On 16th August, 1981, Mr Russell K. Bennett, F.G.A., gave the last in a series of five fortnightly talks on gemstones on Radio Severn Sound.

On 30th August, 1981, Mr Michael O'Donoghue, M.A., F.G.S., F.G.A., gave a talk entitled 'Some unusual gemstones' at a show held at Harrogate by the British Lapidary and Mineral Dealers Association, and on the 13th November, 1981, he addressed the Gemmological Association of Hong Kong on 'Some man-made materials with possible gem application'.

On 26th September, 1981, Mr Peter G. Read, C.Eng., F.G.A., demonstrated an expanded 'professional' version of his Gem-data computer program to members of the German Gemmological Association during their autumn Technical Weekend at Idar-Oberstein.

MEMBERS' MEETINGS

Midlands Branch

On 25th September, 1981, at the Society of Friends, Dr Johnson's House, Colmore Circus, Birmingham, the film 'A very special stone' was shown. Also Messrs D. E. Price and D. Morgan, FF.G.A., addressed the meeting on stone cutting, and brought some new and interesting specimens for examination.

On 29th October, 1981, at the Society of Friends, Mr David J. Callaghan, F.G.A., gave a talk entitled 'Antique gems and jewellery'.

On 27th November, 1981, at the Society of Friends, a 'Swap, chat and news' evening was held, when members had an opportunity to exchange specimens and notes on all aspects of gemmology.

North-West Branch

On 24th September, 1981, at Church House, Hanover Street, Liverpool, Mr Alan Hodgkinson, F.G.A., gave an illustrated talk entitled 'Journey into gemmological space'. The lecture covered rubies, emeralds, sapphires, opals and amber.

On 22nd October, 1981, at Church House, the Annual General Meeting of the Branch was held, when Mrs Irene Knight, F.G.A., was elected Chairman, and Mrs E. Cartmel re-elected Secretary.

On 19th November, 1981, at Church House, Messrs D. Alderson and W. Hartshorne from Isis Minerals visited the Branch, and members had the opportunity to view crystals and pottery.

South Yorkshire and District Branch

On 6th September, 1981, a trip was arranged to London, visiting the International Watch, Jewellery and Silver Trades Fair at Earls Court, and the Institute of Geological Sciences and Natural History Museum, South Kensington.

On 19th November, 1981, members visited the City Museum, Sheffield. The Keeper of Natural Sciences, Mr Tim Riley, gave a conducted tour of the geological gallery.

GEM DIAMOND EXAMINATION 1981

In the Post-Diploma Gem Diamond Examination, fifty-one candidates sat and forty-nine passed, three with Distinction. The following is a list of their names arranged alphabetically.

QUALIFIED WITH DISTINCTION

Guinot Sierra, Agustin Ignacio, Castellon de la Plana, Spain.
Ross, Rosemary Daphne, London.
West, Clive Graham, London.

QUALIFIED

Ali, Syed Jafer, London.
Anderson, Maximillian Joseph, Harrow.
Bennett, Elaine, Hazel Grove.
Bentley, Carolyn Isabel, Liverpool.
Bill, David Nigel, Hednesford.
Blake, Jeannette Alexandra, London.
Castellote Mas, Guillermo Fernando, Xativa, Spain.
Coelho, Susan Osborn, Richmond.

Coombes, Martin Lewis, Crewe.
Cottrill, Susan D., Cheadle Hulme.
Dickson, Amanda Jane, London.
Emms, Eric Charles, Brentwood.
Falkus, Geoffrey Charles, Hainault.
Faux, Teresa Mary, Winslow.
Fung, Tsee Hung, London.
Gallardo Bravo, Matilde, Valencia, Spain.
Glen, Jill, London.
Goatly, Andrew Martin, Surbiton.
Green, Richard Douglas, Wolverhampton.
Guinot Sierra, Carlos Ma, Castellon de la Plana, Spain.
Günther, Birgit, Idar-Oberstein, W. Germany.
Hall, Michael Geoffrey, Builth Wells.
Harrison, Kathryn, Scawsby.
Hurst, Adam Keith, Lapworth.
Johnson, Colin Michael, Bournville.
Jones, Gwilym Morus, Abergavenny.
Kemp, Roy E. H., London.
Knight, Irene, Liverpool.
Leria, Bernaus, Magdalena, Barcelona, Spain.
Machlup, Peter Mark, London.
Owen, Neil T., Romford.
Perkins, Joanna Cathryn, London.
Perrella Estelles, Loto, Montgat, Spain.
Pietruska, Julia E. J., London.
Reynolds, James Ian, Stannington.
Riedl, Inge, Barcelona, Spain.
Robbins, Susan Carol, London.
Salvat Alegre, José, Barcelona, Spain.
Sayer, D. J., Weston-super-Mare.
Sever, Katherine Mary, Altrincham.
Shaw, Raymond Noah, Prestwich.
Sweeney, Patrick J., London.
Underwood, Barbara C., Manchester.
Williams, Geoffrey Francis, Cobham.
Wilson, Geoffrey Alexander, Prestwich.
Wright, Michael William, Redhill.

EXAMINATIONS IN GEMMOLOGY, 1981

In the 1981 Examinations in Gemmology, 484 candidates completed the Diploma Examination and of these 190 succeeded in passing, twenty of them with Distinction. In the Preliminary Examination 922 candidates sat and 542 passed.

In the opinion of the Examiners, no candidate achieved the high standard needed to warrant the award of the Tully Medal.

The Anderson/Bank Prize for the best non-trade candidate of the year in the Diploma Examination was awarded to Mrs K. E. Sneddon, of Hong Kong.

The Rayner Diploma Prize for the best candidate for the year who derives his main income from activities essentially connected with the jewellery trade was awarded to Mr E. B. Taylor, of Middlewich.

The Anderson Medal for the best candidate of the year in the Preliminary Examination was awarded to Miss A. F. Voll, of Kowloon, Hong Kong.

The Rayner Preliminary Prize for the best candidate of the year under 21 years of age who derives her main income from activities essentially connected with the jewellery trade was awarded to Miss I. M. Nash, of Watford.

The following are lists of the successful candidates arranged alphabetically.

DIPLOMA EXAMINATION

Anderson/Bank Prize

Sneddon, Katherine E., Hong Kong.

Rayner Diploma Prize

Taylor, Ernest B., Middlewich.

QUALIFIED WITH DISTINCTION

Ashworth, Marie C., Toronto, Canada.
Batycki, Charlene G., Toronto, Canada.
Ebata, Taiichiro, Toyama, Japan.
Grimston, Lady Iona C., London.
Hawker, Robin W. A., Hobart, Australia.
Jones, Jeffrey M., London.
Kano, Shinzo, Toyonaka, Japan.
King, Antoinette E., Rye.
Laurie, Amanda, Bicester.
Little, Derek, Dundee.
McKellar, John R., Presteigne.
Meckoni, Prafulla H., Bombay, India.
Otsuka, Nobuko, Tokyo, Japan.
Peebles, Kathleen W., Johannesburg, S. Africa.
Rademaker, Jaap, Baarn, Netherlands.
Sastrowidjojo, Hendro, Surabaya, Indonesia.
Venning, Ronald O., Toronto, Canada.
Walton, Betty M., Toronto, Canada.

QUALIFIED

Absalom, Christine S., Effingham.
Acheson, Michael A., Geneva, Switzerland.
Adlestone, Mark I., St Annes-on-Sea.
Advani, Vinod, Bombay, India.
Ahmad, Zaheer, London.
Akizuki, Haruo, Ichikawa, Japan.
Ali Mohamed, Shabia K., Santa Ana, U.S.A.
Aliprandi, Riccardo G., Rome, Italy.
Allyn, Dale F., Eugene, U.S.A.
Alvis, Alayne G. D., Colombo, Sri Lanka.
Anfield, Jennifer J., Birmingham.
Ashra, Shirish, London.
Babber, Harish R., Southall.
Bana, Habibullah, San Clemente, U.S.A.
Barber, Anjali, Nairobi, Kenya.
Bardsley, John N., London.
Beevers, Jacintha M., Hong Kong.
Begeer, Dolfje M., Voorschoten, Netherlands.
Bekesch, Nicholas, Oshawa, Canada.
Bell, Keith, Ottawa, Canada.
Bennett, Sharon L., Little Marlow.
Boorman, Robert F., Bisley.
Boyd, Robert T., Toronto, Canada.
Boyes, Richard W., Garston.
Breau, Karen L. Johnson, Toronto, Canada.
Caffoor, Ali A. A., Banjul, Gambia.
Chavan, Umesh, Bombay, India.
Chawla, Gulzari, Downsview, Canada.
Chouiki-Doorn, Jacqueline, Spykenisse, Netherlands.
Clarke, Francis B., Upminster.
Cowing, Michael D., Glen Burnie, U.S.A.
Currie, Lynnette J., Manurewa, N.Z.
Darracott, Britt-Marie, London.
Davis, Robert J., Margate, Australia.
Dayasagara, Kalupahana L. D., Colombo, Sri Lanka.
Dewar, Penelope S., Stockport.
Dolleslager, James T., Houston, U.S.A.
Endean, Christine H., Hong Kong.
Fell-Smith, Simon A., Paddington, Australia.
Francey, Donald T., Christchurch, N.Z.
Freeman, Darlene M., Belmont, U.S.A.
Furse, Anna A., London.
Gasco Galindo, Ignacio, Barcelona, Spain.
Gea Lopez, Francisco J., Barcelona, Spain.
Gettings, Barbara A., London.
Girling, Matthew D., London.

Graham, Peter D., Liverpool.
Grant, Judith M., Carmel, U.S.A.
Haghani, Victor J., London.
Hamada, Shiko, Suita, Japan.
Haniffa, Ahamed I., Colombo, Sri Lanka.
Heiskanen, Anu P. K., Helsinki, Finland.
Henderson, Shirley W. A., Bothwell.
Hermans, Johannes S., Delft, Netherlands.
Hettena, Andre, London.
Hettiaratchi, Theja C., Berlin, W. Germany.
Hinde, Rosemary J., Hong Kong.
Hogarth, Graeme R., Kendal.
Honse, Dennis R., Portland, U.S.A.
Horton, David R., London.
Houseago, James A., Lowestoft.
Hutchinson, Marjorie E., London.
Iwata, Kazuyoshi, Gifu, Japan.
Jensen, Edna, Huddinge, Sweden.
Jones, Maureen D., Wellington, N.Z.
Kageyama, Chiyomi, Kobe, Japan.
Kelly, John S., Cardiff.
Kelly, Susan M. B., Algester, Australia.
Kennedy, Karen K., Toronto, Canada.
Kettley, Helen M., London.
Keuskamp, Diederik, Streefkerk, Netherlands.
Khancharoensuk, Somsri, Los Angeles, U.S.A.
Kinoshita, Kazuko, Ashiya, Japan.
Kita, Masako, Fukuoka, Japan.
Kitamura, Seiki, Tokushima, Japan.
Kobayashi, Yuko, Tokyo, Japan.
Kosik, Thomas A., Arlington, U.S.A.
Kothari, Rajan S., Bombay, India.
Kröger, Carol M., Rio de Janeiro, Brazil.
Krstic, Jovanka, Beograd, Yugoslavia.
Lacambra Pifarre, Carmen, Barcelona, Spain.
Lal, Daulet R. B., Bombay, India.
Lambley, Jenifer G., Hong Kong.
Law, Sheila, London.
Lindlau, Gisela, Aichwald, W. Germany.
Litchfield, Anne-Marie, Northampton.
Littlejohn, Gordon H., Tunbridge Wells.
Livstrand, Ulf R., Saltsjöbaden, Sweden.
Louw, Everhardus J., Cape Town, S. Africa.
McAteer, Alice M., London.
McEwan, Robert S., Perth.
McGeorge, Robyn, L., Beecroft, Australia.
McPherson, Heather, Coalville.
Maeda, Katsutoshi, Fukuoka, Japan.
Malkani, Sunil C., Bombay, India.
Mansfield, Stephen McL., Burton.
Mariathasan, Loganayagi, Colombo, Sri Lanka.
Marikar Bawa, Mohamed S. N., Idar-Oberstein, W. Germany.
Martin, Paul, Nuneaton.
Martuccio, Celeste, Leamington Spa.
Masuda, Masami, Shizuoka, Japan.
Masurel, Helga, Leiden, Netherlands.
Mater, Louise H., Laren, Netherlands.
Mizushima, Nobuhiro, Osaka, Japan.
Molagoda, Tikiri B. P., Talatuoya, Sri Lanka.
Mourad, Huguette, Beirut, Lebanon.
Nakamura, Masanori, Osaka, Japan.
Nakamura, Takeshi, Kanazawa, Japan.
Nakao, Kuzuya, Wakayama, Japan.
Nakayama, Keichi, Komatsushima, Japan.
Nelischer-Millar, Anita I. A., Toronto, Canada.
Nojiri, Masatomi, Fukuoka, Japan.
O'Hare, Jane, Corwen.
Ohno, Hiroko, Tokyo, Japan.
Okuda, Makoto, Osaka, Japan.
Ottaway, Terri L., Toronto, Canada.

Paramalingam, Jayanthi, Mt Lavinia, Sri Lanka.
Parcel, Rodney F., Jr, Perris, U.S.A.
Parry, Sarah, Wadhurst.
Pattni, Pravin A., London.
Pietroboni, Carlo, Forch, Switzerland.
Podsiadly, Maria T., Birmingham.
Postma, Renate E., Breda, Netherlands.
Potter, Brian S., London.
Preston, Stephen P., Birmingham.
Prince, Ann-Elise, London.
Protopopoff, Monica, Beecroft, Australia.
Puig-Doria Pala, José Ma, Barcelona, Spain.
Quincey, Mary E., Rugby.
Raymond, Robert S., Brentwood.
Rigby, Ian W., Wolverhampton.
Ro, Yosetsu, Tokyo, Japan.
Rome, Martin L., London.
Ruplinger, Peter K., Sandy, U.S.A.
Ryan, Margaret E., Hong Kong.
Sadler, Philip A., London.
Saez Balsalobre, Lidia, Barcelona, Spain.
Shimada, Nobuo, Kashiwa, Japan.
Shimomura, Seisaku, Tokyo, Japan.
Singleton, Graham S., Sudbury.
Smith, Catharine, Lutterworth.
Spooner, Carole A., Wokingham.
Steward, Annelies, Calgary, Canada.
Suguro, Norio, Tokyo, Japan.
Swain, Anthony P., Deganwy.
Swersky, Ann H., Ramat Hasharon, Israel.
Thorne, Deirdre, Salisbury, Zimbabwe.
Trinkl, André A., Johannesburg, S. Africa.
Troth, Peter D., St Ouen, Jersey.
Trueman, Laraine M., Stafford.
van den Berge, Tania A. P., St Amandsberg, Belgium.
van der Zwaag, Hemko, Zeist, Netherlands.
Vermaas, Franciska J. M., Rotterdam, Netherlands.
Versendaal-Ovink, Beatrix E. W., Hendrik Ido Ambacht, Netherlands.
Vietti, Stuart, Penrith.
Vigo Ripoll, Leticia, Barcelona, Spain.
Vikamsey, Indira J., Bombay, India.
Warrenberg, Jonathan M., Ilkley.
Wescott, H. Marjatta, Tokyo, Japan.
Wijeratne, Chakkrawarthige H. R., Colombo, Sri Lanka.
Wilkie, William, Helensburgh.
Williams, Bruce M., Walla Walla, U.S.A.
Wong, Kitty, Kowloon, Hong Kong.
Yamamoto, Kazui, Fukuoka, Japan.
Yenson Chu, Mabel, Kowloon, Hong Kong.
Yoshino, Mariko, Tokyo, Japan.
Zanoon, Norfel W., Colombo, Sri Lanka.
Zebrak, Tracy J., Hove.
Zipf, William T., Bethel Park, U.S.A.
Zwikker, Marijke, Nijmegen, Netherlands.

PRELIMINARY EXAMINATION

Anderson Medal
Voll, Aloha F., Kowloon, Hong Kong.

Rayner Prize
Nash, Isobel M., Watford.

QUALIFIED

Aalto, Veikko O., Hämeenlinna, Finland.
Abi-Habib, Cynthia S., Riyadh, Saudi Arabia.
Aburrow, Michael B., Wimborne.
Adams, Myra, Huddersfield.
Advani, Vinod, Bombay, India.
Aguilar Agraz, Amparo, Barcelona, Spain.
Ainsworth, Nicola L. A., London.
Alabaster, David R., Stratford-upon-Avon.
Alfsen, Edgar J., São Paulo, Brazil.
Ali Mohamed, Shabia K., Santa Ana, U.S.A.
Allyn, Dale F., Eugene, U.S.A.
Amos, Gillian L., Pontypridd.
Anand, Sumedha, Bombay, India.
Andrews, Clive G., Selsdon.
Anwar, Abdul A. M., Beruwala, Sri Lanka.
Arbestain Ribas, Inmaculada, Barcelona, Spain.
Arendtsz, Natalie A., Negombo, Sri Lanka.
Ärfström, Berndt G., Märsta, Sweden.
Arjalaguer Vilardell, Daniel, Barcelona, Spain.
Armstrong, Gillian, Preston.
Arora, Ravindera, Hounslow.
Ash, Malcolm J., Bradford.
Baixauli Sanjuan, José F., Barcelona, Spain.
Baker, Judith, Ottawa, Canada.
Bala's, Aranka, Colombo, Sri Lanka.
Balius Matas, Pilar, Barcelona, Spain.
Bana, Habibullah, San Clemente, U.S.A.
Bandarage, Samangi, Colombo, Sri Lanka.
Bank, Monika I., Idar-Oberstein, W.Germany.
Barre Martin, Anne M., Barcelona, Spain.
Basnayake, Senarath B., Katugastota, Sri Lanka.
Beckley, Robert A., Carshalton.
Beech, Georgina, Eccles.
Beesley, Janet S., Skipton.
Begeer, Dolfje M., Voorschoten, Netherlands.
Bekesch, Nicholas, Oshawa, Canada.
Bell, John A., Sevenoaks.
Bell, Keith, Ottawa, Canada.
Bennett, Andrahennadige S., Tangalle, Sri Lanka.
Bennett, Edward O., Nugegoda, Sri Lanka.
Bennett, Norman P. J., Plymouth.
Bercott, David S., Glasgow.
Bird, Nigel G. D., Epsom.
Bishop, Ian C., Gillingham.
Blackburn, Mary-Rose, Roodeport, S.Africa.
Block, Rachel J. K., London.
Bolton, Robert G., Guiseley.
Bon, Maria H., Schoonhoven, Netherlands.
Borofsky, Norman, Toronto, Canada.
Boutureira Rilo, Juan L., Barcelona, Spain.
Bowman, Josephine T., London.
Bradley, Alison A., Didcot.
Bratz, Kristin M., Oslo, Norway.
Brookes, Hilary A., Birmingham.
Brown, Sheila, London.
Buckingham, Nola E., Brisbane, Australia.
Bull, Christopher J., Pulborough.
Cabanas Casas, Terencia, Barcelona, Spain.
Capella Tomas, Ma Josefa, Barcelona, Spain.
Cardew, Charles J. S., Thornton Heath.
Carlin, John, Brighouse.
Carvey, Robyn, Hong Kong.
Castro Masaveu, Alicia, Barcelona, Spain.

Cattermole, Mavis E., Nairobi, Kenya.
Caycedo, Miguel J., Ilford.
Cervera Perez, Rafael, Barcelona, Spain.
Cestaro, Thomas L., Cheshire, U.S.A.
Chao, George Y., Ottawa, Canada.
Cheung, Cliff P. L., Toronto, Canada.
Choi, Tony Y. M., Happy Valley, Hong Kong.
Chow, Yin L., Hong Kong.
Christou, Chris, London.
Chung, Penelopie O. L., Kowloon, Hong Kong.
Clarke, Norman V., Blandford Forum.
Clipston, Neville W., Durban, South Africa.
Clowes, Paul R., Solihull.
Collins, Glen M., Glasgow.
Collins, Susan M., Liverpool.
Collyer, Christine A., Birmingham.
Cornioley, Jean-René, Fribourg, Switzerland.
Cottafavi, Aliette, Geneva, Switzerland.
Cousins, Nigel T., Deal.
Couston, John F., Kerala, India.
Cowie, Gillian A., Liverpool.
Cowing, Michael D., Glen Burnie, U.S.A.
Cox, Amanda R., London.
Cruickshank, Mary, Nairobi, Kenya.
Cvetkovic, Borjanka, Raipur, India.
D'Adamo, Marina, Milan, Italy.
Dalmau, Rubert, Ma Magdalena, Barcelona, Spain.
Dam, Hegwig M., Warnsveld, Netherlands.
Danielsen, Alf P. T., Oslo, Norway.
Dayrit, Michelle S., Makati, Philippines.
Dean, Rebecca A., Poynton.
de Beer, Christiaan T. J., Durban, S.Africa.
Deeley, Peter J., Birmingham.
Del Rey, Mario, São Caetano Do Sul, Brazil.
Denyer, Philip, Rickmansworth.
de Silva, Antoinette T. J., Colombo, Sri Lanka.
Dias Abeyegunawardene, Christina S., Colombo, Sri Lanka.
Dijkman, Christine S., Taitam, Hong Kong.
Dillon, Stephanie, Los Angeles, U.S.A.
Dirlam, Dona M., Santa Monica, U.S.A.
Dixon, Zoë H., St Albans.
Dodding, Susan D., Great Harwood.
Dotterer, Ford K., Hong Kong.
Dougherty, William C., Alexandria, U.S.A.
Dowie, Anthony R., Christchurch, N.Z.
Dowie, Nigel J., Christchurch, N.Z.
Doyle, Martin, Hull.
Dūblin, Theo, Arlesheim, Switzerland.
Duerden, David A., London.
Duke, Ray, Southend-on-Sea.
Duque Oliart, Francisco, Barcelona, Spain.
Eadie, John, Glasgow.
Ebers, Carl N., Frinton-on-Sea.
Edmondes, Eleanor J. C., Birmingham.
Ehrenborg, Charlotte, Gex, France.
Elapata, Sam A. I. G., Colombo, Sri Lanka.
Elias, Abdul H., Mombasa, Kenya.
Elias, Farook A., Mombasa, Kenya.
Elias Sospedra, Gemma, Barcelona, Spain.
Ellerton, Anne L., Toronto, Canada.
Elvidge, Caroline A., London.
Emerick, Heather, London.
Esterhuizen, Karel F., Durban, S.Africa.
Esufally, Mohamed M. H., Colombo, Sri Lanka.
Faiers, Caroline, Aldham.
Faller, Noel P., Londonderry, N.Ireland.

Fanning, Jill, Birmingham.
Fernandez Nunez, Carlos L., Barcelona, Spain.
Fernando, Dudley L., Colombo, Sri Lanka.
Fernando, Phedias C. B., Moratuwa, Sri Lanka.
Ferreira, Anslem C., Colombo, Sri Lanka.
Finell, Mona, Helsinki, Finland.
Firth, Barbara, London.
Franks, Patrick M., Altrincham.
Fritzen, Tove, Bekkestua, Norway.
Fuller, Maris E., Kowloon, Hong Kong.
Furnival, Michele E., Toronto, Canada.
Furr, Gregory E., Wokingham.
Galloway, Jane E., Toronto, Canada.
Galsterer, Maureen G., Saginaw, U.S.A.
Garton, Anthony M., Bournemouth.
Gaw, Rossana W., Hong Kong.
Gemayel, Farid, Antelias, Lebanon.
Geurts, Godefridus R. J. M., Heerlen, Netherlands.
Gibbon, Michael T., Luton.
Gilbert, Charles F., New York, U.S.A.
Gilbert, Clive L., London.
Gill, Jogindar S., Kuala Lumpur, Malaysia.
Gill, Rani, Edgware.
Gilmour, Kevin D., Sheffield.
Gimpel, Beatrice, London.
Gimpel, Remy F., London.
Glover, Brian M. G., Wallasey.
Gobla, Michael J., Westminster, U.S.A.
Goeritz, Louise, London.
Gonsalves, Bonita S., Colombo, Sri Lanka.
Goss, Alan C., Welwyn Garden City.
Grabau, Antonella, Geneva, Switzerland.
Gracia Armendariz, Luis, Barcelona, Spain.
Gracia Mañez, Marina, Barcelona, Spain.
Greatwood, Sheila O., Mitcham.
Greene, Michael A. F., London.
Griffiths, Paul A., Sutton Coldfield.
Grimal Moreno, Sara, Barcelona, Spain.
Grinyer, Raymond F., Newcastle, S.Africa.
Grishko, Alexander, Agincourt, Canada.
Grootswagers, Johannes P. J., Breda, Netherlands.
Gunaratne, Renuka J., Moratuwa, Sri Lanka.
Guneratna, Witanage D., Panadura, Sri Lanka.
Ha, Shek T., Kowloon, Hong Kong.
Hadfield, Margit E., Canterbury.
Haghani, Victor J., London.
Hakoune, Jacques, Antwerp, Belgium.
Hall, Cheryl D., Toronto, Canada.
Hamer, Saskia M., The Hague, Netherlands.
Hamilton, Ann, Bridge of Weir.
Hammam, Nada, Riyadh, Saudi Arabia.
Harding, Richard W., Solihull.
Hardman, Elaine S., Stanley, Hong Kong.
Hardy, Joanna, London.
Harmer, Inge, Brisbane, Australia.
Harmer, John B., Brisbane, Australia.
Hartley, Alison K., Westhoughton.
Hawkins, Sandra C., Toronto, Canada.
Hay, Elizabeth R., Rondebosch, S.Africa.
Healey, John M., Windsor.
Hebden, Leonora A., London.
Heikkilä-Tiainen, Merja M., Hämeenlinna, Finland.
Heino, Tauno T. T., Eura, Finland.
Heinonen, Elina K. J., Loimaa, Finland.
Hendrick, D. M. Sriya, Kandy, Sri Lanka.

Henwood, Amelia R., Basingstoke.
Henwood, Glyn A., Basingstoke.
Hettiaratchi, Theja C., Berlin, West Germany.
Hodgson, Joanna K., Glossop.
Hofer, Stephen C., Santa Monica, U.S.A.
Hong, Kuong S., Causeway Bay, Hong Kong.
Honse, Dennis R., Portland, U.S.A.
Hoogewerff, Regitse C., Diepenveen, Netherlands.
Hook, Allen J., Brighton.
Horn, Graeme F., Glasgow.
Horsey, Anita C., Washington, D.C., U.S.A.
Housley, John G., Sheffield.
Hung, Chi-chuan, Manila, Philippines.
Hurlbert, Kim E., Cayucos, U.S.A.
Hutchinson, Leslie B., London.
Hutton, Andrew J., South Croydon.

Imai, Seiichi, Fukuoka, Japan.
Inamochi, Sachiko, Niigata, Japan.
Inoue, Kazuo, Tokyo, Japan.
Irani, Khodadad B., Bombay, India.
Iriarte Villar, Alberto, Barcelona, Spain.
Ishii, Koji, Funabashi, Japan.
Ishiwatari, Tamotsu, Tokorozawa, Japan.
Isohaaro, Hannu Y. T., Hämeenlinna, Finland.
I. te Brinke, Wilhelmina C., Winterswijk, Netherlands.

Jarché, Lynne R., London.
Jayawardene, Padma, Kew.
Jayaweera, Susil, Peradeniya, Sri Lanka.
Jhaveri, Kalpana R., Bombay, India.
Jokela, Leena A., Helsinki, Finland.
Jolliff, James V., Edgewater, U.S.A.
Jonas, Zeev, Jerusalem, Israel.
Jones, Mark S., London.

Kadota, Hiroka, London.
Kageyama, Chiyomi, Kobe, Japan.
Kallio, Marja-Leena, Lohja, Finland.
Kanagasababapathy, Gowry, Colombo, Sri Lanka.
Kano, Shinzo, Toyonaka, Japan.
Karpelowsky, Raymond, London.
Kasagi, Nobuko, Nishinomiya, Japan.
Kauhanen, Pentti R., Helsinki, Finland.
Kavanagh, James P. X., Dublin, Ireland.
Kawai, Junko, Osaka, Japan.
Kawai, Yoshito, Utsunomiya, Japan.
Kawasaki, Teruko, Tokyo, Japan.
Kearny-Kibble, Mathilde F., Repulse Bay, Hong Kong.
Kelderman, Klass P., Alphen a/d Rijn, Netherlands.
Kellner, Louis, Hove.
Kennedy, Stephen J., London.
Kesola, Kalervo J., Valkeakoski, Finland.
Ketelaar, Arend C. R., Leidsendam, Netherlands.
Key, Roger, Nairobi, Kenya.
Khan, Deborah R., Bromley.
Kierkels, Johannes J. P. E., Belfeld, Netherlands.
Kikelo, Peter Muindi, Nairobi, Kenya.
Kishida, Seiko, Birmingham.
Kjellen, Ewa B., San Clemente, U.S.A.
Knights, Bridget C., Shrewsbury.
Kobayashi, Yuko, Tokyo, Japan.
Kohmura, Kyoko, Kyoto, Japan.
Kok-Visser, Astrid S., Nairobi, Kenya.
Kolamunne, Ahangamgoda A. S., Sri Lanka.
Korhonen, Pentti K., Hämeenlinna, Finland.
Kothari, Harsukh N., Bombay, India.
Kozen, Shigekazu, Osaka, Japan.
Kraan, Jan W., Amsterdam, Netherlands.
Krementz, Richard, III, Newark, U.S.A.

Kularatnam, Kulasingham S., Colombo, Sri Lanka.
Kularatne, Rajapkse P. G., Muruthalawa, Sri Lanka.
Kumaratilake, Wickramasinghe L. D. R. A., Kelaniya, Sri Lanka.
Kussela, Irene, Hämeenlinna, Finland.
Lack, Kenneth A., San Clemente, U.S.A.
Laguna Manchon, Ma José, Barcelona, Spain.
Laine, Raimo E. L., Hämeenlinna, Finland.
Laitinen, Mauri P., Valkeakoski, Finland.
Lake, Anne M., Oakville, Canada.
Larsson, Alf C., Kyrkslatt, Finland.
Latham, Glenn M., Gambrills, U.S.A.
Law, Ada P. K., Aberdeen, Hong Kong.
Leary, Sean P., Washington, D.C., U.S.A.
Leckie, Frances, London.
Lee, Karen E., Twickenham.
Leidensdorff, Carine L., Brussels, Belgium.
Leung, Ronald T. T., Hong Kong.
Li, Jollio C. M., Kowloon, Hong Kong.
Lietwiler, Christian W., Oxon Hill, U.S.A.
Lindlau, Gisela, Aichwald, W.Germany.
Lithander, Brita K., Stockholm, Sweden.
Lopez Vidal, Antonio, Barcelona, Spain.
Lu, Milton R. K., Taipei, Taiwan.
Lui, Tsze C., Kowloon, Hong Kong.
Lum, Koke C., Kuala Lumpur, Malaysia.
Lyyvuo, Raili T., Helsinki, Finland.
Macdonald, Roy W., Eaglesham.
McGeorge, Robyn L., Beecroft, Australia.
McHugh, Charles, Adlington.
McKendrick, Stewart W., Reading.
McKinney, Landrum G., Jr, Kowloon, Hong Kong.
McLean, Peter J., Ryde, Australia.
McLeod, John W., Papakura, N.Z.
McQueen, B. Young, Jacksonville, U.S.A.
Ma, Lisa L. H., Wanchai, Hong Kong.
Machin Hernandez, Pedro, Barcelona, Spain.
Mak, Michael M. C., Hong Kong.
Malkani, Sunil C., Bombay, India.
Mallawarchchi, Gayani N., Kadawata, Sri Lanka.
Manmatharahah, Soosaipillai R. P., Jaffna, Sri Lanka.
Mann, Hazel J., Chatham.
Mantecon Burgos, Jesús, Barcelona, Spain.
Manzi, Michael, Penzance.
Marasinghe, Keerthiratne, Avissawella, Sri Lanka.
Marti Beltran, José Ma, Barcelona, Spain.
Masuda, Masami, Shizuoka, Japan.
Masurel, Helga, Leiden, Netherlands.
Matsuda, Tomoko, Tokyo, Japan.
Mau, Enoch C. Y., Kowloon, Hong Kong.
May, Brian J., Stellenbosch, S.Africa.
May, Brian H., Camberley.
Mayer, Stefan P., Idar-Oberstein, W.Germany.
Meacham, John F., Victoria, Canada.
Mednuik, Melanie A., Witham.
Mehta, Rohinton S., Bombay, India.
Mehtonen, Margaretha E. G., Espoo, Finland.
Mellows, Jacqueline M., Bexleyheath.
Meppelink, Jan P., Amsterdam, Netherlands.
Michaels, David B., Alexandria, U.S.A.

Miller, Marvin D., Fairfax, U.S.A.
Miller, Victoria J., Toronto, Canada.
Mine, Kayoko, Kita Kyushu, Japan.
Miralles Morey, José L., Barcelona, Spain.
Miravette Martinez, Ma Gloria, Barcelona, Spain.
Mizushima, Nobuhiro, Osaka, Japan.
Mok, Dominic W. K., Kowloon, Hong Kong.
Molyneux, John D., St Helens.
Moore, Roscelyn M., Camberley.
Moore, Stephen A., Leicester.
Mora Balcells, Helena, Barcelona, Spain.
Moran, Diane M., Upton.
Morgan, Gerald W. G., London.
Morishita, Kentaro, Tokyo, Japan.
Morishita, Yukuru, Tokyo, Japan.
Moseley, Tanya L., Ashford.
Mouzannar, Nabil I., Beirut, Lebanon.
Mulaffer, Mohamed Z., Colombo, Sri Lanka.
Munasinghe, Kalyani S., Colombo, Sri Lanka.
Murahashi, Kozo, Sasebo, Japan.
Murlans Ferrando, Núria, Barcelona, Spain.
Nakao, Kazuya, Wakayama, Japan.
Nakao, Shigeru, Nara, Japan.
Napola, Jussi P. D., Vantaa, Finland.
Naya Daniel, Francisco, Barcelona, Spain.
Naya Daniel, Mario, Barcelona, Spain.
Neale, David A., Copthorne.
Negueruela Tremino, Antonio, Barcelona, Spain.
Nevalainen, Aarne E., Hämeenlinna, Finland.
Nevill, Amanda J., Hong Kong.
Newing, Robin J. T., London.
Newman, Susan W., Henfield.
Ng Chan, Cecilia P. K., Hong Kong.
Nicholas, Christopher E., Colombo, Sri Lanka.
Nilam, Mohamad C. M., Weligama, Sri Lanka.
Nishino, Teiichi, Osaki, Japan.
Nivera, Maria D. G., Hong Kong.
Noon, Graham, Epsom.
Novejarque Lopez, Ma del Carmen, Barcelona, Spain.
Nurminen, Tuija P. A., Helsinki, Finland.
Obbink, Gertrude J., Aalten, Netherlands.
Ohno, Hiroko, Tokyo, Japan.
Øiesvold, Astri S., Aarnes, Norway.
Okada, Mari, San Clemente, U.S.A.
Okuda, Makoto, Higashiosaka, Japan.
Oliete Sainz, Juan A., Barcelona, Spain.
Olson, A. Richard, Manzini, Swaziland.
Orchant, Lewis, Glasgow.
Osacar Soriano, Ma Cinta, Barcelona, Spain.
Palfreyman, William D., Canberra, Australia.
Palmer, Robert B., London.
Palomäki, Jukka A. J., Katinala, Finland.
Palomäki, Tuula M. L., Katinala, Finland.
Paradise, Thomas R., Millbrae, U.S.A.
Parisée, Claudette, Vanier, Canada.
Parker, David T., Sunderland.
Parker, Hazel, Macclesfield.
Pattani, Hitesh K., Bombay, India.
Pattiaratchi, Chandrika L., Colombo, Sri Lanka.
Pattni, Rajendra A., Nairobi, Kenya.
Pellicer Beltran, Rodrigo, Barcelona, Spain.
Percival, Colin A., Sheffield.
Perera, Lekamage A. R., Pannipitiya, Sri Lanka.
Perera, Welliwattage P. R., Pannipitiya, Sri Lanka.

Perez Segarra, Montserrat, Barcelona, Spain.
Peto-Shepherd, Michael D., London.
Phillips, Jean M., Hong Kong.
Pickett, Diana J., Waterlooville.
Pierre, Robert E, La Jolla, U.S.A.
Pierre, Rosemary J., La Jolla, U.S.A.
Pong, Hilda M. M., Hong Kong.
Posner, Lorraine E., Woodford Green.
Prosser, Phillip M., Upper Hutt, N.Z.
Protopopoff, Monica, Beecroft, Australia.
Ranabahu, Mallikage K. T. S., Ratnapura, Sri Lanka.
Raths, Isabelle M., Almeria, Spain.
Rerolle, Jean-Claude, London.
Revert Guillart, Teresa, Barcelona, Spain.
Rhodes, Alexandra M., London.
Rich, Leonard, Manchester.
Rich, Louise R., Manchester.
Ro, Yosetsu, Tokyo, Japan.
Roberts, Kassandra, Bromborough.
Robertson, Melanie A., Guildford.
Roos, Beatrice M., Lucerne, Switzerland.
Rosen, Peter M., Stanmore.
Rosier, Jane L., Thorpe-le-Soken.
Roux, Isabeau R., Cape Town, S.Africa.
Rubera, Anthony N., Dehiwela, Sri Lanka.
Ruiz Vazquez, Christina, Barcelona, Spain.
Ruud, Paul, Drammen, Norway.
St Amand, Mary J., Mill Valley, U.S.A.
Salloway, Nigel J., London.
Santaularia Junyent, Ma Lourdes, Barcelona, Spain.
Sarath, Karunakalage, Ambalangoda, Sri Lanka.
Sarid, Smadar, Chorleywood.
Scales, Jacqueline C., Dunstable.
Schwan, Susanne, Pforzheim, W.Germany.
Schyllander, Anna M., Lidingö, Sweden.
Seaman, James S., Brookfield, U.S.A.
Selmon, Simon, Northwood.
Serra I Castella, Xavier, Barcelona, Spain.
Shah, Chandi R., Nairobi, Kenya.
Shajahan, Ismet K., Colombo, Sri Lanka.
Shannon, Heather, Ottawa, Canada.
Shau, Ying, Hong Kong.
Shaw, Constance H., Toronto, Canada.
Shepherd, Niall C., Poynton.
Shimomura, Seisaku, Tokyo, Japan.
Shivaji, Renuka, Edinburgh.
Sibblies, Howard St L., London.
Silvela Canosa, Jesús A., Barcelona, Spain.
Simon, Patrizia, Idar-Oberstein, W.Germany.
Sin, Shiu K., Kowloon, Hong Kong.
Singh, Janaki, Paris, France.
Sirkiä, Paula I., Pori, Finland.
Sivarajasingham, Tharmarajah, Kelang, W.Malaysia.
Smiley, Laurianne, Clondalkin, Ireland.
Smith, Frank K. T., Oldham.
Smith, Jackie E., Cumbernauld.
Smith, Raymond, Ponteland.
Smith, Vaughan A., Aldershot.
Snell, Keith H., Maghull.
Solis Mariscal, Ma Angeles, Barcelona, Spain.
Somasiri, Asurappulige S., Thulhiriya, Sri Lanka.
Soni, Sara, London.
Soriano Meler, Esther, Barcelona, Spain.
Specterman, Andrew M., Manchester.
Speed, Graham C., Slough.
Steert, Ineke, Amsterdam, Netherlands.
Steinhauer, Mary H, Adelphi, U.S.A.

Stephens, Gareth O., Auckland, N.Z.
Stern, Ngoc T., London.
Stewart, Robert M., Swanmore.
Stimler, Stuart I., Harrow.
Strøm-Blakstad, Torilo, Moss, Norway.
Suarez Corbato, Teresa, Barcelona, Spain.
Subiros Domingo, Bernadette, Barcelona, Spain.
Summersgill, Susan M., Warrington.
Susinno, Marie H., Rockville, U.S.A.
Suzuki, Yuko, Tokyo, Japan.
Takakura, Momoyo, Tokyo, Japan.
Takamura, Kozue, London.
Tam, David C. C., Kowloon, Hong Kong.
Tan, Hup F., Singapore.
Tate, Stephen J., Farnham.
Tate, Yvonne, Farnham.
Taylor, James D., London.
Taylor, Timothy C. H., London.
Termier, Françoise, London.
Termier, Jean P., London.
Tether, John G. G., Lusaka, Zambia.
Thavat, Paul, Auckland, N.Z.
Thomson, Ian C., Dumfries.
Thomson, Pearl J., New Barnet.
Tiainen, Kauko K., Hämeelinna, Finland.
Tielinen, Tapio T., Hämeenlinna, Finland.
To, Matthew K. H., Hong Kong.
Toivainen, Heidi S., Helsinki, Finland.
Tomas Martin, Isabel, Barcelona, Spain.
Tomasella, Yves, Douai, France.
Tong, Kwong K., Hong Kong.
Townson, Peter R., London.
Torode, Carl F., Gillingham.
Trickey, Sheila A., Henley-on-Thames.
Trueman, Laraine M., Stafford.
Tsuda, Takashi, Osaka, Japan.
Tsui, Carol, Kowloon, Hong Kong.
Tsui, Juliana Y. W., Hong Kong.
Tsuji, Takao, Saga, Japan.
Turk, Noriko, Hong Kong.
Turley, Warren J., Stafford.
Tuokko, Marjo A., Helsinki, Finland.
Vaintola, Eevaleena, Hämeenlinna, Finland.
van Deijl, Wilhelm M. E., Bloemfontein, S.Africa.
van Deijl, Willem L., Parow, S.Africa.
van Stockkom, Francisca A. J. A., Dongen, Netherlands.
van Veltzen-Ritmeÿer, Elisabeth T. H., Rotterdam, Netherlands.
Vedeler, Nina, Hosle, Norway.
Venemans, Anne C., Schoonhoven, Netherlands.
Vidal Noguera, Francisco, Barcelona, Spain.
Virani, Nilesh A., Bombay, India.
Virtanen, Juha, Helsinki, Finland.
Waghela, Mahesh R., Bombay, India.
Warren, Timothy D., London.
Waterworth, Eileen, Hong Kong.
Watson, Dermot, Belfast, N.Ireland.
Watson, Gordon, Lanark.
Watson, Pauline E. A., Dorking.
Wear, William F., Bedford.
Weber, L., Breda, Netherlands.
Weerasekera, Cheryl C., Colombo, Sri Lanka.
Weerasuria, Ajith H., Colombo, Sri Lanka.
Wells, Bruce I., Glasgow.
Weston, Anne E., London.
Wetten, Veronica F. K., Hong Kong.
Whatley, David G., London.
Wibbens, Casandra, Schoonhoven, Netherlands.
Wickramasinghe, Rohan H., Colombo, Sri Lanka.
Wigbout, Olga C., Leeuwarden, Netherlands.
Wigley, Reginald H., Hong Kong.

Wijekoon, Sumeda K., Halgranoya, Sri Lanka.
Wijenayake, Meththananda D., Nugegoda, Sri Lanka.
Wilkins, Kenneth E., Christchurch, N.Z.
Williams, Paula R., London.
Wittin, Shirley J., Birmingham.
Wojda, John A., Whitchurch.
Wong, Josha C. C., Hong Kong.
Wong, Dorothea S., Hong Kong.
Wong, Kin W., Kowloon, Hong Kong.
Worp, Paulien, Almelo, Netherlands.
Wright, Mary, Lymm.
Yamasaki, Kazutaka, Kochi, Japan.
Yoshino, Mariko, Tokyo, Japan.
Yuen, Yau T., Hong Kong.
Zain, Zahari, Birmingham.
Zappa, Chrissanthe, North Cheam.
Zarzuela Mondaray, Ma Jesus, Barcelona, Spain.
Zwikker, Marijke, Nijmegen, Netherlands.
Zylstra, Christine, Schoonhoven, Netherlands.

COUNCIL MEETING

At the meeting of Council held on Tuesday, 22nd September, 1981, at Saint Dunstan's House the following were elected to membership:

FELLOWSHIP

Bennett, Sharon L., Little Marlow. 1981
de Silva, Carmel L., Morden. 1979
Machlup, Peter M., Johannesburg, S. Africa. 1979
Parry, Sarah, Wadhurst. 1981
Potter, Brian S., London. 1981
Prince, Ann-Elise, London. 1981
Salakian, Silva, Salisbury, Zimbabwe. 1979
Troth, Peter D., Jersey. 1981
Trueman, Laraine M., Stafford. 1981
Yoshida, Katsuji, Wakayama, Japan. 1980.

TRANSFERS FROM ORDINARY MEMBERSHIP TO FELLOWSHIP

Absalom, Christine S., Effingham. 1981
Acheson, Michael A., Geneva, Switzerland. 1981
Ahmad, Zaheer, London. 1981
Akizuki, Haruo, Ichikawa, Japan. 1981
Aliprandi, Riccardo, Rome, Italy. 1981
Beevers, Jacintha M., Hong Kong. 1981
Boorman, Robert F., Bisley. 1981
Boyes, Richard W., Garston. 1981
Caffoor, Ali A., Banjul, Gambia. 1981
Currie, Lynnette J., Manurewa, N.Z. 1981
Darracott, Britt-Marie, London. 1981
Davis, Robert J., Margate, Tas., Australia. 1981
Dolleslager, James T., Houston, Tex., U.S.A. 1981
Freeman, Darlene M., Belmont, Ca, U.S.A. 1981
Furse, Anna A., London. 1981
Grant, Judith M., Carmel, Ca, U.S.A. 1981
Hamada, Shiko, Suita-City, Japan. 1981
Hermans, Johannes S., Delft, Netherlands. 1981
Hinde, Rosemary J., Hong Kong. 1981
Horton, David R., London. 1981
Houseago, James A., Lowestoft. 1981

Hutchinson, Marjorie E., London. 1981
Kageyama, Chiyomi, Hyogo Pref., Japan. 1981
Kano, Shinzo, Toyonaka, Japan. 1981
Keuskamp, Diederik, Streefkerk, Netherlands. 1981
Kinoshita, Kazuko, Ashiya, Japan. 1981
Kita, Masako, Fukuoka, Japan. 1981
Kobayashi, Yuko, Tokyo, Japan. 1981
Kosik, Thomas A., Arlington, Va, U.S.A. 1981
Kothari, Rajan S., Bombay, India. 1981
Kröger, Carol M., Rio de Janeiro, Brazil. 1981
Lambley, Jenifer G., Hong Kong. 1981
Laurie, Amanda, Bicester. 1981
Littlejohn, Gordon H., Tunbridge Wells. 1981
Livstrand, Ulf R., Saltsjobaden, Sweden. 1981
McKellar, John R., Presteigne. 1981
Maeda, Katsutoshi, Fukuoka, Japan. 1981
Masuda, Masami, Shizuoka, Japan. 1981
Mizushima, Nobuhiro, Osaka, Japan. 1981
Mourad, Huguette, Beirut, Lebanon. 1981
Nakamura, Masanori, Osaka, Japan. 1981
Nakao, Kazuya, Wakayama, Japan. 1981
Nakayama, Keichi, Komatsushima, Japan. 1981
Nojiri, Masatomi, Fukuoka, Japan. 1981
Ohno, Hiroko, Tokyo, Japan. 1981
Okuda, Makoto, Osaka, Japan. 1981
Otsuka, Nobuko, Tokyo, Japan. 1981
Parcel, Rodney F., Jr, Perris, Ca, U.S.A. 1981
Pattni, Pravin, London. 1981
Peebles, Kathleen W., Johannesburg, S. Africa. 1981
Podsiadly, Maria, Birmingham. 1981
Quincey, Mary E., Rugby. 1981
Rademaker, Jaap, Baarn, Netherlands. 1981
Ro, Yosetsu, Tokyo, Japan. 1981
Ruplinger, Peter K., Sandy, Utah, U.S.A. 1981
Ryan, Margaret E., Hong Kong. 1981
Shimomura, Seisaku, Hiroshima Pref., Japan. 1981
Singleton, Graham S., Cardigan. 1981
Spooner, Carole A., Wokingham. 1981
Swain, Anthony P., Deganwy. 1981
Swersky, Ann H., Ramat Hasharon, Israel. 1981
Thorne, Deirdre, Salisbury, Zimbabwe. 1981
Williams, Bruce M., Walla Walla, Wash., U.S.A. 1981
Wong, Kitty, Hong Kong. 1981
Yamamoto, Kazui, Fukuoka, Japan. 1981
Yenson Chu, Mabel, Hong Kong. 1981
Yoshino, Mariko, Tokyo, Japan. 1981

ORDINARY MEMBERSHIP

Abi-Habib, Cynthia S., Riyadh, Saudi Arabia.
Amini, Soraya, London.
Anand, Shalini, Bombay, India.
Andrews, Clive G., Selsdon.
Ashworth, Ian E., Bristol.
Austin, William E., Colton, Ca, U.S.A.
Bahtiarian, B. Alex, Englewood, N.J., U.S.A.
Baxter, Gordon E., Whangarei, N.Z.
Beech, Georgina, Manchester.

Beeson, Ronald H., Bexleyheath.
Benham, Robert M., Fair Grove, Mo., U.S.A.
Bernheiser, Charles A., Mohrsville, Pa, U.S.A.
Berthelsen, Lawrence J., Townsville, Qld, Australia.
Bickley, Kerry B., Pretoria, S. Africa.
Booker, Martin, Chester.
Braun, Nicolaas J. M., Amsterdam, Netherlands.
Broad, Arline E., Thames, N.Z.
Bruner, Samuel S., Springfield, Pa, U.S.A.
Burke, Edmund H., Redwood City, Ca, U.S.A.
Burrill, Douglas, Sintaluta, Sask., Canada.

Chan, Chan-Kuen, Hong Kong.
Chan, Lai K. R., Hong Kong.
Chase, David E., Yelverton.
Chung, Sau H., Taipei, Taiwan.
Cirone, Monica A., Campbell, Ca, U.S.A.
Clappison, Diana J., Hull.
Cole, Jo E., Santa Monica, Ca, U.S.A.
Crout, Stephen J., Christchurch, N.Z.
Cunningham, Colin D., Townsville, Qld, Australia.

Darby, Elspeth M., Feltham.
Davidson, Christopher R., Nairobi, Kenya.
Desai, Salim S., Salisbury, Zimbabwe.
De Silva, G. Ranjan, Singapore.
Dias Abeyegunawardene, Christina S., Colombo, Sri Lanka.
Dubler, Martin, Atlanta, Ga, U.S.A.

Esmail, Esmail A., Karachi, Pakistan.
Field, Michael, Dublin, Ireland.
Fixter, Robert H., Lincoln, Neb., U.S.A.
Foster, Timothy C., York.
Fowler, Graham, Broome, W. Australia.
Gateley, John F., Nottingham.
Gaw, Rossana W., Hong Kong.
Gee, Bruce L., Townsville, Qld, Australia.
Gerrard, Michelle A., South Coogee, N.S.W., Australia.
Gnaizda, Anita, Miami, Fla, U.S.A.
Gondai, Nobutoshi, Tokyo, Japan.
Graff, John R., Johannesburg, S. Africa.
Graham, John, Erith.
Grant, Noeline L., Pietermaritzburg, Natal, S. Africa.
Grundy, Andrew M., Leicester.
Gunderson, Brian K., Sioux City, Iowa, U.S.A.
Harriman, Allen L., Perth, W. Australia.
Haxel, Terrie J., Newark, Ca, U.S.A.
Heathcote, Larissa C., Salisbury, Zimbabwe.
Hills, Gavin A., Moonah, Tas., Australia.
Homstad, Keith E., Minneapolis, Mn., U.S.A.
Hatenboer, Willem J., Yssel, Netherlands.
Hsiao, Ying H., Taipei, Taiwan.
Hutchison, Christine, Prestonpans.
Jackson, Karen, Blackpool.
Jaffe, Laura F., Silver Spring, Md, U.S.A.
Kantor, Lonnie, Miami, Fla, U.S.A.
Karunanayake, Sarath P., Dehiwala, Sri Lanka.
Kemble, Bessie L., Richmond, Va, U.S.A.
Kerr, Benjamin J., Wexford, Ireland.
Khan, Pervaiz, Salisbury, Zimbabwe.
Kim, Mami, Tokyo, Japan.
King, Clive H., Tsumeb, S.W. Africa.
Kothari, Umme A., Bombay, India.
Kruss-Leibrock, Martina, Hamburg, W. Germany.
Law, Kenneth Y. P., Hong Kong.
Lehmann-Yuan, Shen K., Taipei, Taiwan.
Lemen, John R., Torrance, Ca, U.S.A.
Lingenhag, Reto, Miami, Fla, U.S.A.

Lok, Noel K. L., Kowloon, Hong Kong.
Lucki, Stella, Red Deer, Alta, Canada.
Marsh, Lesley F., Salisbury, Zimbabwe.
Martinez, Alfonso, Salisbury, Zimbabwe.
Mayer, Anton S., Jersey, C.I.
Mehta, M. G., Bombay, India.
Methuen, Rennie T., Kuopio, Finland.
Mitchell, Jeffrey S., Shreveport, La, U.S.A.
Monticelli, Claude, Luchon, France.
Moss, Andrew G., Sutton Coldfield.
Mouzannar, Nabil, Beirut, Lebanon.
Mughal, Abdul G., Abu Dhabi, U.A.E.
Munday, John J., Eltham, Vic., Australia.
Murton, John, Townsville, Qld, Australia.
Ng, Soon Hoh, London.
Ngan, Hon Ming, Hong Kong.
Nicolaides, Despina, Astoria, N.Y., U.S.A.
Nivera, Divina G., Hong Kong.
Ousley, Mitchell D., Birmingham, Ala, U.S.A.
Pascual, Frances T., Hong Kong.
Pasqui, Mafalda, Genoa, Italy.
Petrides, Demosthenes, Hamburg, W. Germany.
Phillips, Larry D., Albuquerque, N.M., U.S.A.
Pond, Jolie J., Santa Ana, Ca, U.S.A.
Ponn, Roger E., Phoenix, Ariz., U.S.A.
Poon, Eileen O., Hong Kong.
Premprung, Kedsenee, Geneva, Switzerland.
Pritchard, David A., London.
Ratliff, David I., Townsville, Qld, Australia.
Rebuck, Craig N., London.
Rouse, Kenneth A., Newton Abbot.
Shadar, Avigdoz, Tel-Aviv, Israel.
Shapiro, Merle R., Johannesburg, S. Africa.
Shein, Leone, Johannesburg, S. Africa.
Smith, Maureen H., Edinburgh.
Sohrabi, Golnaz F., Geneva, Switzerland.
Spicuzza, Jennifer J., Metairie, La, U.S.A.
Tai, Joyce, Hong Kong.
Takashima, Isao, Tokyo, Japan.
Termier, Jean P., London.
Tomasella, Yves, Bouglon, France.
Tremain, Geraldine, Hong Kong.
Tsui, Carol, Hong Kong.
Upperton, Lesley J., London.
Van Belle, Herman A., Deinze, Belgium.
van den Bemd, Olga M., Wellington, N.Z.
Van Diepen, John W., Germistone, Transvaal, S. Africa.
van Haaren, Mariette, Hong Kong.
Vickers, Charles W., Wakefield.
Walker, Frank D., Dallas, Tex., U.S.A.
Watson, William, Germistone, Transvaal, S. Africa.
Webb, Bryce E., Burbank, Ca, U.S.A.
Weisel, Melvin, Verona, Pa, U.S.A.
Whiffen, Martin J., Southampton.
White, Janet M., Sacramento, Ca, U.S.A.
Whitehead, Wendy I., London.
Williams, Paula R., London.
Wong, Ngiam C., Singapore.
Woo, Po Kun A., Hong Kong.
Yakoob, Elias A., Karachi, Pakistan.
Yates, Holly E., Ft Lauderdale, Fla, U.S.A.

GOLDEN JUBILEE CELEBRATIONS

On Sunday, 4th October, 1981, a reception was held at the Institute of Geological Sciences in Kensington. The main Hall, containing a magnificent collection of rough and polished gemstones and other minerals, was filled to capacity by over 600 gemmologists from all over the world—nearly all Fellows of the Association—and during the proceedings the President, Sir Frank Claringbull, presented Mr Richard T. Liddicoat, Jr, Hon. F.G.A., President of the Gemological Institute of America, and Mlle Dina Level, Hon. F.G.A., late of the Laboratoire des Pierres Précieuses et Fines et des Perles, Paris, with their Fellowship Diplomas after first introducing them to the assembled company with a felicitous speech of welcome, to which the two Honorands made suitable replies.

On Monday, 5th October, 1981, H.R.H. the Duke of Gloucester opened the Association's exhibition, 'Fifty Years of Gemmology', at Goldsmiths' Hall at a private view in the evening attended by upwards of 600 members. The exhibition was open to the public from 6th to 16th October and was attended by over 3000 visitors. A 76-page Souvenir Catalogue of the Exhibition, containing also a history of the Association and a complete list of all who obtained the Diploma in Gemmology by examination from 1913 to 1980, is available from the Association. The price in the U.K. is £3.10 (including postage and packing) and abroad £3.25 by surface mail or £4.50 by air mail.

In the mornings of Monday, Tuesday and Wednesday, 5th-7th October, lectures were delivered to large audiences of 500 and more in the Great Hall of Kensington Town Hall. The substance of the lectures by Mr B. W. Anderson on the Monday and by Mr R. T. Liddicoat and Mr Robert Crowningshield on the Wednesday was published in the October *Journal* (B. W. Anderson, *The Growing Pains of Gemmology,* J.Gemm., 1981, XVII (8), 515-21: R. T. Liddicoat, *A Brief Summary of Gemmological Instrument Evolution,* J.Gemm., 1981, XVII (8), 570-85: R. Crowningshield and K. Nassau, *The Heat and Diffusion Treatment of Natural and Synthetic Sapphire,* J.Gemm., 1981, XVII (8), 528-41). The substance of Dr Edward Gübelin's lecture on the Tuesday on 'The Significance of Mineral Inclusions in Diamonds' will be reproduced in a future issue of the *Journal.*

On the Tuesday evening there was a boat trip on the River Thames with a buffet meal and dancing. During the journey, a commentary was given on places of interest.

An anniversary dinner was held in the Captain's Room at Lloyds during Wednesday evening when 300 people attended. The Chairman of the National Association of Goldsmiths, Mr Peter Hopper, F.G.A., presented Mr Callaghan, on behalf of the Association, with a magnificent badge of office (see pp. 105/6 below). The speakers were Mr John Pyke, F.G.A., President of the N.A.G., Mr Richard T. Liddicoat, F.G.A., President of the Gemological Institute of America, and the Chairman, Mr David Callaghan, F.G.A.

A second dinner was held on Friday evening in the Captain's Room, when over 250 were present and the principal speakers were Mr Karl Lauvland, F.G.A., Mr Arthur B. Monnickendam and the Chairman. During the evening Mr Oivind Modahl, on behalf of the Norwegian Gemmological Association, presented the Association with a quartz crystal group containing crystals of the rare mineral anatase.

ANNUAL REUNION OF MEMBERS AND PRESENTATION OF AWARDS

The Annual Reunion of Members was held at Goldsmiths' Hall on Monday, 16th November, 1981, and will be more fully reported in the April *Journal.*

PRESENTATION OF AWARDS IN HONG KONG AND TOKYO

The presentation of awards in Hong Kong on 3rd November, 1981, and in Tokyo on 7th November, 1981, will be more fully reported in the April *Journal.*

CHAIRMAN'S BADGE OF OFFICE

To mark the 50th anniversary of the Gemmological Association, the National Association of Goldsmiths commissioned a badge of office for the Chairman.

The badge is a striking but simple design in 18 carat yellow and white gold with bevelled millegrain edges, which are designed to resemble the facets of a cut gemstone. At the top of the design is the coat of arms of the N.A.G., with a textured loop entwined with a diamond loop suspended below it. The diamond loop encloses the larger enamelled coat of arms of the Gemmological Association.

The design symbolizes the close ties between the two Associations and illustrates the G.A.'s origins within the N.A.G., while showing that it grew to become a large and important organization in its own right. Setting off the design is a background of black oxidized gold which highlights the colourful G.A. arms. The total effect is a highly individual one, simple and classic.

Four designers were asked to submit proposals for the badge, and the design chosen is by Michael Laing, of Edinburgh.

The badge was presented to the Chairman, Mr David Callaghan, by Mr Peter Hopper, Chairman of the N.A.G., at the Golden Jubilee Celebration Dinner on 7th October, 1981.

F.G.A. TIE

The new Fellowship tie (see J.Gemm., 1981, XVII (8), 645) is illustrated on p. 106. Prices are now as follows:

U.K. (including postage and V.A.T.)	£4.70
Overseas (including Air Mail)	£4.60

TWO-DAY COURSES—COACHING FOR PRACTICAL EXAMINATION

Mr Alan Hodgkinson, F.G.A., announces two-day courses of individual coaching for the Diploma Practical Examination, with morning sessions involving the setting of an exact replica of the format of the Practical Examination and afternoon sessions looking at the student's performance and showing various ways to improve it, with specific help in the areas requested. Time will be given to showing the techniques of answering the questions and obtaining maximum potential in both practical and theoretical sections. Students will be 'paired', to allow maximum time for practical preparation and coaching, and the two-day sessions will run between mid-May and mid-June. Cost per person for the two-day course will be £100 plus V.A.T. Applications to join the courses should be addressed to Mr Hodgkinson at 2 Hillview Drive, Clarkston, Glasgow, G76 7JD [Telephone: (041) 638 8888].

Left. The Chairman's Badge of Office, designed by Michael Laing, of Edinburgh, and made by Padgett and Braham Ltd, of London. (See p. 105).

Right. F.G.A. Ties. (See p. 105).

XVIIIth INTERNATIONAL GEMMOLOGICAL CONFERENCE

The XVIIIth International Gemmological Conference held in Japan from 8th to 13th November, 1981, will be more fully reported in the April *Journal.*

INDEX FOR VOLUME XVII

The Editor regrets that owing to difficulties in communications due to the recent severe winter weather it has not proved possible to have the Index ready in time for issue with this number of the *Journal.* It will therefore be issued with Part 2 in April.

LETTER TO THE EDITOR

From Mr R. Keith Mitchell, F.G.A.

Dear Sir,

Mr Philip Jerome's interesting find of old 'gem-oriented' newspaper cuttings, described in your July issue,* brings back memories.

He queries what happened to the gems stolen from the old Geological Survey Museum in Jermyn Street, in August 1933. I remember the occasion well. The thief was said to have secreted himself in the Museum when it closed, robbed the display case, and broken out of the Museum. A man was apprehended a few days later.

The theft was reported in the September issue of the *Gemmologist,* and an account of the magistrate's hearing, when the accused elected to be tried by jury, was printed in the November issue. On November 21st Harold Joseph Bennett, 33, a glazier, was sentenced to 17 months hard labour for receiving some of the gems, which he said he had found. He was found not guilty on the charge of breaking out of the Museum. During the hearings adverse comments were made on the part played by some Trade personalities, especially in view of low prices paid and the apparent haste with which some of the stones were recut.

Most of the larger gems were eventually restored to the Museum and are probably still in their public display today. This is, of course, at South Kensington, for they moved from the Jermyn Street site shortly after the theft. There is some mystery about the five-coloured tourmaline, which does not appear in the schedule of gems stolen and is certainly not among those regained. I suspect that the newspapers got hold of the statement that five (different) coloured tourmalines were stolen.

Yours etc.,
R. KEITH MITCHELL

18th August 1981.
Orpington, Kent.

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*J.Gemm., 1981, XVII (7), 450-4.—Ed.

CORRIGENDA

In J.Gemm., 1981, XVII (8), on p.588, line 14, for 'parallel' read 'vertical' and on p.627, line 5, for 'The' read 'They'.

Historical Note

The Gemmological Association of Great Britain was originally founded in 1908 as the Education Committee of the National Association of Goldsmiths and reconstituted in 1931 as the Gemmological Association. Its name was extended to Gemmological Association of Great Britain in 1938, and finally in 1944 it was incorporated in that name under the Companies Acts as a company limited by guarantee (registered in England, no. 433063).

Affiliated Associations are the Gemmological Association of Australia, the Canadian Gemmological Association, the Gem and Mineral Society of Zimbabwe and the Gemmological Association of Hong Kong.

The *Journal of Gemmology* was first published by the Association in 1947. It is a quarterly, published in January, April, July, and October each year, and is issued free to Fellows and Members of the Association. Opinions expressed by authors are not necessarily endorsed by the Association.

Notes for Contributors

The Editor is glad to consider original articles shedding new light on subjects of gemmological interest for publication in the *Journal*. Articles are not normally accepted which have already been published elsewhere in English, and an article is accepted only on the understanding that (1) full information as to any previous publication (whether in English or another language) has been given, (2) it is not under consideration for publication elsewhere and (3) it will not be published elsewhere without the consent of the Editor.

Articles published are paid for, and any number of prints of individual articles may be supplied to authors provided application is made on or before approval of proofs. Current rates of payment for articles and terms for supply of prints may be obtained on application to the Secretary of the Association.

Although not a mandatory requirement, it is most helpful if articles are typed (together with a carbon copy) in double spacing on one side of the paper, with good margins at sides, top and foot of each page. Articles may be of any length, but it should be borne in mind that long articles are more difficult to fit in than short ones: in practice, an article of much more than 10 000 words (unless capable of division into parts or of exceptional importance) is unlikely to be acceptable, while a short note of 400 or 500 words may achieve early publication.

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