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GEMMOLOGICAL ASSOCIATION
OF GREAT BRITAIN

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ABSORPTION SPECTRA AND PROPERTIES OF METAMICT ZIRCONS *

By B. W. ANDERSON

THE absorption bands shown in the spectrum of light transmitted through a mineral can usually be ascribed to atoms of one particular element, though in the past mistaken ascriptions have often been made. These "colouring" atoms may be present either as an essential or (more often) as an "accidental" constituent of the mineral concerned. But the actual positions of the bands depend primarily on the electric field surrounding the atoms, on their "polarization"—that is, on the crystal structure of the host mineral.

Striking examples of this are shown not only in the extreme similarity between absorption bands seen in closely-related minerals (enstatite and hypersthene; jadeite and spodumene) but more subtly by similarities between minerals which may seem to belong to quite different chemical or crystal groups, and yet have an underlying structural affinity. Thus, the spectrum of taaffeite is very similar to that of blue spinel, and the spectrum of sinhalite is closely allied to that of peridot—one reason why its discovery was so long delayed.

Now in zircon the gradual breakdown in crystal structure, which can be conveniently measured by the density of the stone, can

* Substance of a talk given at the 9th International Gemmological Conference at Helsinki 1962.

also be clearly followed by the gradual deterioration of the uranium absorption bands from the sharp lines displayed by normal fully crystallized zircon, through weaker and vaguer development of the same bands until, with completely metamict zircon, the usual absorption spectrum consists merely of a vague band in the red near 6500Å, sometimes accompanied by a narrow band in the green at 5200Å—the latter a band not seen in normal zircon.

The reverse process can be demonstrated quite simply in the case of intermediate zircons by heating a pebble to bright redness for a few minutes in a bunsen flame, when the sharpness of the spectrum lines will be found to have been notably enhanced by this treatment, and the density of the specimen to have risen.

With zircons of lowest metamict type, however, the writer has found quite a different effect to be the rule. With these stones, heating at 800-900°C will induce a strong and clear-cut series of absorption bands, not of the normal zircon spectrum, but in a different pattern and at different wavelengths. The main differences between the spectra are, that whereas in the normal zircon spectrum the strongest band is in the red at 6535Å, in the anomalous spectrum the most powerful band is a rather broad one at 6690, flanked by a doublet at 6910 and 6855 on the long-wave side and a band about 6525 on the other side, forming a “triple band” effect, and also that in the blue and violet regions, where the normal spectrum shows two powerful bands at 4830 and 4315, the anomalous spectrum has very strong bands quite differently placed, at 4730 and 4510Å. The diagram reproduced here shows the distribution of absorption bands in the normal and anomalous spectra, as seen through a grating spectroscope.

The anomalous spectrum has already been observed in several untreated low metamict zircons, but these are exceedingly rare. By an extraordinary chance, the zircon in which we first saw absorption bands was of this type, and in 1957 Dr. P. Zwaan published a detailed account of another such specimen which he found in the Museum collection at Leiden. Dr. E. Gübelin, in a private letter, has recently sent the writer particulars of yet another stone displaying the anomalous bands: the properties of all these are given in the table below.

The discovery that these anomalous bands can be developed in *any* specimen of low metamict zircon simply by heat treatment

came as a complete surprise. The experiment was first undertaken with zircons showing the strange 5200 band which had been observed and collected over a number of years. Interest in this band had been brought to a head by being shown a fine *orange* metamict stone by Dr. E. H. Rutland, through whom the stone was purchased. This had the 5200Å band more clearly developed than in any other specimen seen, and served as a reminder of the need to try and elucidate its origin. It was decided to ascertain whether this band could be enhanced by heat treatment, as are the bands of the normal spectrum.

The first experiment was with a roughly polished specimen weighing 2.70 carats. This had a density of 4.04 and a single refractive index of 1.819. The spectrum showed the usual blurred red band of metamict zircon plus a weak narrow band at 5200Å which was the focus of interest. An initial heating for two hours at 600°C had no effect either on the absorption bands or on the physical properties of the stone. But after heating for three hours at 800°C the strong anomalous spectrum already mentioned made its appearance, while the density and refractive index had fallen to 3.98 and 1.785, respectively.

Experiments with other low metamict zircons, some rough and some cut, gave exactly parallel results, and it was found that stones not showing the 5200 band behaved in a precisely similar manner. The results on several such specimens are tabulated below and data for the few unheated natural stones which show the anomalous spectrum are also given for comparison.

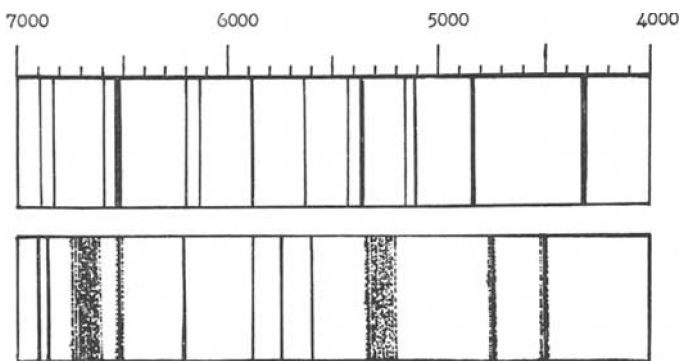
Properties of metamict zircons showing the anomalous spectrum					
NATURAL			INDUCED		
<i>Cts.</i>	<i>d</i>	<i>n</i>	<i>Cts.</i>	<i>d</i>	<i>n</i>
5.19	3.95	1.792	2.32	3.975	1.778
12.64	3.965	1.792	1.20	3.96	1.799
Zwaan	3.965	1.778	1.55	3.96	1.784
Gübelin	3.918	1.780	1.95	3.935	1.783

With sufficiently low-density metamicts, in which no trace of the original zircon spectrum remains, the development of the

anomalous spectrum on heating seems inevitable. In one case, a very small pebble was heated in the flame of a bunsen burner for not much more than a minute, and even this was sufficient to produce the anomalous bands. With zircons having a density of 4.08 or over or with any zircon showing even traces of the normal spectrum lines, the results of heat-treatment are quite different: the density and refractive index are found to have increased and a normal zircon spectrum makes its appearance. The “watershed” between the two represents the dividing line between Stevanovic’s “a” class of zircons of lowest density and his “c” or intermediate group. In one curious case having density as high as 4.08, but showing in its spectrum only the red smudge and 5200Å band, the stone seemed to be sitting astride the watershed, since heating produced a strong mixture of normal and anomalous bands, while the density had increased slightly to 4.12.

Not only in the positions of the bands does the abnormal (A) spectrum differ from the normal (N) but in the fact that it is unpolarized whereas the N spectrum is clearly polarized. This seems to suggest that the uranium is now inhabiting a cubic lattice—possibly the cubic form of ZrO_2 reported in metamict zircons by some X-ray workers. Dr. G. F. Claringbull and others are now investigating this and other possibilities.

Heating to 900° resulted in no change in the anomalous spectrum though further diminution in density and refractive index



Absorption bands in the normal zircon spectrum (above) and the anomalous spectrum (below)

were observed. Professor W. F. Eppler has kindly subjected chosen stones to higher temperatures. Two hours at 1000° still resulted in no change in the A spectrum, but at 1100° two of the chosen stones showed some development of lines of the normal spectrum, with polarization evident, and in one of these the density had undergone an increase from 4.00 to 4.21—definitely a sign that it was on its way back to normal zircon.

Similar reversion towards crystalline zircon when low metamict types had been heated to 1250° was noted by Lietz (1937), while Chudoba has stated that when heated for a long period at 1450°, all zircons revert to normal. This temperature is approaching that for the actual melting point of the mineral.

The curious lowering of an already low density and refractive index on moderate heating before beginning the long climb towards full crystallinity, “reculer pour mieux sauter”, as the French phrase puts it, is not unique to zircon. The same effect was observed in experiments on that new metamict gem mineral, ekanite, and it confirmed the opinion that this was indeed another metamict. Possibly because of their variable hafnium content these low metamict zircons differ slightly from one another in their properties, though 3.96 for their density and 1.78 for their refractive index seem good average figures. With ekanite the figures for density (3.28) and refractive index (1.597) compare well in constancy with those for a pure crystalline mineral, which is very remarkable. Measurable amounts of double refraction are sometimes observable in even these metamict zircons: it is possible however, that this may be due to the so-called “form birefringence” seen, for example, in chalcodony.

The specimens dealt with in this study have all been Ceylon stones. Ceylon zircons have undergone internal changes more than those from most other localities, not only because of their vast geological age (Pre-Cambrian), but because their content of radioactive elements is relatively high. Traces both of thorium and uranium are frequently present in zircons: thorium belongs to the same sub-group of the periodic classification of elements, and both thorium and uranium compounds are isomorphous with their zirconium analogues. In this connection, Mr. T. G. Jones, at the A.E.R.E., Harwell, kindly obtained the following readings on a sensitive beta-gamma ray counter. For a zircon from Indo-China,

nil; from Burma, 160; Ceylon, density 4.14, 267; Ceylon metamict, 365; Ceylon metamict with anomalous spectrum, 334 c.p.m. One may note that zircons from Indo-China are normal types and show only very faintly the uranium absorption lines. Burma zircons are also normal, and have a larger uranium content than Ceylon zircons, as indicated by both their emission and absorption spectra, but are geologically younger.

It is clear that this investigation is incomplete. All that has so far been established is an interesting and apparently invariable pattern of behaviour in low metamict zircons, in which heat treatment at 800-900°C causes a reduction in density and refractive index accompanied by the development of a series of strong absorption bands in a pattern which is not that of the well-known spectrum of normal or intermediate zircon. The mystery of the 5200Å band which started the investigation and of the crystal phase in which the anomalous spectrum is developed is still unsolved, but is being pursued by other workers.

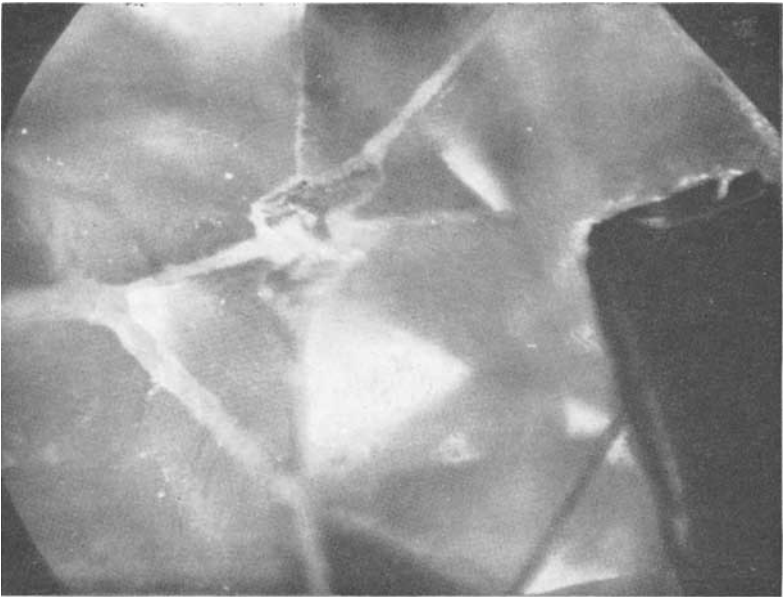
Fifteen years ago, an article was published under the heading "Zircon—no longer a gem of mystery": an excellent article, but with certainly an optimistic or pessimistic title, according to one's viewpoint.

For the research-worker, at least, it is a matter for rejoicing that so many mysteries remain to be solved, not only in zircon but in almost every precious stone.

WORN EDGES ON DIAMONDS

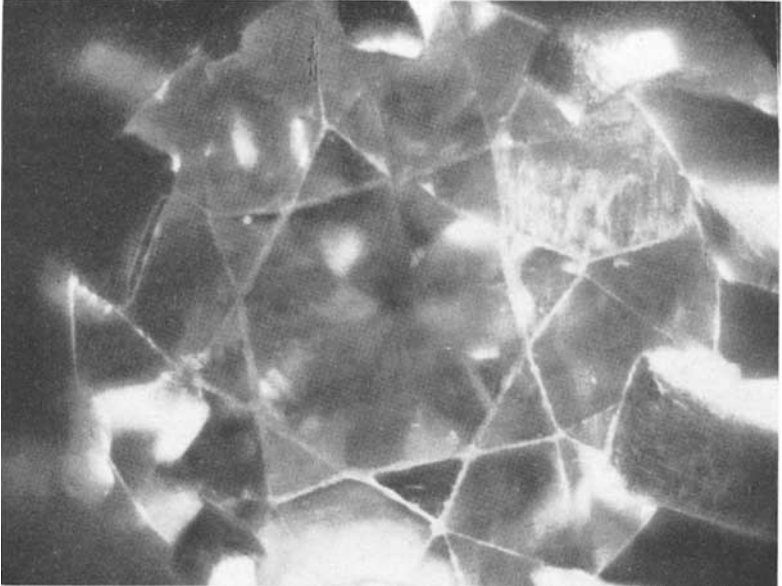
Recently there has been seen a number of diamonds which have shown “worn edges”, and owing to the fact that zircon commonly wears on the edges, such “worn” diamonds have been questioned as to whether they are truly diamonds.

The cause of such “wearing” at the edges has never been adequately explained. The usual conjecture has been that the stone or stones had become abraded by rubbing against other diamond set jewellery in a jewel case, or by “paper wearing” whilst in a stone packet with other diamonds. The first conjecture was found to be less tenable when a diamond cluster ring, which had the central stone “proud”, showed the surrounding diamonds to have their inner edges “worn”, those edges which were protected by the mounting of the central stone. The second conjecture, that of



“paper wearing” in a stone packet, was not completely convincing. Another consideration was that there could have been a failure of the edges to meet correctly during the cutting process. This appeared to be rather “far-fetched”, but it may not have been so improbable as first thought.

Professor S. Tolansky in his latest work, "The history and use of diamond", mentions the following:—"An alternative to the old classical scaife for polishing diamond has been introduced in the form of a metal or resin-bonded diamond-impregnated scaife instead of the old cast-iron scaife which used loose diamond grain. Such an impregnated wheel polishes faster than the traditional scaife. Furthermore, it is actually possible to polish both with and against the grain, much to the surprise of the traditional craftsman.



In spite of the greater speed and power of the impregnated wheel, the classical scaife is still likely to be used by the gem polisher for a long time because the impregnated scaife has one quite serious drawback: it has been found that it is difficult to produce sharp edges between the two meeting faces by this procedure".

Is this a probable answer to the recent prevalence of diamonds with "worn facet edges"?

R.W.

SOME OBSERVATIONS ON AQUAMARINE AND QUARTZ

By W. F. EPPLER

PEGMATITE signifies a particular kind of rock somewhat similar to granite but of later origin. It is characterized by crystals of sometimes considerable size, i.e. feldspar and quartz, and furthermore by other crystals containing rarer elements like fluor (topaz), lithium (kunzite, hiddenite), boron (tourmaline), beryllium (emerald, aquamarine, euclase, chrysoberyl, alexandrite), and others. It is said that the pegmatite originated after the main solidification of the granitic magma, filling smaller and larger fissures in the granite and in the adjoining rocks. The conditions under which the pegmatite and its minerals crystallized are called pneumatolytic to hydrothermal and this means that elevated pressures and higher temperatures were effective together with gaseous agents of great chemical efficacy. After the solidification of the system by very slow cooling, the more resistant gem crystals became obtainable by the weathering of the mother-rock.

We mostly are accustomed to see the pegmatite minerals of gem quality in museums, or private collections, or shaped into well cut gemstones. Our gems represent only a very small percentage of the crystals found in nature. The more abundant material is not suitable for gem-purposes and rejected. But it often contains interesting inclusions which reveal significant marks of growth of the host crystal for which the aquamarine offers more than one example.

On the basal plane of an aquamarine crystal (approximately half an inch in diameter and nearly one inch long) some "dust" was observable which could not be removed by scraping or by using strong acids (HF not used). The dust must have adhered very strongly. Figs. 1 and 2 reveal the dust to be an irregularly distributed accumulation of small crystals other than beryl or aquamarine. Near the centre of the pictures, the black and nearly square-shaped spot represents a magnetite. The dark-rimmed and rounded grains are epidote, while the slender and elongated crystals were found to be apatite. These heterogeneous crystals are attached to underlying splinters of quartz, shown better in Fig. 2. Here, the chips of quartz resemble a pavement with

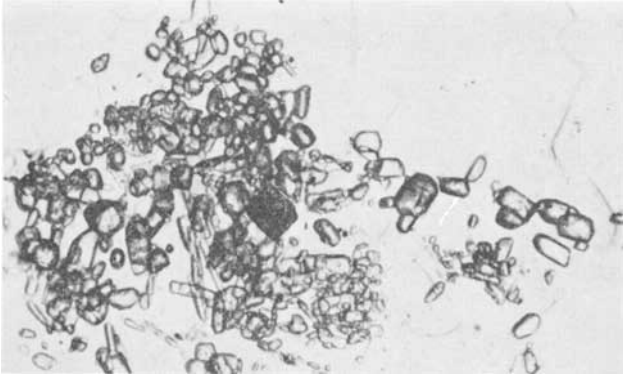


FIG. 1. Quartz splinters with epidote, apatite, and magnetite adhering to the basal plane of an aquamarine, embedded in bromobenzene. $120\times$.



FIG. 2. As Fig. 1, crossed polarizers. $120\times$.

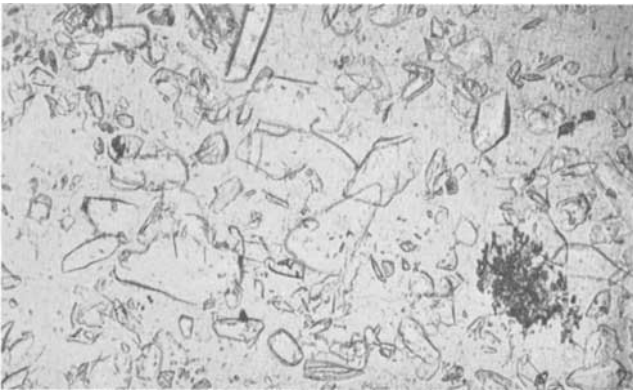


FIG. 3. Chips of quartz on the top of a synthetic beryl, immersed in bromobenzene. $120\times$.

different orientation of each chip. The quartz in its turn adhered to the base of the aquamarine crystal.

A very similar phenomenon could be observed in experiments for synthesizing beryl according to the hydrothermal method. Under certain conditions, the upper side of the seed of beryl used was covered with irregularly formed chips of quartz, as one of the nutrient components (Fig. 3 and 4). They also could not be removed and proved to be fixed by the growing layer of synthetic beryl during the cooling at the end of a run. This observation gives an explanation for the presence of the closely attached heterogeneous crystals on the basal plane of a natural aquamarine as follows:—

Firstly, it can be assumed that in the hydrothermal bomb at supercritical conditions the solid parts of the nutrient are moved by a convectional current up and down the reaction chamber.

Secondly, it can be deduced that within the pegmatite in its hydrothermal state convectional currents were also active, transporting the mother-liquor and small solid particles in directions given by the local circumstances.

Thirdly, it is a fact that the quartz chips only started to grow together with the top layer of the synthetic beryl at the beginning of cooling. Therefore it can further be assumed that in the natural pegmatitic phase a temporary drop in temperature also caused the attachment of solid particles to the aquamarine. Such an assumption makes it possible to accept the idea that with a following rise in temperature the aquamarine continued to grow and included the attached particles. Indeed, this also can be observed in natural beryl as demonstrated by Figs. 5 and 6. Such groups of inclusions are encountered at different levels of the same aquamarine crystal, indicating that a temporary drop of temperature is far from exceptional during the growth of aquamarine. On the contrary, most of the gemstones of the pegmatite series reveal growing marks from which growth in surges can be deduced with certainty, and it is in all probability that this phenomenon is caused by alternating temperatures.

Now it is worthwhile to speculate where the dustlike particles come from. The pegmatite filled fissures in rocks which formerly were compact. The fissures or clefts were opened by tectonic activity by which event the rock was partially crushed and shattered. Something resembling “clouds of dust” must have been pro-



FIG. 4. *As Fig. 3, crossed polarizers. 120 ×.*

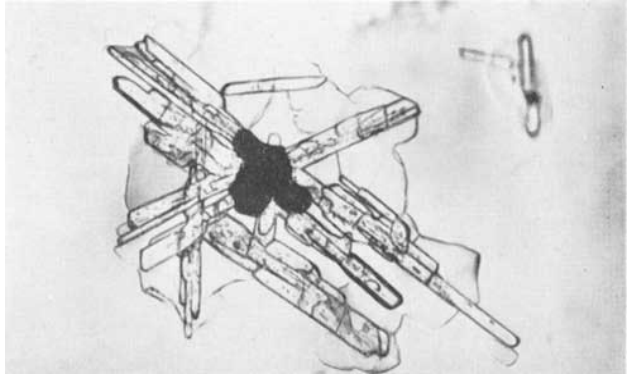


FIG. 5. *A group of heterogeneous crystals as inclusions parallel to the basal plane of an aquamarine. Black—ilmenite; elongated crystals—apatite; partly resorbed particles with only a faint relief—quartz of varied orientation. 120 ×.*

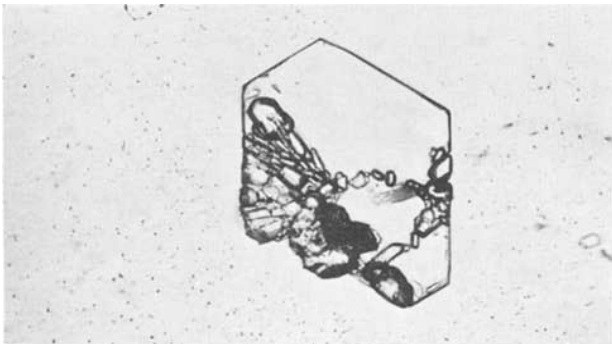


FIG. 6. *A quartz plate bearing small crystals of ilmenite, epidote, and other minerals as an inclusion parallel to the basal plane of an aquamarine. 120 ×.*

duced by the parting of subterranean mountains, after which event an immediate entering of highly tensioned gases into the new gap followed. The gases—or the mother liquor in supercritical condition—reacted with the walls of the fissures and with its débris, and formed the pegmatite and its typical crystals with inclusions of some of the dust. Such a version possibly explains the presence of the very interesting particles on and within the aquamarine.

In Figs. 5 and 6, the extraordinary inclusions are shown parallel to the basal plane of the aquamarine. Perpendicular to this direction, i.e. parallel to the prism zone, the heterogeneous crystals prefer to follow the direction of the c-axis. In Fig. 7, a rod-like quartz is regulated in this direction and it is covered with grains of epidote and with tiny apatites. Fig. 8 exhibits the same kind of inclusions with partly resorbed forms, while in Fig. 9 a pavement of slightly rounded chips of quartz bears elongated crystals of apatite. It seems likely that the growing aquamarine deposited the undesired material in suitable places with regard to its crystal lattice, and this is the direction of the c-axis.

Retrospectively, the observations of this particular kind of inclusions in aquamarine, and their origin, give an explanation for the presence of similar inclusions in a star-beryl owned by B. W. Anderson (*Journ. Gemmology*, Vol. VII, No. 5, Jan. 1960, 183-191). Here also, very similar chips of quartz are in tight contact with rounded crystals of epidote accompanied by apatite. They are not so strictly orientated with regard to the host crystal but, most probably, they have been originated and embedded by a similar process of pegmatitic action as shown before.

Just by chance, another example of this unusual kind of inclusions was found, this time in a rock crystal from Brazil. Gemmologists are familiar with the ghost-like crystal planes in quartz,

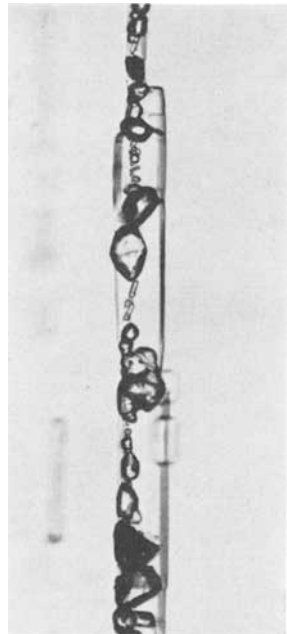


FIG. 7. A rod-like quartz follows the c-axis of an aquamarine and is covered with epidote and tiny apatites. 120 ×.

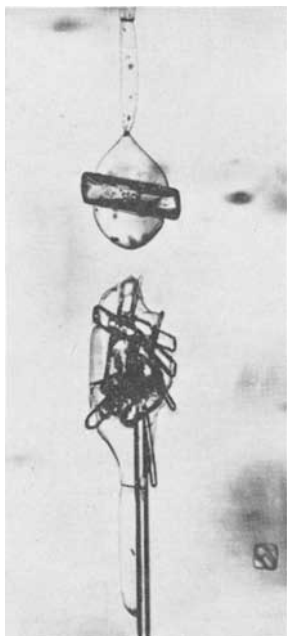


FIG. 8. *Upper part: a heavily resorbed quartz carries an elongated epidote and ends in a thin apatite.*

Below: a partly resorbed quartz is covered with elongated apatites and bears two grains of epidote.

The system of inclusions follows strictly the direction of the aquamarine's c-axis. 120 ×.

FIG. 9. *Partly rounded chips of quartz are attached to overlaying apatites. The dark spot in the upper part is lepidocrocite. The group of inclusions is parallel to the prism zone of an aquamarine. 120 ×.*

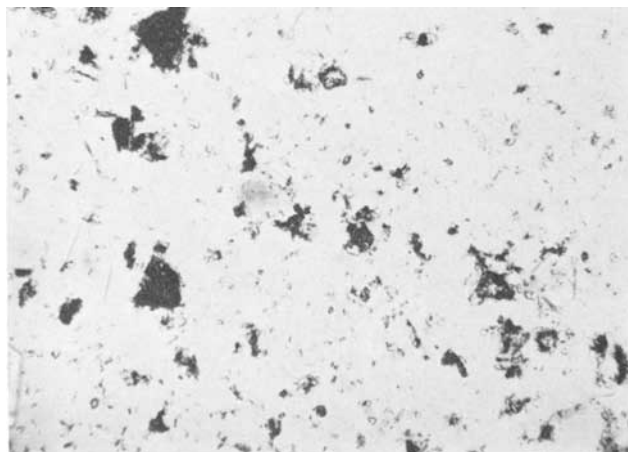
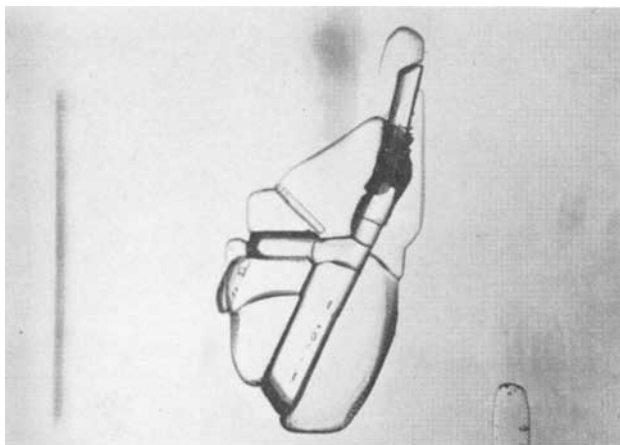


FIG. 10. *Prism face of a ghost quartz with unknown crystals (black) and chips of quartz. 65 ×.*



FIG. 11. *As Fig. 10, crossed polarizers. 65 ×.*

following the outer crystal faces and producing the impression of a smaller quartz crystal embedded in a larger one. Sometimes, two or even three such rock-crystals seem to be put one onto the other, always parallel to each other. Obviously, the smaller ghost-like crystals indicate steps of growth in the course of which the former crystal faces are covered with some foreign material which makes them visible.

Fig. 10 exhibits a view on the prism face of a ghost quartz embedded in a rock-crystal. The tiny dots and the black spots are crystals or groups of crystals not yet identified. Besides these, larger chips of quartz are irregularly distributed over the plane, much better visible with crossed polarizers, as shown in Fig. 11.

A view along the prism face in the direction of the *c*-axis (Figs. 12 and 13) reveals the borderline between the ghost quartz (below) and the rock-crystal (above). It consists of a multitude of small crystals among which greater chips of quartz are attached to the former prism in a direction parallel to the basal plane. It is not difficult to understand that the quartz splinters were generated during the pegmatitic activity in a manner very similar to the origin of the chips of quartz included in the aquamarine.

In summarizing, these unusual inclusions in aquamarine and in quartz are able to give an idea of the impetuous and very vigorous forces which were active to create the pegmatite and its beautiful gem materials.

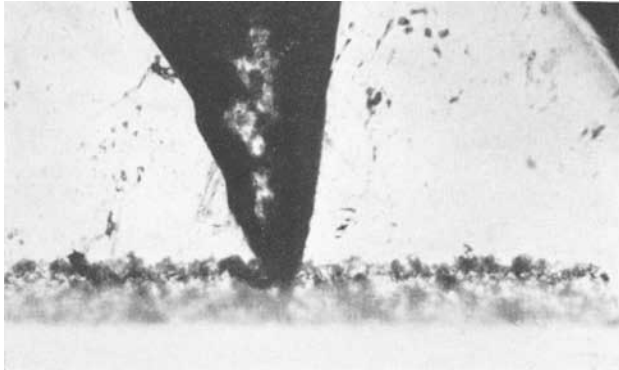


FIG. 12. *View parallel to the c-axis of a Brazilian rock-crystal showing the borderline of a ghost quartz. The black funnel represents a tube of growth parallel to the base plane. 120 ×.*

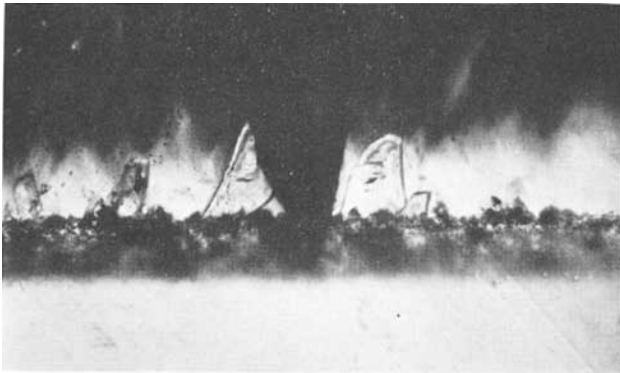


FIG. 13. *As Fig. 12, crossed polarizers. 22 ×.*

Gemmological Abstracts

MURPHY (M. O.). *Turquoise in the Cerrillos Hills*. Lapidary Journal, Vol. 16, No. 8, pp. 720-740 and 806, November 1962.

A full account of the history of the turquoise deposits of the Cerrillos Hills of New Mexico. The geography and geology of the hills are first discussed. Archaeological researches have established that the earliest mining of turquoise, at Mt. Chalchihuitl, was during the late Basket Maker culture, which flourished about 500 to 700 A.D. The early mining was carried out by the Indians using stone hammers and wedges, and using fire and water to fracture the rock. The open pit dug by these early miners is said to be 130 feet in depth and 250 feet in width. Some ancient Indian mining was carried out by tunnelling. There is considerable information about the finding of turquoise ornaments at Pueblo Bonito, and about the trade in turquoise in those times and later. The use of the name chalchihuitl is discussed. It is said that a tragic caving in of one of the turquoise mines was a chief cause of the uprising which finally drove out the Spaniards. The modern mining of turquoise from this locality started during the last half of the 19th century, and a note is given about the Tiffany Turquoise Mine and its connexion with G. F. Kunz and the Tiffany Jewellery Company. The Tiffany Company disputes having had any controlling connexion with the mine. There is a review of the future possibilities for the recovery of turquoise from the Cerrillos Hills.

26 illus., 14 refs.

P.B.

WEBSTER (R.). *Turquoise; natural, treated, synthetic, and simulated*. Lapidary Journal, Vol. 16, No. 8, pp. 758-777 and 806, November 1962.

A general article on turquoise from all localities; on the minerals which simulate turquoise, on the various treatments carried out to improve turquoise and on the various artificial substances

made to imitate it. The ancient names applied to turquoise are discussed and something of the old lore and superstition is told. Good accounts are given of the geology of the Sinai and Persian deposits and of the mining at these places. Other oriental deposits are mentioned and there is a good general survey of the North American localities. Artificial treatments applied to turquoise in order to improve the colour or to "bond" the more porous types are discussed in detail. Variscite, lazulite, chrysocolla, shattuckite, and a new mineral papagoite, as well as the recently produced dyed howlite, are described as simulating materials. There is a good account of odontolite. The various types of imitation turquoise are discussed and a number of tests are given.

12 illus., 65 refs.

P.B.

SMITH (I.). *Turquoise of the south-west.* . Lapidary Journal, Vol. 16, No. 8, pp. 786-793, November 1962.

A valuable article on the turquoise jewellery of the American south-west with particular reference to the work of the Salado people (1300 A.D.). Many of the turquoise mines are described as well as the mining and fashioning of the turquoise both in olden times and the present day.

12 illus., 50 refs.

P.B.

SEAL (M.). *The surface structure of diamonds.* Gems and Gemology, Vol. X, No. 10, pp. 309-314, Summer 1962. (Reprinted from Engelhard Industries Technical Bulletin of Sept. 1961.)

Describes the surface structures on natural and synthetic diamond crystals under examination by optical and electron microscopy.

16 illus.

P.B.

CROWNSHIELD (R.). *Developments and highlights at the Gem Trade Lab. in New York.* Gems and Gemology, Vol. X, No. 10, pp. 304-308, Summer 1962.

Reports on specimens of turquoise which have been painted and subsequently coated with plastic; conch shell used as white coral, a very shallow diamond mounted with a smaller diamond below it, and three ordinary type diamond doublets. Various

colours in quartz triplets (soudé stones), carved jade-like serpentine and an unusual Chinese-drilled cultured pearl are mentioned. Unusual minerals encountered were a large faceted brazilianite, brown kornepurines, a rare cat's-eye hambergite, a green euclase and a very rare transparent hodgkinsonite.

12 illus.

P.B.

LIDDICOAT (R. T.). *Developing the powers of observation in gem testing.* Gems and Gemology, Vol. X, No. 10, pp. 291-303 and 319, Summer 1962.

A timely article explaining the value of an initial observation by the unaided eye or by the use of a lens in assessing the nature of a stone. Characters, such as the doubling of the back facets, strong dispersion, types of characteristic fractures, curvature of the facets (concave facets in moulded glass) and inclusions, will give important data. Abrasions of polished surfaces, which might inhibit later instrumental tests, should be looked for. The finding of taaffeite is given as an illustration that even small doubling of the facets can be seen. There is a short discussion on corrected and uncorrected lenses. The use of the hand-lens is adequately discussed, particular attention being paid to the various ways of illuminating the specimen under examination. Notes are given on how to find out whether a spot is inside the stone or on the surface. Observation of the lustre as a guide to the refractive index and the difference in lustre of the two parts of a garnet-topped doublet will tell a lot. Types of fracture and certain optical effects will often provide indications, or even conclusions, as to the nature of the stone.

15 illus.

P.B.

LIDDICOAT (R. T.). *Developments and highlights at the Gem Trade Lab. in Los Angeles.* Gems and Gemology, Vol. X, No. 10, pp. 315-319, Summer 1962.

The use of hydrochloric acid as a test for lapis-lazuli is mentioned. Unusual stones examined in the laboratory were cat's-eyes in apatite, zircon and kornepurine. A natural "padparadscha" sapphire is mentioned and other stones examined were ekanite, dyed serpentine, colourless brazilianite and a ruby-coloured tourmaline. The Plato method was used to determine a colourless sapphire brilliant as a synthetic stone.

4 illus.

P.B.

ANON. *Diamonds mined off the seabed*. Mining Mag., Vol. 107, pp. 40-41, 1962.

A brief report on the first results of prospecting for diamonds off the coast of South-West Africa, and near the Cape of Good Hope: 45 diamonds were obtained from the South-West Africa coast.

R.A.H.

DAVIES (R. G.). *A green beryl (emerald) near Mingaora, Swat State*. Geol. Bull. Punjab Univ., No. 2, 51-52, 1962.

Green beryl occurs along shear zones in carbonate-talc rock or in quartz veins, in broken lenses of ultrabasic rock consisting of antigorite, talc, chlorite, calcite, chromite, and magnetite, near Mingaora, Swat State, Pakistan.

R.A.H.

EPPLER (W. F.). *Die diagnostische Bedeutung der Einschlüsse in Edelsteinen*. The diagnostic significance of inclusions in precious stones. Umschau in Wissenschaft u. Tech., 62 472-475, 1962.

S.P.

FONTES (C.). *Sobre os diamantes Brasileiros*. Gemologia, 25, pp. 31-35, 1961.

A brief note of some of the outstanding diamonds found in Brazil, with details of colour, weight and ownership of the 16 largest.

S.P.

BOOK REVIEW

TOLANSKY (S.). *The history and use of diamond*. Methuen, London, 1962. 21 half-tone plates, 11 line illus. Small f'cap 4to. 30s.

Professor Tolansky is well-known for his studies of the micro-structure of diamond surfaces and it is a pleasurable and rewarding surprise to read this simply written and entertaining account of diamond. It does not pretend to be a text-book—for instance a chapter on the wearing of diamonds by women touches upon an aspect usually absent from texts about the gem—and in many ways it gains because of this. Aimed at interesting people in diamond it succeeds admirably, and those who browse through its 166 pages should be encouraged to probe the subject more deeply.

S.P.

THE IRRADIATION OF GEMSTONES

By *THOROLD JONES*

Atomic Energy Research Establishment, Harwell

Read at the Eighth International Gemmological Conference, Milan October, 1960

INTRODUCTION

It would not be inaccurate to say that from the time material things began to exist, changes in them must have taken place. It is logical to assume therefore, that the changes in which we are particularly interested have also been occurring, and whilst one does not ponder on, say, the changes effected by heat, it can also be assumed that a simple mineral such as rose-quartz would have lost its beautiful colour after sufficient exposure to the sun's rays many millions of years ago. There is no known record of when gemstones first were deliberately heat-treated with the intention of changing their colour, and incidentally, how far back the heat-treatment of zircons can be traced has yet to be revealed. A more accurate picture, however, can be shown in regard to colour changes effected by the bombardment of gem stones with particles of various energies. During the last century diamonds were exposed to gamma rays emitted by radium¹ and this resulted in a change of colour. The discovery of X-rays and their uses, made available an additional source and various workers used this means for treating minerals and gem stones. Once again, colour changes resulted. One must not forget, too, the natural bombardment of minerals with particles emitted by naturally radioactive elements occurring in the earth's crust and studies of these effects have been going on for nearly one hundred years. Evidence that such irradiation has taken place in respect of diamond is presented by Dugdale². The whole field presents a fascinating subject for study, which will probably receive attention in the future.

IRRADIATION SOURCES

When nuclear fission made its impact on civilization it brought with it an entirely new era which has affected nearly everything in life. With this era came new sources of energy with which to treat materials and as is now widely known much benefit is derived from the research work on irradiation. There is insufficient time to

dwell even broadly on this aspect and remarks must be confined to the work which has been carried out on minerals and gemstones.

ATOMIC PARTICLES AND COLLISIONS

There are a number of elementary particles which can be used for bombardment of solids. One of the more important of these is the neutron which is an electrically uncharged or neutral particle capable of penetrating matter and colliding with and displacing the atoms composing that matter. When it does collide with an atom it imparts some of its energy to that atom which can move far enough to collide with and displace yet another atom (Plate I). “Knocked-on” atoms cause the most damage to the lattice and this affects the physical properties of the crystal and in some cases causes severe changes. When beryl, which has a similar structure to quartz, is irradiated sufficiently there is so much distortion of the lattice that the crystal does in fact become non-crystalline or amorphous. It seems almost superfluous to mention that the colour of gemstones can be due either to inherent constituents (idiochromatism) or to impurities (allochromatism) which form part of the electronic

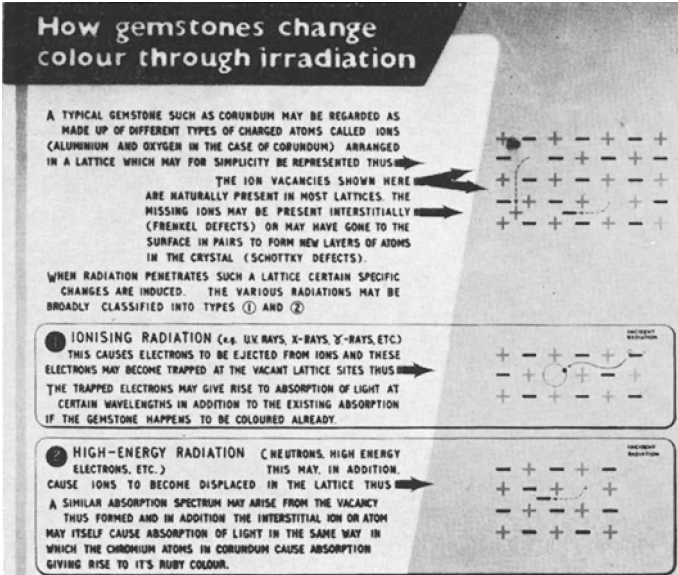


PLATE I

structure of the lattice and it is on the nature and arrangement of this lattice that the selective absorption of light depends. The irradiation changes the lattice arrangement and so it might be expected to change the light absorption also. Often this change is in the visible region of the spectrum and so the stone changes colour. Now in the same way that fabricated metal is relaxed or annealed by heat treatment it is possible, to a limited extent, to restore the original arrangement of the atoms in a non-metal by controlled heating. Many of the pleasantly coloured diamonds owe their colour to this treatment and provided care is exercised no damage to the stone is likely to occur.

Examples of gemstones that have been irradiated with interesting results are: chrysoberyl, phenakite, topaz, garnet and zircon.³

A phenakite and a zircon belonging to B. W. Anderson were irradiated both in BEPO for one hour at $9 + 10^{11}$ n/cm²/secs.(n.v.t.), and in the Van de Graff accelerator for three hours at $\frac{1}{2}$ MeV continuously and in each case an unattractive yellow colour was induced, which was removed by heat-treatment at 500°C.

A diamond was irradiated in BEPO for three weeks when it became black and opaque and heat treatment at a temperature in excess of 1500°C failed to restore any of its original transparency. A similar phenomenon is reported by Crawford and Wittels.⁴

FIRST EXPERIMENTS AT HARWELL

In the early days at Harwell the graphite moderated uranium reactors were used for very many purposes, one of them being the irradiation of diamonds with neutrons, and this work was carried out by Dugdale.⁵ The results of the experiments were not significant and they caused little comment in the commercial world.⁶

Interest revived in recent years mainly because it was thought that a poor quality stone could be improved sufficiently to enhance its colour and, of course, its value. As is now known this idea has been proved to be erroneous but in spite of this, however, diamond dealers continue to have their poor quality stones irradiated⁷ and heat-treated and it appears that there is a very slowly growing demand for irradiated stones which are mainly bluish-green and yellow in colour. At least one patent specification for diamond treatment has been filed in the British Patent Office. In the United States the main selling point is that such stones are marketed

as "Cyclotron diamonds".⁸ The point should not be missed, however, that this is likely to be a novelty market of limited duration. The chief method now employed for treating diamonds is the one using fast neutrons resulting from the fission of uranium in an Atomic Pile or Reactor, as it is now commonly called. The use of particle-accelerator machines or "atom smashers" for colour alteration is expensive but some of the stones so treated are attractively coloured. In a typical electron irradiation the depth of the damage region might be a fraction of a millimetre in contrast to neutron irradiation where the damage is distributed randomly throughout the irradiated material. It is not surprising, therefore, that the discolouration of an electron-bombarded stone is often only superficial and it could be removed by very drastic repolishing.

A collection of other precious stones was assembled in duplicate and one set was irradiated in the uranium graphite reactor BEPO for periods varying from three to six days. The result of the treatment from the gemmologist's point of view is interesting, and disappointing, because none of the stones have been improved in appearance but as could be seen from the absorption spectra quite definite changes have occurred. No measurable changes have occurred in the physical properties of these stones but it should be remembered that they have had a comparatively short period in the reactor.

METHODS OF DETECTION

It is reassuring to know that natural blue diamonds can almost infallibly be identified and a recent simple device, based on the fact that they are semiconductors of electricity and invented by Custers, Dyer and Raal,⁹ can be set up and operated with a minimum of expense and complication. One must, however, be quite clear about the difficulties attending differentiation between naturally-coloured diamonds and diamonds that have been coloured by bombardment; modern stones whose colours have been altered by nuclear machine or pile-irradiation, have a radioactivity of limited duration. Dugdale² confirms that residual radioactivity in diamond after irradiation is undetectable with a Geiger counter quite soon after bombardment. It is therefore necessary to observe the behaviour of suspect stones when they are subjected to ultra-violet rays or viewed through the spectroscope.¹⁰ In general, however, it

does appear that there is still no clear-cut diagnostic test in regard to irradiated diamonds.

It is interesting to note that although the collection of irradiated gem stones is now some years old, it still retains measurable radio-activity indicating that some of the stones contain elements which possess a long half-life, that is, they take a long time to lose their activity. Using a sensitive beta-gamma counter an approximate radiometric survey was carried out on all the stones exhibited. It must be appreciated however, that whilst effort was made originally to assemble pairs, the specimens were not, as can be seen from Table I, strictly comparable.

TABLE I
RADIOMETRIC ANALYSES OF IRRADIATED GEMSTONES
BETA - GAMMA COUNTER

<i>Specimen</i>	<i>Counts per Minute</i>		<i>Remarks</i>
	<i>Standard Stone</i>	<i>Treated Stone</i>	
Green Tourmaline	Nil	136	
Kunzite	1	84	
Peridot	1	4,384	
Orthoclase	Nil	115	
Rhodolite Garnet	1	666	
Demantoid Garnet	4	74	
Almandine Garnet	3	2,293	
Natural Ruby	4	9	
Natural Sapphire	Nil	8	
Synthetic Ruby	Nil	513	
Synthetic Sapphire	7	5	
Synthetic Sapphire	3	—	
Natural Blue Spinel	—	2,393	
Synthetic Ruby	4	10	
Synthetic Sapphire ("Alexandrite")	Nil	33	
Synthetic Sapphire	Nil	211	
Synthetic Pink Sapphire	6	10	
Cairngorm	Nil	12	
Amethyst	7	4	
Rose Quartz	4	Nil	
Opal	Nil	95	Recent irradiation
Zircon	2	1,242	
Zircon	Nil	1,051	
Zircon	19	4,633	
Zircon	11	4,760	
Brazilian Topaz	10	8	
Brazilian Topaz	7	Nil	
Beryl	5	2,636	
Spinel	Nil	4,549	
Spinel	11	6,959	
Emerald	Nil	93,693	Recent irradiation
Periclane	13	—	
Cultured Pearl	Nil	—	
Cultured Pearl	12	—	
Cultured Pearl	10	—	
Natural Pearl	6	—	
Cultured Pearl (Neutron)	—	2,778	Recent irradiation
Blister Pearl (Neutron)	—	3,402	" "
Baroque Pearl (Neutron)	—	184,000	" "
Cultured Pearl (Electron)	—	3	" "
Cultured Pearl (Electron)	—	2	" "
Cultured Pearl (Electron)	—	4	" "
Synthetic Rutile	—	50	" "
Blackened Diamond (Neutron)	—	10	" "
Blue Diamond (Electron)	—	8	" "
Blue Diamond (Electron)	—	9	" "

All the standard stones gave low readings whereas, with few exceptions, all the irradiated stones gave significant and in some cases high readings. After a further large collection had been examined (Table II) there is some justification for accepting a critical radiometric analyses as a guide to the origin of a specimen.

TABLE II
RADIOMETRIC ANALYSIS OF UNTREATED JEWELLERY AND GEMSTONES

<i>Specimen</i>	BETA - GAMMA COUNTER	<i>Counts per Minute</i>
Three-stone diamond ring		7
Rough industrial diamond		3
Pink synthetic sapphire ring		7
Natural Yellow sapphire		Nil
Natural rough corundum		2
Natural black "Silky" sapphire		Nil
Natural blue star sapphire		3
Natural dark green sapphire		Nil
Natural blue sapphire		14
Green zircon and white sapphire ring		178
Orange zircon ring		Nil
Eleven stone green zircon bracelet		972
Yellow zircon		73
Crystal of brown zircon		98
Blue zircon		11
Orange zircon		21
Crystal of Red spinel		Nil
Crystal of Red spinel		5
Rough Madagascar aquamarine		6
Colourless beryl		Nil
Morganite (beryl)		Nil
Aquamarine		1
Hessonite garnet		7
Pyrope garnet		Nil
Pyrope garnet		Nil
Pyrope garnet		Nil
Hessonite garnet		Nil
Hessonite garnet		4
Green glass		12
Yellow glass		Nil
Green glass		47
Green glass		Nil
Green glass		Nil
Soude emerald (quartz)		Nil
Green tourmaline		Nil
Green tourmaline		Nil
Green tourmaline		Nil
Yellow tourmaline		12
Parti-coloured tourmaline		9
Peridot		Nil
Peridot		Nil
White topaz		Nil
White topaz		11
Pink topaz		Nil
Orange topaz		1
Amethyst		Nil
Kunzite		1
Apatite		Nil

DICHROISM

Work on the collection of irradiated stones was started in 1957.¹¹ Some striking dichroic effects were seen in what were previously colourless stones and novel though this appears, it must be remembered that a coloured birefringent stone could be expected to exhibit some pleochroism. The rhomb of calcite irradiated in connection with the pearl experiments, exhibits strong dichroism.

Kunzite, which normally displays distinct dichroism of pale pinks, presented a sharp contrast of pink and brown after irradiation, and it is worthy of note that the irradiated stone was originally bombarded with X-rays, after which it became a delightful "hiddenite" green. Unfortunately, however, this colour disappeared and the stone reverted overnight whilst it was beneath an ordinary tungsten filament lamp and Pough¹² comments on the need for such specimens to be kept cool and in darkness. The colourless sapphire boule after irradiation displayed distinct dichroism, whilst the irradiated ruby boule twin-colours contrast markedly with those of the untreated one.

A cut blue zircon after irradiation displayed no dichroism yet a synthetic sapphire ("alexandrite"), normally showing two shades of pink, showed a sharp contrast of pink and orange after treatment.

The square-cut synthetic blue sapphires, normally blue and mauve, changed to green and mauve and what was taken to be a natural blue sapphire was matched for colour with a synthetic blue sapphire. Quite inadvertently a natural blue spinel has been selected and this stone became a rich brownish-red, which is no doubt related to the colour seen when natural blue spinel is viewed through the Chelsea colour filter.

There was nothing consistent in the behaviour of naturally pleochroic stones after irradiation, therefore no significance should be attached to these results, and indeed as would be expected, there is in some cases considerable disparity in the absorption spectra of the pairs of stones.

In 1942¹³ Cork wrote of experiments carried out at the University of Michigan. He bombarded crystals with deuterons in a cyclotron, and on occasions, instead of forming colour centres in the bombarded area, colour formed at the edges and he puts this reversal down to too intense a bombardment.

He found, as did the writer, that X-ray bombardment produced an ephemeral effect but neutron-treated stones, which were permanent at room temperature, would revert if subjected to annealing temperatures of 500°C.

It is interesting confirmation that his rose-quartz experiment produced a result comparable with that produced at Harwell and the disparity between his diamond annealing temperatures and those of other workers tends to support the view that these temperatures are not critical.

At Princeton, Bass¹⁴ studied the effects of gamma irradiation on certain minerals and concluded that no important changes had been effected other than those concerned with colour, in minerals of interest to gemmologists which included quartz, fluor spar and epidote.

FLUORESCENCE

The collection of irradiated stones was examined under a concentrated beam of ultra-violet light emitted by a quartz-mercury vapour lamp and, whilst no significant data accrued, it was noted that outstanding differences in fluorescence were always related to severe colour changes after irradiation.

PEARLS

The irradiation of pearls, natural or cultured, has not, so far, occupied the attention of many workers,¹⁵ but one case of colour change has been reported from Japan. Neutron bombardment of pearls was carried out in BEPO and the results can scarcely be called dramatic, the colours are not very attractive and subsequent heat-treatment would, without any doubt, effectively drive off combined-water and decompose the organic constituents. Profiting by the experience gained with diamonds it was thought a good idea to subject pearls to electron bombardment in the Van der Graaf Particle Accelerator and the first mild dose of fast electrons of 1 MeV at 1 microamp for one minute produced a greenish colour. As considerable heat is evolved during the process special precautions were taken to cool the pearl. Rather surprisingly, a further identical dose caused a reversion and the pearl became white again but whether this was due to auto-annealing by the second attack or whether it was due to excess heat is not clear, but severe superficial cracking would indicate the latter (Plate II). A repeat of the experiment with two pearls again resulted in the green colour. One of these pearls was then placed under a powerful quartz mercury-vapour ultra-violet lamp for three hours but this had no effective annealing action. Petrological examination of some of the specimens was carried out employing conventional techniques. The pearls were lapped onto glass slides using "Hyprez" diamond paste and fluid. Next, the specimens were secured to the slides with "Araldite" Resin and after curing at relatively low temperature,

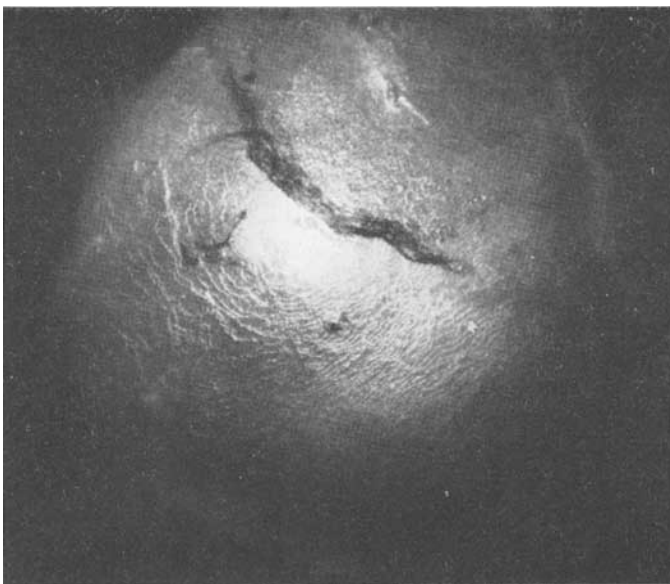


PLATE II

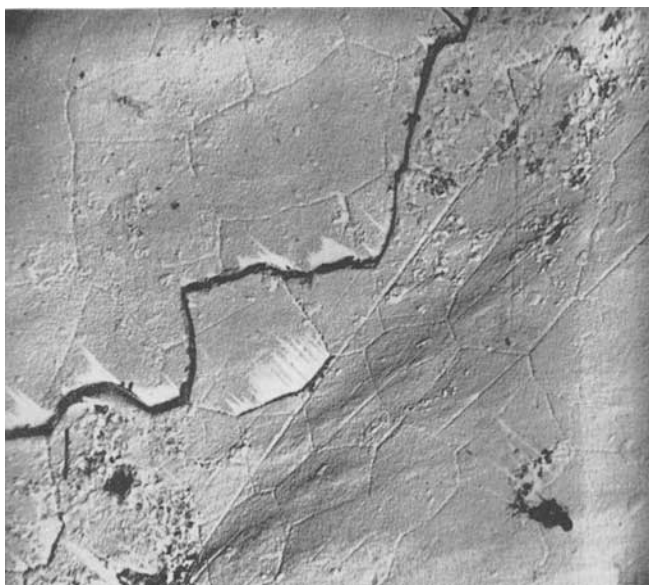


PLATE III

cut with a thin diamond wheel. Final lapping was achieved with "Hyprez" diamond paste and fluid on a disc of high-alumina porcelain. So thin were the ultimate sections that they suffered damage during the final stages but it clearly could be seen that bombardment had effected the organic layers and there was no discernible change in the calcium carbonate layers, apart from the platy layers and hexagonal cross-sections having an increased relief after irradiation, and this shows up extremely well in the electron micrograph (Plate III). A cultured pearl was cut into two, one half irradiated in BEPO and the two halves polished and macro-photographed. No further evidence is necessary of the damage sustained (Plate IV). A baroque Australian pearl was sectioned and one half irradiated with neutrons in BEPO and microscopic examination revealed a considerable amount of damage. Under an ultra-violet analytical lamp it was observed that the faint greenish fluorescence of all the pearls had slightly deepened in colour after irradiation.

The cause of the discolouration of pearl after irradiation is not entirely clear in spite of further experiments carried out on the constituent carbonate. A specimen of clear crystal calcite was

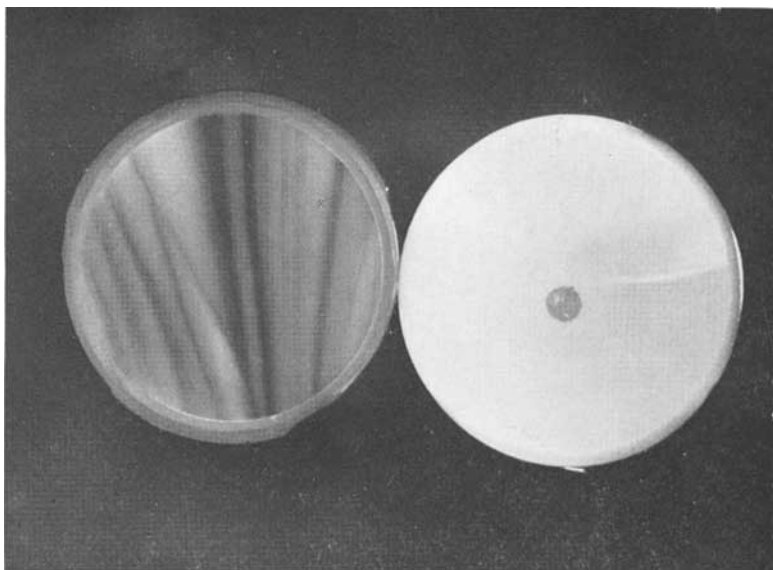


PLATE IV

bombarded with neutrons in BEPO for 56 hours at a flux of $11.6 + 10^{11}$ nvt, after which it became a deep yellow in colour. It is possible that decomposition of the conchiolin contributes to the colour change but after microscopical examination the conclusion to be drawn is that a change has occurred in the surface platelets, which, by diffraction and interference, produce the much-prized "orient".

This change, subtle though it may be, could be responsible for selective absorption affecting the diffraction-interference effect and resulting in the greenish "orient" now to be seen in the irradiated pearls.

CONCLUSIONS

It will be seen that several interesting effects arise from the irradiation of gemstones. It appears impossible at present to predict colour changes of diamonds on irradiation and bombardment of precious stones usually results in deterioration in appearance. Interesting effects relating to dichroism and fluorescence, which require further investigation, have been noted.

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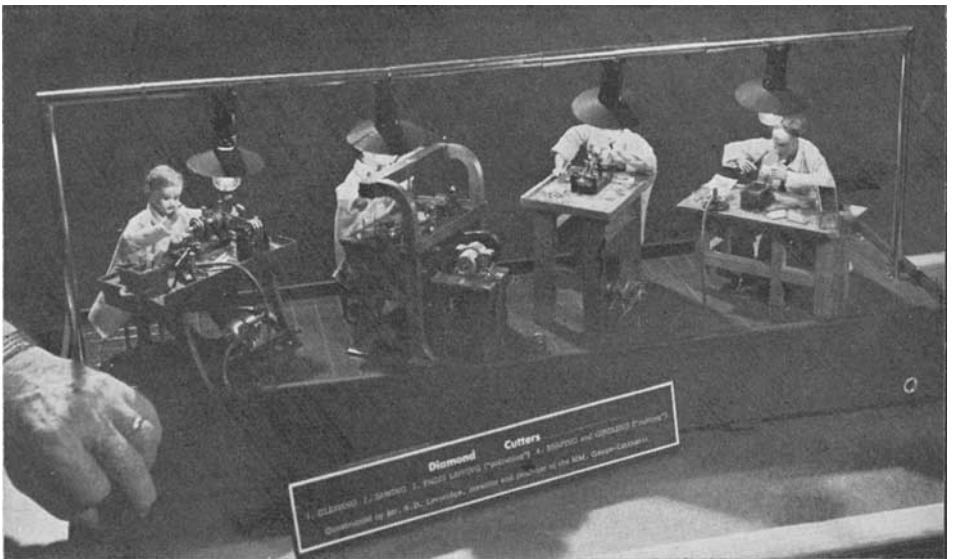
DIAMOND CUTTING IN LILLIPUT

Dean Swift failed to include in his book the practice of the diamond cutting art by the Lilliputians, but an attempt to make up for this omission has been made by the inventor of the A. D. Leveridge Mm. Gauge-Estimator.

Illustrated is Mr. Leveridge's latest creation, which is the fruit of a long period of patient and painstaking work. To obtain an idea of the diminutive size of the diamond cutting factory, which he personally constructed, note the maker's hand and a pencil shown in the picture. The full length of this group of four different work benches is only 24 inches, and their height only 4 inches. Each bench has its electric lamp, motor, and robot workman.

The cleaver's hammer drops rhythmically upon his knife, which he positions each time, all in a life-like manner. The girdling machine, the sawing machine and the scaife are only one inch in length or diameter. In like proportions are the cleaver's boxes, and all the loupes, dops, tangs, weights, tweezers, bunsen burners, hammers, wrenches, lamps, motors, belts—even diamond papers and rough stones.

The tiny factory has attracted much attention in the U.S.A. and it is expected that it will be exhibited at diamond trade shows.



ASSOCIATION NOTICES

PRESENTATION OF AWARDS

Fellows of the Association from all over Britain and successful students coming from places as far away as Auckland, New Zealand and Pennsylvania, U.S.A., gathered at the Goldsmiths' Hall on 5th November, 1962, for the annual reunion and prize presentation.

The presentation was made by Mr. Robert Webster under whom many had studied and with whose books even more are familiar. He took the opportunity of making a forecast concerning the way in which gemmological knowledge might—and needed—to be advanced in the future.

Mr. Webster recalled that it was 28 years since he walked up the steps and on to the platform at the Hall for the first time to receive his diploma. In the early days, he said, gemmology was much simpler. Provided students could absorb and communicate a lot of data and figures they usually succeeded in the examinations. The percentage of failures was low. By the mid-thirties things had begun to change. New instruments and new techniques were introduced which affected practice more than theory and this development had continued. It was one reason why the third year of study had been introduced during which some modest research could be done.

After the war the change had been complete. This had mainly been caused by the search for new minerals with possible war uses and many found their place as gem stones. This had continued until to-day there were present problems in gemmology to which the answer was not known.

Because of this and further developments he forecast that the gemmologist of the future would need to know far more of chemistry, physics and even electronics than he knew to-day. He saw the role of the gemmologist in the future as one that was split into two, with the split ever widening.

Most of the students who took the examinations were jewellers. He realized that with all their other commitments, the jeweller could not take on an extra-gemmological series of studies, however valuable it might be to his trade. Already the jeweller had to know far more than in the past about more subjects. The basic training he could get in his Fellowship course should, however, be sufficient for his trade needs. There was another group of students who were not connected with the jewellery trade but took up gemmology from an inborn liking for the subject. They often had a good grounding in science. They could be a valuable help to the Association and indirectly to the trade in the knowledge they gained.

Unfortunately, said Mr. Webster, the trade was made up of small firms that were unlikely to get together to establish a laboratory for research in the way that large firms did in their different fields. Pure research work in gemmology was needed and not just the odd bits of work that might be sandwiched between routine jobs. A small but expert group of Fellows might be able to get together and do such research. They often had access to the necessary equipment that could help them. Such a group might produce the answers to some of the problems which at present, lacking the time and equipment, we cannot.

Thus he saw the gap between the ordinary "trade" gemmologist and the scientific gemmologist continually widening, because there would have to be much greater attention paid to research in the future.

Presiding over the gathering was the Chairman, Mr. F. H. Knowles-Brown, who took the opportunity of thanking the Worshipful Company of Goldsmiths for the hospitality afforded them and reminded those present that a Hall had stood on the present site for over 600 years. The Chairman congratulated Mr. Webster on his latest book and acknowledged the great work he had done for gemmology and was sure that he would not mind his mentioning that as a colleague of Mr. B. W. Anderson great things had been expected of him as B. W. Anderson was, in his opinion, probably the world's most eminent gemmologist.

Mr. B. W. Anderson, in proposing a vote of thanks, spoke of his link with Mr. Webster over the past twenty years or so as student, colleague and friend. He said it was particularly appropriate that Mr. Webster should have made the prizegiving on this occasion, the year which saw his new book published. Moreover, Mr. Webster was the man who had helped so many of those who had received awards, to pass the examinations by the teaching he had done.

He recalled that the very first class he had taken at the Chelsea Polytechnic had been a star one, including among its students not only Mr. Webster, but also Mr. Keith Mitchell, Mr. W. Flower and Mr. Ross Popley. It was also the 1934 class at Chelsea that marked the period of the evolution of the Chelsea filter, now used throughout the world as a useful gemmological tool.

MIDLANDS BRANCH

A meeting of the Midlands Branch of the Association was held at the Imperial Hotel, Birmingham, on Friday, 26th October, when the Chairman, Mr. W. W. Bowen introduced the guest speaker, Mr. Lionel Burke, Publicity and Group Public Relations Officer to De Beers Consolidated Mines, whose subject was "Diamond Distribution".

Mr. Burke began with a brief historical review of De Beers and explained that the syndicate came into being because of the need for consolidation among individual diggers, in order to protect their interests. At the beginning of this century, the discovery in the Transvaal of a chain of gem-quality diamonds almost ruined the company, but to-day De Beers control some 40% of the world output of diamonds.

On the question of markets, Mr. Burke named Amsterdam, Antwerp, London and New York as the largest and most significant, and said that in London each registered buyer (of which there are several hundreds, all cutters and dealers)

receives an invitation to apply for inclusion in the monthly "sites", where carefully graded diamonds are sold in series only—and for cash. He emphasized the importance of a stabilized market to the whole of the diamond industry.

At question-time, Mr. Burke answered several interesting points raised by members, and the meeting closed with a sincere vote of thanks to Mr. Burke, proposed by Mr. Norman Harper, Vice-Chairman of the Association.

COUNCIL MEETING

A meeting of the Council was held at Saint Dunstan's House, Carey Lane, London, E.C.2, on Monday, 5th November, 1962. Mr. F. H. Knowles-Brown presided.

Details were received of the specialist course in gem diamonds, which had been commenced at the Jewellery and Silversmithing School, Birmingham, with Mr. Norman A. Harper as lecturer. The Council agreed in principle to act as an examining body in connexion with the course.

The following were elected to Fellowship, Ordinary and Probationary membership:—

ELECTED TO FELLOWSHIP

Aho, Risto, Laaksolahti, Finland	Hinton, Bernard A., Toronto, Canada
Allnutt, Anthony J., London	Hollens, John F., Pinner
Asprey, Maurice, London	Hudson, Douglas G., Whitstable
Bacon, Stephen J., London	Johne, Vera A., Oslo, Norway
Berkel, Joannes V. M. v., Utrecht, Holland	Johne, Thor A., Oslo, Norway
Borgen, Annemarta, Oslo, Norway	Jones, David C., Leamington Spa
Borgen, Per O., Sarpsborg, Norway	Klerk, A. F. C. de, Oud-Gastel, Holland
Chesebrough, Rosser, Sherman Oaks, Calif, U.S.A.	Leimu, Veikko H. K., Hämeenlinna, Finland
Crank, Susan Elizabeth, Bolton	Lieberman, Ian S., Ilford
Dowse, John E., Birmingham	Marshall, John F., Sutton Coldfield
Egli, Ernest, Geneva, Switzerland	Marshall, Nigel, Birmingham
Erichsen, Bjørn T. N., Horten, Norway	Marno, Raimo A. U., Helsinki, Finland
Evans, Rennie M., Toronto, Canada	Moi, Gerd, Oslo, Norway
Farrant, Eric R., London	Møller, Jørgen E. R., Copenhagen, Denmark
Fine, Jay, Orillia, Canada	McCarty, Fay V., Birmingham
Foulkes, Peter C. A., London	McGoldrick, Bernard, Liverpool
Freedman, Israel, London	Otteren, Karl-Jørgen, Sandnes, Norway
Gillougley, James H., Glasgow	Pettersen, Egil N., Fredrikstad, Norway
Goad, Michael J., Toronto, Canada	Petzall, Ossi G., Falkoping, Sweden
Griffiths, John A., Kidderminster	Potterat, Raymond, Geneva, Switzerland
Gunaratne, Herbert S., Colombo, Ceylon	
Harper, David C., Welling	
Heidelberger, Martin, Zürich, Switzerland	

Robinson, David M., Liverpool
 Sarin, Baldev K., London
 Shotton, John J., London
 Simpkins, Una M., Caddington
 Thompson, Colvin G., London
 Travis, Denis J., Esher
 Turnbull, Elizabeth, Sunderland
 Turton, Phillip J., Solihull

Virkkunen, Leena K. M.,
 Roihuvuori, Finland
 Waters, Peter A., Manchester
 Weighell, Stephen N., London
 Werkhoven, P. J. K. van,
 Hilversum, Holland
 Weston, Raymond W., Solihull
 Wilkins, David, Swindon
 Williams, Geoffrey F., Esher

TRANSFERRED FROM ORDINARY AND PROBATIONARY MEMBERSHIP
 TO FELLOWSHIP

Blyth, Elizabeth R., Nanaimo,
 Canada
 Bradley, Robert C., Didcot
 Burke, Frieda, Philadelphia, U.S.A.
 Charles, Russell, Camp Hill, U.S.A.
 Cropp, Alan R., Lucerne,
 Switzerland
 Fleming, John A., Auckland,
 New Zealand
 Fraleigh, Jack, Toronto, Canada
 Gould, Henriette Johannesburg,
 S. Africa
 Humphreys, Alan L., Andover
 Jones, David W., Crawley Down
 Kan, Noah, Hong Kong

Kern, Edward, West Hartford,
 U.S.A.
 Lee, Raymond G., Torquay
 Lodge, John W.,
 Newcastle-upon-Tyne
 McChlery, George M. A., Glasgow
 Maunton, Frederick J., Bromley
 Nickolds, Ann M., London
 Penner, Ernest, Islington, Canada
 Ranger, Clive J., Bromley
 Searle, Ian V. H., Ilford
 Selvon, Dennis R., Woodford Green
 Sheriff, Hassan, London
 Simpkins, Una M., Sidcup
 Tivoli, Harold, Kansas City, U.S.A.

ELECTED TO ORDINARY MEMBERSHIP

Bensusan, Kilian E., Sepulveda,
 Calif, U.S.A.
 Böhmke, Frederich C., Shabani,
 Southern Rhodesia
 Bond, Cecil A., Waltham Abbey
 Chambers, Edward F.,
 North Chelmsford, U.S.A.
 Chevrot, Pierre, Geneva, Switzerland
 Climie, Robert, Ballindalloch, Banff
 Dowie, Frederick G., Christchurch,
 New Zealand
 Francis, George M., Fallbrook,
 Calif, U.S.A.
 Fuller, John P., London
 Ghisalberti, Danilo, Luzern,
 Switzerland
 Giesler, H., München, Germany

Greene, Jane B., Princeton, N.J.,
 U.S.A.
 Hayes, Harold, Liverpool
 Hills, Edward G., Sudbury
 Huddy, William J., Newton Abbot
 Hudson, Felix N., Dunfermline
 Jhaveri, Jatin J., Bombay, India
 Le Vierge, Arthur W., Bournemouth
 Marapana, Purandara B.,
 Ratnapura, Ceylon
 Mason, Fitz R., London
 Niblett, George B. F., Reading
 Nilam, Mohamed A. M., Colombo,
 Ceylon
 Pattni, Kanji D., Nairobi, Kenya
 Ralling, Thomas G., Salisbury,
 Southern Rhodesia

Reavis, Isham, St. Louis,
Missouri, U.S.A.
Scott, William N., Melbourne,
Australia
Schrader, Paul J., Killeen, Texas,
U.S.A.
Städelin, Alwin, Lucerne, Switzerland

Sunder, Dularamani, Hong Kong
Tillander, Edith U. M., Helsinki,
Finland
Watson, Maurice,
Welwyn Garden City
Watts, James W., Grimsby
Windsor, Dharmadasa, Singapore

ELECTED TO PROBATIONARY MEMBERSHIP

Brimelow, William, Grantham
Crabtree, Geoffrey C., Nelson
Davis, Max, Wembley
Forbes, David R., Salisbury,
Southern Rhodesia
Kay, John C., Harrow
Kevorkian, Bedros, Beirut, Lebanon
Lewis, Sylvia R., London
Mainzer, Frank W., Amsterdam,
Netherlands

Pearsons, Martin H., Romford
Porter, Robert, Brisbane, Australia
Riding, Frank, Preston
Scheer, D. B.v.d., Oegstgeest, Holland
Schwartz, Raymond N., London
The, Tiong-hien, Djakarta, Indonesia
Tillander, Gemma D. A., Helsinki,
Finland
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TALKS BY MEMBERS

- BLYTHE, G.: "Gemstones", Women's Fellowship Group, Pritewell, 1st October, 1962.
BAGLESS, G.: "Gemstones", Darlington Ladies' Circle, 19th September, 1962.
WEBSTER, R.: "Gemstones and their modern simulants", Norwich and District Jewellers' Association, 10th September, 1962.
KENT, D.: "Jewellery", N. W. Kent Townswomen's Guild, Beckenham, 12th December, 1962.

MEMBERS' MEETINGS 1963

- Feb. 15th Photographic evening Medical Society of London, Chandos Place, W.1. 7 p.m.
Feb. 27th Midlands Branch Dinner and Dance, King's Highway, Quinton, Birmingham.

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