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THE JOURNAL OF GEMMOLOGY

and

PROCEEDINGS OF THE
GEMMOLOGICAL
ASSOCIATION
OF GREAT BRITAIN

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EDITORIAL

It is unusual for the *Journal of Gemmology* to begin with an Editorial, but special issues call for special treatment, and I have a precedent in the brief introduction by the late Gordon Andrews to Vol. XII, No. 7 (July 1971), which was a 70th Anniversary Tribute to B. W. Anderson.

The present issue of the *Journal* is a special one to celebrate the Golden Jubilee of the Gemmological Association, which, after over twenty years existence as a Committee of the National Association of Goldsmiths, finally 'came of age' in its own name on the 24th September, 1931.

That is not, however, the only anniversary calling for celebration this year. The 3rd July, 1981, was the eightieth birthday of B. W. Anderson, that great gemmological researcher, practiser and teacher to whom, like so many others, I owe all such knowledge of gems and gem materials as I possess—apart, in my case, from such elements as had first been instilled in me by the late C. J. Payne, with whom I had been at school twenty-five years

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earlier and who, as my correspondence-course tutor, with exemplary patience and lucidity answered the no doubt surprising questions of a student reared on the classics and entirely devoid of scientific training.

James Payne unhappily is no longer with us, but it is good to be able once again to wish Basil Anderson many more happy returns of his birthday and to see another article from his pen leading off this Jubilee number of the *Journal.* In his article, Mr Anderson traces the progress of gemmology up to 1931, progress which has continued during the past fifty years with increasing momentum and to which both he and the Gemmological Association have made—and surely will continue to make—significant contributions: for, though anniversaries come and go, the work of research and the spread of knowledge continues, and it is worth emphasizing on an occasion like this that in addition to progress made in the past there is much still to be made in the future, in which it is reasonable to predict that the Gemmological Association and its Fellowship will play their part. In this connexion it is pertinent to observe that all the papers in this Jubilee number are contributed (in whole or in part) by Fellows—among them the President and Vice-president of the Gemological Institute of America, which also celebrates this year a fiftieth anniversary—its foundation in 1931—and to which we offer our fraternal greetings.

J.R.H.C.

THE GROWING PAINS OF GEMMOLOGY

By B. W. ANDERSON, B.Sc., F.K.C., F.G.A.

This being the Jubilee Year of Britain's Gemmological Association, it seems an appropriate time to look back through the years and trace the progress of gemmology since the inception of the science during the closing years of the nineteenth century.

As long as a hundred years ago a number of mineralogists had shown a special interest in the branch of mineralogy dealing with the properties of precious stones and had demonstrated a clear way to progress in this fascinating science.

But for a very long time, on the part of those whom we can describe collectively as 'The Trade' (that is, the men who make a living from gemstones whether as prospectors, lapidaries, dealers, manufacturers, retail jewellers, or pawnbrokers), any attempt to introduce scientific methods in their approach to gems was in general viewed with hostility or suspicion. After all, each in his own field had built up and inherited an array of special skills and rule-of-thumb knowledge which enabled him to make a comfortable living and be acknowledged as an 'expert', so that when eventually classes were first instituted for training jewellers' assistants in the first principles of gemmology, there was seldom much encouragement for pupils from their seniors, who (naturally enough) disliked the thought of being corrected in any of their judgements by some junior armed with a textbook and some newfangled instruments.

Admittedly, until the turn of the century, the problems (apart from tricky decisions on values) were relatively few and simple. Only four gemstones were ranked as 'precious'—diamond, ruby, sapphire, and emerald, together with pearl, which occupied a special place in the same high rank. The remaining gemstones were labelled 'semi-precious' or 'ornamental' and their naming was largely based on their colour. Thus all red stones were thought of as some inferior form of ruby, all green stones, some form of emerald, etc., with accepted adjectives attached to distinguish between them. The only fakes to resemble at all closely the sacred four were either pastes or the simpler forms of doublet, which

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could be dealt with with the aid of a hard file or detected by an experienced eye behind a watchmaker's glass. Unusual problems or uncertainties could be referred to the lapidary of their choice (lapidaries being more numerous and more influential than they are today), quite a wise procedure, as in the course of handling and working on multitudes of stones of all kinds these craftsmen acquired an intimate knowledge of their appearance, habits, cleavages, hardness and that mysterious factor, their 'feel on the wheel'.

One major drawback (though not considered as such by the Trade) concerned that traditional unit of weight, the carat, which, like the grain, was originally based on a seed, and varied (incredibly enough) from country to country, between the limits 0.1885 gram to 0.2135 gram. In England a weight called the carat is said to have been in use since Norman times, but had never been recognized as a 'legal' weight. This, for precious stones and metals, was the Troy ounce which, until 1914, was equivalent to 151.5 carats. To make matters more complicated the actual weights used by gem merchants with their balances were numbered 1000, 500, 200, 100, 64, 32, 16, 8, 4, 3, 2 and 1 carats, followed by the fractions ½, ¼, ⅛, 1/16, 1/32 and 1/64. Moreover, it was against convention to present the weight (when found) as a single fraction, but rather as a succession of the weights actually used. Thus, a stone paper might be marked '5 fine blue sapphires: 65 ½ 1/32 1/64'. I remember once seeing a positive tangle of such fractions on the outside of an old stone packet belonging to my friend and mentor Edward Hopkins, and realized that these represented an attempt to carry out a hydrostatic density experiment using the fractional weights available! There was nothing, of course, to prevent any dealer from buying a set of metric weights (grams and milligrams) from a laboratory supplier for use in such an experiment, but such behaviour would mark one as decidedly eccentric in those early days.

There were, admittedly, a number of enlightened, responsible people in the trade, who were ready to attend the lectures on gemstones occasionally given by noted mineralogists. Two such lectures were delivered in 1897 at the Royal Society of Arts by Professor Henry Miers (who, as Sir Henry Miers, was, nearly forty years later, elected the first President of the Gemmological Association). These talks were remarkable in their scope, detailing

Sir Henry Miers, M.A., D.Sc., F.R.S., the Association's first President. *(After the drawing by H. McD. Campbell, by courtesy of the Principal of London University.)*

methods for measuring density, refractive index, dichroism, etc., and even the use of the spectroscope in seeing absorption bands in zircon and almandine garnet. He mentioned the tiny diamonds presumed to have been made by Moissan, and the synthetic rubies made by Frémy, and stated: 'large numbers of artificial rubies are now used in jewellery. The only respect in which they differ from the natural stone is that they have been formed by a different process'. And in his concluding remarks Miers added: *'The absolute necessity of accurate scientific knowledge in commercial and practical undertakings is now fully recognized. The jeweller's trade stands almost alone in failing to realize that such knowledge has a real commercial value'.*

It is remarkable that these words were spoken several years before the first of the Verneuil synthetics burst upon the jeweller's world. As an interesting example of a continuing chain of witness to the gemmological message in those early days, Noel Heaton, B.Sc., in 1911 delivered an excellent and well illustrated lecture (also at the Royal Society of Arts) on 'Artificial Gemstones' and on that occasion Henry Miers himself was in the chair. It is also interesting to note from the records of the occasion that remarks were made after the lecture by such well-known names as J. H. Steward (maker of the Herbert Smith refractometer), who gave credit to Herbert Smith for the instrument he had designed; E. Hopkins (lapidary, dealer, and future examiner) and B. J. Tully, known later for a remarkable refractometer of his design and for the Medal named in his memory.

A notable occasion in the history of trade gemmology came in 1908, when Samuel Barnett, of the Education Committee of the National Association of Goldsmiths, proposed the formation of teaching classes and examinations in gemmology. This, when eventually implemented, marked the beginning of organized Trade gemmology, not only in this country but in due course for the whole world. Getting things going was a slow and difficult process: jewellers on the whole were still apathetic or even hostile to being taught their job. Any prospective students were scattered throughout the country, and there was at first no suitable textbook to give coherence to the movement. A few lectures were given in 1909 and a correspondence course for jewellers initiated, while in 1910 Noel Heaton (already mentioned above) was appointed special lecturer by the Education Committee, and delivered his excellent talks in several different centres. It was at this point that the beneficial intervention of Dr G. F. Herbert Smith began to show effect.

Herbert Smith was a mineralogist, who for years held responsible posts in the Mineralogical Department of the British Museum (Natural History). In 1907 the improved second model of his jeweller's refractometer, skilfully and robustly manufactured by J. H. Steward, made its first appearance on the market. This famous little instrument enabled the jeweller for the first time to make positive identifications of almost any faceted gemstone even when mounted as a jewel. A year or two later Herbert Smith added to this service when the first edition of his book *Gemstones* appeared in 1912. The book was of special value, not only for its full instructions on how to use the refractometer, but for its workmanlike descriptions of the various gemstones and their properties. The next advance came when, just before the Great War, Irvine G. Jardine, M.Sc., a physicist with a good working knowledge of mineralogy, was persuaded to prepare and conduct the first complete course in gemmology at Chelsea Polytechnic, under the title 'Mineralogy for Jewellers'. Examinations were held in 1913, 1914, and 1915 at Chelsea before the war put an end to such humane activities. Classes were renewed in 1922, and exams have been held annually ever since without a break, though in World War II I must admit that I was at one point teaching only two students in various odd places according to the bombing schedule at that time!

At long last, in 1914, the Board of Trade, having found that there was now sufficient trade support for such a change, issued an Order in Council which decreed that the metric carat of 200 milligrams should be adopted as the legal weight for precious stones.

Having reached this point I should like to go back in time again before the end of the nineteenth century to give a brief account of what a splendid lead had been given to gemmology for those who cared to take it, by mineralogists in Britain and other countries.

In 1883, A. H. Church (a name well known to gemmologists) published *Precious Stones* as a slender volume serving as an excellent introduction to gemmology and particularly noteworthy in giving really careful instructions for measuring specific gravity, which was at that time the surest non-destructive means of identifying any unmounted gemstone. The density figures quoted by Church were those he himself had determined—an unusual and welcome feature. In the U.S.A. *Gems and Precious Stones of North America* by the famous mineralogist G. F. Kunz was published in 1890 and was of far more than local importance. But the greatest book on gemmology in those early days was undoubtedly *Edelsteinkunde* by Max Bauer, published in Leipzig in 1896. Bauer was the earliest of a long chain of German professors of mineralogy to which gemmology owes a profound debt. One of his pupils, incidentally, was Karl Schlossmacher who later (1931) revised Bauer's book and himself became a professor and one of the world's most respected gemmologists. Fortunately for English-speaking readers Dr L. J. Spencer (substantially aided by his wife) translated Bauer's work, and this was published as *Precious Stones* in 1904 by Charles Griffin & Co. in London. This massive and valuable descriptive account of gemstones would by now be an expensive collector's item, to be consulted only in libraries, had it not been made available to everyone by Griffin, and by Dover Publications Inc. in 1968 in a two-volume paper-back at £2.10s., which must be the greatest bargain ever offered in books on our subject.

I should like to emphasize that it is a great mistake to think that there is nothing to be gained in reading books on gemmology written long ago: nearly always something can be learned—always provided that the author is a sincere student of the subject and not merely a copyist and compiler of books for profit. Other books that can be commended which appeared in the early years of the century are *The Gem Cutter's Craft* by L. Claremont (London, 1906), which is much more than a craftsman's handbook; *Precious Stones* by W. Goodchild (London, 1908); and *A Book of Precious Stones* by L. Wodiska (New York and London, 1909), which has a particularly interesting section on synthetic gems.

Then in 1912 came G. F. Herbert Smith's *Gemstones* as already mentioned above. The fourth edition (1923) was my stand-by when I first started work in the Gem Testing Laboratory, but one had to wait until 1940 for a much needed enlargement and revision. After Herbert Smith's death in 1953, *Gemstones* did not die, but took on a new and valuable life thanks to tactful and scholarly revisions by F. Coles Phillips.

The opening of an independent pearl and gem testing laboratory in Hatton Garden in 1925 was a very necessary step in providing the trade with a specialized centre where authoritative reports could be obtained. Though understandably enough its services were at first available only to members of the Precious Stone Section of the London Chamber of Commerce who were responsible for its inception and all the costs involved, it was before long available to members of the N.A.G. and other Trade organizations.

The year 1931, to which the above outline is intended as a preparatory introduction, despite the fact that the world was only slowly emerging from the Great Depression which followed the Wall Street Crash of 1929, undoubtedly marked the birth of a sudden expansion of gemmology in almost every civilized country. The 'Zeitgeist' was for some reason all in our favour. In addition to the birth of our Association as a separate entity, a parallel German organization was being founded; a pearl and gem testing laboratory was established in Paris under the tutelage of Georges Gobel; Robert M. Shipley with little but a G.A. Diploma, a Herbert Smith refractometer and unrelenting determination on his side was beginning his conquest of North America with 'Gemology' as his banner; and finally, and not the least important of these promising signs of growth, there came in August 1931 the first number of Arthur Tremayne's brainchild *The Gemmologist,* which for the first time provided a vehicle for the exchange of gemmological information. For all its faults this remarkable little monthly journal was a godsend to our growing science and its eventual demise in 1962 is still lamented by those veterans who remember it in its heyday.

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GARNETS FROM UMBA VALLEY, TANZANIA: IS THERE A NECESSITY FOR A NEW VARIETY NAME?

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ABSTRACT

The garnets from Umba Valley, Tanzania, consist of solid solution series of the garnet end members pyrope, almandine, and spessartite with low contents of a grossularite component. Density and refractive index of members of the series pyrope-almandine vary between 3.71 and 4.04 g/cm^3 and between 1.738 and 1.787 respectively. Members of the solid solution series pyrope-spessartite show density values between 3.82 and 4.05 g/cm^3 and refractive indices between 1.751 and 1.788. A gemmological distinction of members of both solid solution series is possible by a spectroscopic investigation. The name pyralspite garnets for all members of the solid solution series pyrope-almandine-spessartite, which is used in petrology and mineralogy, is also recommended for gemmological nomenclature.

Since about 1979 orange-red coloured garnets have been offered in the gemstone trade whose colour is similar to that of spessartite. Though a large variation in the colour of these new garnets exists, it can generally be described as somehow lighter and more yellowish than that of spessartite, which is closer to orange-brown. The garnets (as pebbles) originate from one or more placer deposits in the Umba Valley, Tanzania, and were first sold without an exact investigation of their chemical composition under the name of 'Malaya-garnets' (Bank 1979, Curtis 1980). When the necessity of naming these garnets properly, i.e., according to scientific standards, was put before the authors, several samples of these garnets were first investigated by physical and chemical methods. It had to be clarified whether the samples mentioned belong to a new, naturally occurring phase with garnet structure, which would justify a new mineral name, or whether they were members of a solid solution series of the already known end members of the garnet group without a necessity for a new mineralogical name. The results of these investigations were described comprehensively

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by Schmetzer & Bank (1981) and are compared in this article with the investigations of other garnet specimens from the Umba Valley.

The so called 'Malaya-garnets' are members of the solid solution series between the already known end members pyrope and spessartite. The values of density and refractive index are found to be between 3.82 and 4.05 g/cm^3, and between 1.751 and 1.788, respectively. For these gemstones known as 'Malaya-garnets', two or more different solid solution series seem to exist, which probably come from different prospects and/or various mother rocks. On the one hand, members of the solid solution series pyrope-spessartite with grossularite components up to 10% were observed, without, however, a distinct Fe-content—that means, without an almandine component. On the other hand, a different garnet solid solution series is also present, consisting of the end members pyrope-spessartite, but these grains also show a distinct almandine component. Garnets similar to this second series have already been described by Jobbins *et al.* (1978) from the Umba Valley, Tanzania, and by Schmetzer & Ottemann (1979) from the same locality and from the placer deposits near Ratnapura, Sri Lanka. Garnets from this series, containing small amounts of V_2O_3 and/or Cr_2O_3, show an alexandrite-like colour change.

Taken as a whole, the samples of the different series mentioned up to now differ distinctly in their chemical composition from another main group of garnets from the Umba Valley. This second group of garnets was comprehensively investigated by Zwaan (1974) and Jobbins *et al.* (1978), who showed that it consists of members of the solid solution series pyrope-almandine with small molecular components of spessartite and grossularite. Their density values were determined to range from 3.71 to 4.04 g/cm^3 and their refractive indices from 1.738 to 1.787.

Members of the solid solution series spessartite-almandine, which is another series of natural almandine garnets, are not yet known from the Umba Valley, whereas they were described from other East African localities (cf. Medenbach *et al.* 1978).

Before the correct naming of the 'Malaya-garnets' from the Umba Valley can be discussed, the possibility of their gemmological determination has to be considered. As in most of the natural solid solution series one can observe a correlation between the physical properties and the chemical composition of a specific crystal also in the different known garnet series. The garnets from the Umba Valley show a broad variation in their chemical composition and therefore also respective differences in their physical properties.

Since in gemmological practice it is not possible to investigate each single stone with chemical or x-ray methods, only the gemmologically relevant data of a sample which can be determined with certainty, will be regarded in the following text. For this reason it is necessary to look first at the properties of the respective end members of the garnet solid solution series. These data were investigated either on synthetically produced end members or calculated from the values of members of the natural garnet solid solution series with known chemical composition. Within the limits of error of both methods, these data are in good agreement (Table 1, Figure 1). It is evident, that by means of the gemmological

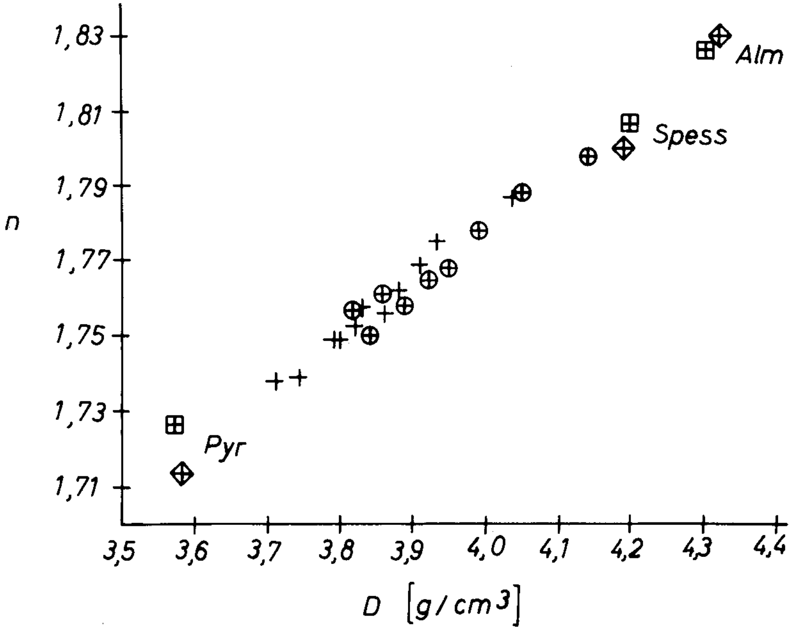

FIG. 1. Refractive index and density of pyralspite garnets, Umba Valley, Tanzania; after Zwaan (1974), Jobbins *et al.* (1978), Schmetzer & Bank (1981). + members of the solid solution series pyrope-almandine, ⊕ members of the solid solution series pyrope-spessartite, ◈ pyrope, almandine and spessartite (end members) after Skinner (1956), ⊞ pyrope, almandine and spessartite (end members) after McConnell (1966).

TABLE 1

Density and refractive index of garnet end members.

garnet end member	formula	density [g/cm^3]		refractive index	
		1	2	1	2
Pyrope	$Mg_3Al_2[SiO_4]_3$	3.582	3.570	1.714	1.727
Almandine	$Fe_3Al_2[SiO_4]_3$	4.318	4.298	1.830	1.827
Spessartite	$Mn_3Al_2[SiO_4]_3$	4.190	4.194	1.800	1.808
Grossularite	$Ca_3Al_2[SiO_4]_3$	3.594	3.598	1.734	1.732

1 after Skinner (1956)
2 after McConnell (1966)

properties, density and refractive index, which can be easily determined, samples of the garnet solid solution series from the Umba Valley, pyrope-almandine and pyrope-spessartite, can easily be distinguished from members of the solid solution series spessartite-almandine or from nearly pure spessartite end members. Neglecting the almandine and grossularite components in the series pyrope-spessartite as well as the spessartite and grossularite components in the series pyrope-almandine which rarely amount to more than 10%, the chemical composition of a single stone can be determined. The properties of the garnets from Umba Valley are located on a straight band between the end members pyrope, spessartite, and almandine, as shown by Figure 1 and in Table 2.

Unfortunately it is more difficult to distinguish between members of the pyrope-spessartite and the pyrope-almandine series, because this is not possible with the density and the refractive index of a sample. Sometimes a distinction is possible by means of the colour; however, in general there is no distinct difference between the colour of a pyrope-almandine garnet with a certain spessartite component and members of the pyrope-spessartite series with a certain almandine component. A spectroscopic determination of members of the described solid solution series by means of a comparison of the intensity of the Fe-absorption bands produced by the almandine component, with that of the Mn-absorption bands, produced by the spessartite component, is possible in gemmological practice with the hand

TABLE 2

Density and refractive index of garnets from Umba Valley, Tanzania; after Zwaan (1974), Jobbins *et al.* (1978), Schmetzer & Bank (1981).

composition, members of the solid solution series	density [g/cm^3]	refractive index
pyrope-almandine ± spessartite ± grossularite	3.71 - 4.04	1.738 - 1.787
pyrope-spessartite ± grossularite	3.84 - 3.95	1.751 - 1.768
pyrope-spessartite ± almandine ± grossularite	3.82 - 4.05	1.757 - 1.788
spessartite ± pyrope ± almandine ± grossularite	4.14	1.798
spessartite-almandine	not described from Umba	

spectroscope; but this method needs chemically analysed garnets as standards and certainly very much time, skill and experience. Furthermore, it has to be mentioned here that in some of the Umba garnets, investigated chemically by means of the electron microprobe, a strong chemical zoning was observed. This zoning did not produce differences in the colour in various parts of a stone.

In summary, the garnets up to now called 'Malaya-garnets' from the Umba Valley, Tanzania, are members of the solid solution series pyrope-spessartite, with varying contents of an almandine and grossularite component. Garnets of this composition are not restricted to the Umba Valley but were also described from Ratnapura, Sri Lanka. A distinction of members of the pyrope-spessartite series from those of the pyrope-almandine series on the basis of the colour of a sample is not possible with certainty. A spectroscopic distinction is possible but very expensive and time consuming.

The difficulty of a rapid and certain distinction of the garnet solid solution series described raises the question of whether there is a strong necessity for a differentiation of members of the pyrope-spessartite series from those of the pyrope-almandine series in the gemmological nomenclature, or whether it is possible to use one expression for all garnets from the Umba Valley.

However, the possibility exists to call the garnets from the Umba Valley with a name which refers to the chemical composition of both series. This possibility is given by an abbreviation customary in petrology; here, garnets of different series between the end members pyrope, almandine, and spessartite are called pyralspites or pyralspite garnets (Matthes 1961). It seems proper to the authors to use this name for all garnets from the Umba Valley, because this name corresponds to the chemical composition of the samples. In case of need, the colour of a specific stone could be added to the name in order to give a better description. Therefore, in our opinion, there is no necessity to introduce a new 'fantasy name' for the Umba garnets, just to promote the sale of garnets from a new locality.

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THE HEAT AND DIFFUSION TREATMENT OF NATURAL AND SYNTHETIC SAPPHIRES

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INTRODUCTION

The subject of heat treatment of corundum has been touched upon only lightly in the gem literature. Although rumours that purplish rubies could be improved by heating were circulated more than thirty years ago, the commercial heating of blue sapphire has become so important that it can no longer be dismissed.

One of the first references that we can find is in an article 'Fakes & Frauds, Caveat Emptor' by J. H. Oughton in the *Australian Gemmologist,* Vol. 11 (4), 91, p.17, November 1971. In this article he refers to a single 'fraud' in which very silky Australian sapphires were presumably heated in a liquid; this was supposedly drawn into hollow tubes which appeared as silk and greatly improved the transparency of the stone. Later, he theorized, the liquid evaporated and the silk became visible again. This account seems to be that of an isolated case since we have not heard reliable reports that heated stones revert. Since the silk in Australian sapphire is caused by rutile needles rather than by hollow tubes, it is doubtful that this is an accurate report. However, a note by the same author in the November 1974 issue of the *Australian Gemmologist* (Vol. 12, p.117) seems to be on the track: here he states that a great deal of inky Australian sapphire is exported for treatment and that he has found no means to detect such treatment.

Also, in 1971 E. A. Jobbins described the 'Heat Treatment of Pale Blue Sapphire from Malawi' in Vol. 12, p.342 of the *Journal of Gemmology.* Evidently this experiment was conducted with the goal of darkening the colour under the assumption that this occurs when blue-green beryls are heated to turn them blue, when in fact the yellow component is merely bleached and the blue aquamarine remains (K. Nassau, *Gems & Gemology,* Vol. 16, p.343, Fall 1980).

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In recent months the GIA-GTL, Inc. has come to realize that the equating of blue sapphires and aquamarines in the matter of heat treating is highly misleading. First, the heat-treatment of many heated blue sapphires is detectable and, secondly, the potential value differences are great. Moreover, insidious additional treatments are being practised so that the sapphire problem is far from clear cut.

Information on the behaviour of ruby and sapphire on heat treatment is known from the manufacture of the synthetic material (K. Nassau, *Gems Made by Man,* Chilton, 1980) and from other technological studies. Based on such knowedge we can define the nine types of treatment of Table 1. The changes of the first five treatments can penetrate completely throughout a stone, but the effect of the next four is confined to the surface of a stone and is easily lost on repolishing. Several of the processes can occur simultaneously, depending on the condition used. More detail will be given in a forthcoming report (K. Nassau, to be submitted to *Gems & Gemology*).

There are also many hearsay reports, some of which are obviously unreasonable, and all of which should be taken with a heavy sprinkling of salt until confirmed by hard evidence. Thus the 4000 °C heat treatment reported to G. Tombs (*Z.Dt.Gemmol.*

TABLE 1.

Heat Treatments used on Sapphires and Rubies*

TREATMENT	RESULT
A. Heating only:	
1. Medium temperature	Develops potential asterism
2. High temperature, rapid cooling	Removes silk and asterism
3. Reducing heating	Develops potential blue colour
4. Oxidizing heating	Diminishes blue colour
5. Extended heating	Diminishes Verneuil banding and strain
B. Heating under unknown conditions:	
6. ?	Introduces fingerprint inclusions
C. Heating plus surface diffusion of impurities:	
7. Adding TiO_2	Produces asterism †
8. Adding TiO_2 and/or Fe_2O_3	Produces blue colour †
9. Adding Cr_2O_3, NiO, etc.	Produces other colours †

*Treatments 1 to 4 correspond to processes also occurring in nature; treatments 5 and 6 are used on synthetic material; treatments 7 to 9 do not correspond to natural processes, can be detected and, accordingly, it would seem that their use should be disclosed.

†Effect is limited to a region near the surface.

Ges., Vol. 29, p.79, 1980) is even above the melting point, while the 1000 °F reported to E. Sasaki (ibid., p.66) is as unreasonably low.

SIMPLE HEAT TREATMENT AND IDENTIFYING CHARACTERISTICS

In the mid 70s we began to hear that Thai dealers were appearing in Colombo, Sri Lanka, in search of a type of milky white corundum that has become known as 'Geuda stone' (possibly the name of a mine). It was rumoured that back in Bangkok this material was heated to produce quite acceptable clear blue faceted stones. This treatment is presumably a combination of treatments 2 and 3 of Table 1. GIA-GTL, Inc. received a sample of Geuda sapphire from New York dealer Alan Caplan in 1977 (Figure 1). For a short time in about 1976, parcels of heated blue sapphire were offered in New York as treated sapphires for considerably less than untreated stones. Buyers were wary until it was discovered that no positive proof of heat treatment was forthcoming. Gradually the trade here and abroad began to equate the heating of sapphires with the heat treatment of aquamarine, for which no tests exist. Geuda stones have been discussed by H. S. Gunaratne in this *Journal,* (January 1981, Vol. 17, p.292.).

Looking back twenty-five to thirty years at the tests on which we used to rely for distinguishing natural blue sapphires from synthetics, it now appears that most heated Ceylon sapphires do have indentifying characteristics. For one thing, we rarely ever encountered a natural blue sapphire with the dull, chalky green fluorescence we see in a large percentage of heat treated stones. At the same time, we do not see the iron absorption line at approximately 4500 Å in the spectroscope in most heated stones. Under magnification we frequently see internal stress fractures (Figure 2) around single crystal inclusions and in areas where there had been fingerprint inclusions. Also, cross-hatched colour-banding (Figure 3) and areas of rutile needles reduced to Kashmir-like colour-zoning were never seen in the past, while the then common rutile silk is no longer seen now. Cut stones that are heated need to be repolished and evidence of this takes the form of pock-marked facets or girdles not completely retouched (Figure 4). Also the girdles may have many planes unlike a normal girdle (Figure 5).

FIG. 1. Geuda sapphire.

FIG. 2. Internal stress fractures around single-crystal inclusions in heat-treated natural sapphire.

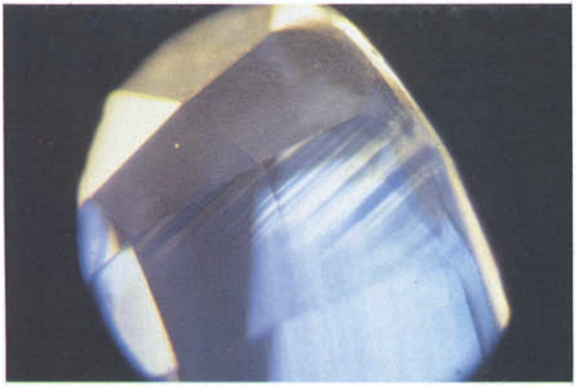

FIG. 3. Cross-hatched colour-banding in heat-treated natural sapphire.

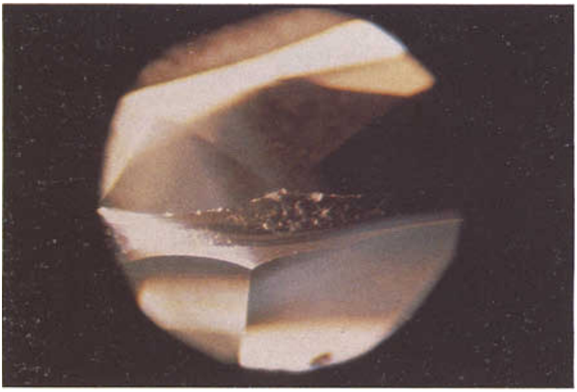

FIG. 4. Pock-marks in incompletely retouched girdle of cut stone after heat treatment.

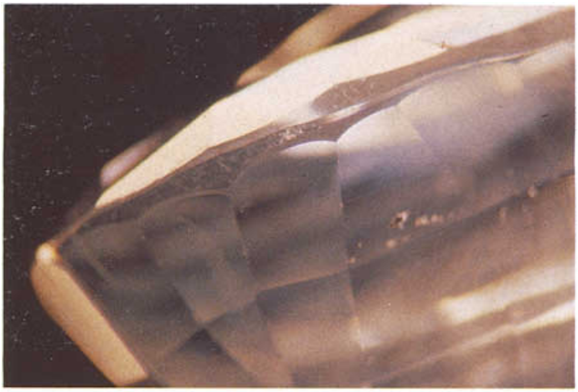

FIG. 5. Girdle of cut stone after heat treatment, having many planes (unlike normal girdle).

Rumours that yellow colour in natural sapphires is being produced through heat treatment by a laboratory in the U.S.A. have persisted since early 1980. The GIA-GTL, Inc. has had occasion to test several orange-yellow to yellow-orange natural sapphires (*Gems & Gemology,* Summer 1980, Vol. 16, p.320.) which did not have a characteristic fluorescence or an iron absorption. Failing to secure permission to conduct a simple fade test in direct sunlight, the reports indicated that the origin of the colour is unknown, but if it were due to irradiation, as all gemmologists know, the colour will fade. We have now had an opportunity to fade-test some beautiful orange-yellow sapphires which did not fade and were claimed to be a product of this new lab.

In view of the fact that the colour is unnaturally intense and the fact that the colour is due to treatment, the Labs indicate this on reports. This would appear to be a case of discrimination, since so many blue sapphires have their colour and appearance enhanced by heating and the Labs do not at present mention it. The reason, of course, is that tests for blue sapphires are not conclusive in many cases. If a yellow to orange sapphire had no diagnostic inclusions, it would be necessary to do a careful Plato test to separate it from a Verneuil synthetic.

The development of potential asterism by employing heating as in process 1 of Table 1 where nature did not complete the process, has been used on an experimental basis for a long time.

Lightening of a deep blue colour by process 4 of Table 1 has been reported; this may lead to green or yellow sapphire if an underlying yellow colour is also present. This process is probably used on the pale and/or milky Ceylon and Australian rough reportedly heat-treated to produce yellow to orange sapphire (although, if it turned colourless, irradiation could then have been used to produce a yellow to orange, which is, however, not commercially acceptable as the colour is not stable to light or heat). Similarly produced may be the heated Australian sapphires, presumably lightened from the very dark blue and reported to have a pronounced green dichroic direction. Purple sapphire could be converted to ruby by this treatment.

Much less is known about the heating of rubies. It is felt by many experienced dealers that a great percentage of Thai rubies have been improved in colour by heating. At one time such stones were said to be from a new mine. The old purplish to brownish typical Thai ruby has virtually disappeared from the market, suggesting that it now reaches the market enhanced by heat. The red ruby coloration is not affected by heat, but undesirable modifiers such as blue can be removed.

Even less is known about the prevalence of heating cloudy Burma rubies to increase transparency and improve colour. It is rumoured that it may require several heatings to accomplish the desired results and there is considerable risk of damage involved.

SURFACE DIFFUSED SAPPHIRES AND IDENTIFYING CHARACTERISTICS

In the fall of 1979 we reported in *Gems & Gemology* (Vol. 16, p.194) the testing of a red-orange natural sapphire in which most of the colour lay on the surface (Figure 6) with some facets lacking colour entirely. We deduced that it seemed to be an example of colour diffusion using process 9 of Table 1. This process is among those outlined in U.S. patent 3,897,529 issued to R. R. Carr and S. D. Nisevich of the Union Carbide Corporation in 1975 and can produce a full range of diffusion colours from orange to red to pink. At that time we did not anticipate seeing the same process used with blue sapphires. However, in September of 1980 in the New York lab we encountered the first of an avalanche of such blue, diffusion-enhanced stones, clearly made by process 8 of Table 1. Their detection is simple if they are unset and can be immersed in methylene iodide. It is usually not necessary to use the microscope if a clear immersion cell is available. The stone and cell are held a few inches above a white paper so that the splotchiness of colour caused by unequal repolishing of the facets is revealed (Figure 7). Because the raw material may be heavily colour-zoned and the diffused surface colour evens out the appearance, the Gem Trade Laboratory simply states on reports for these stones—'Natural Sapphire, Wt.   . Note: Color has been surface enhanced by an artificial diffusion process'.

In May, 1981 we encountered our first heavily zoned stones in which colour seemed to be concentrated at facet junctions (Figure 8). Such zoned rough is reported to be typical of the Ootu Mine in Sri Lanka. The explanation has to be that the stones were diffused in the preform stage, possibly after unsuccessful heat-treating attempts. It resulted in some of the most handsome blue treated stones we have seen. This type of diffused colour treatment is not recognizable without immersion and might be impossible to detect in a mounting. At the same time we encountered our first example of a colour-diffused cabochon. The colour has been removed from an area around the girdle (Figure 9) reminding us of the faceted stone in Figure 22 in the Spring 1981 issue of *Gems & Gemology,* Vol. 27, p.46). Most of the surface-diffused stones we have seen do not fluoresce under short UV. None of the twenty cabochons in the necklace (Figure 10) from which this stone was removed for testing

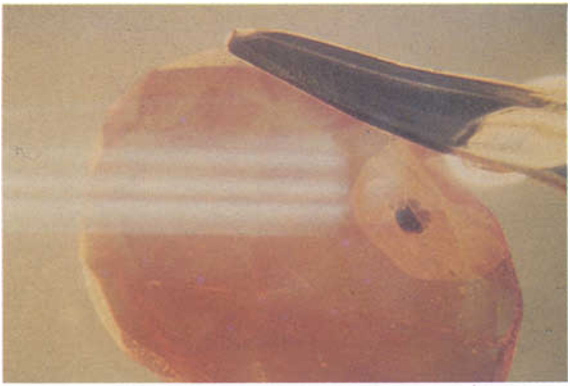

FIG. 6. Red-orange sapphire with most of the colour on the surface.

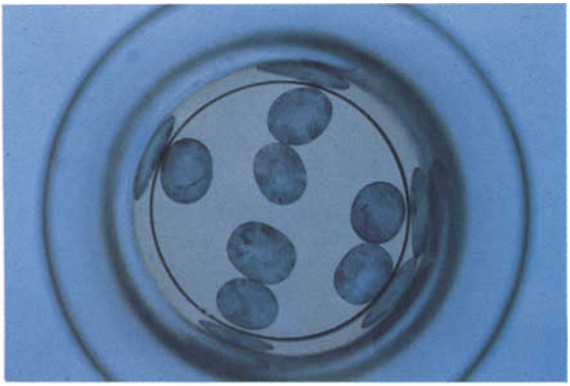

FIG. 7. Splotchiness of colour in diffusion-enhanced sapphires.

FIG. 8. Colour apparently concentrated at facet junctions in a heavily zoned stone.

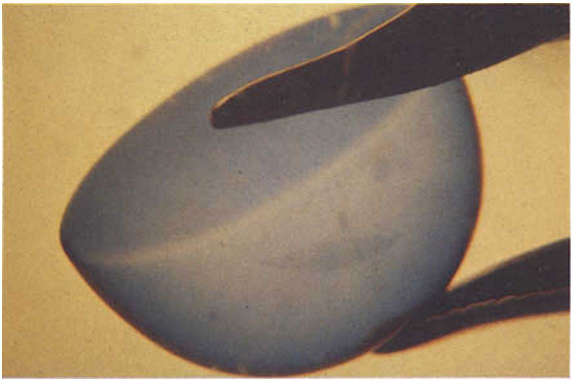

FIG. 9. Colour-diffused cabochon sapphire, with colour removed from an area around the girdle.

FIG. 10. Necklace from which colour-diffused cabochon sapphire in Figure 9 was removed.

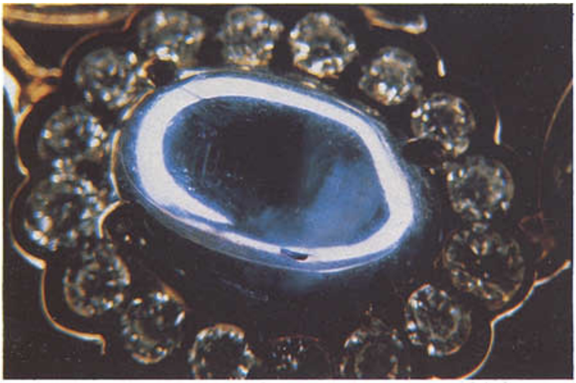

FIG. 11. 'Bleeding' inward of colour in colour-diffused cabochon sapphire.

was recognized as diffused when first observed in the setting. Then we noted a clue in a few of the stones which indicated diffused treatment: this was the 'bleeding' inward of colour from open pits, fissures, and fractures (Figure 11). We examined some of our own faceted diffused stones and noted the same features.

Many experienced dealers feel they can recognize both diffused and heat treated blue sapphires by a certain watery appearance or thinness of colour. Perhaps compared with older Burma, Ceylon, and Australian stones this is a factor, but, if the heated or diffused stone was originally heavily colour-zoned, this characteristic is not evident.

We and others have reported the lack of success in securing eyewitness accounts of the actual heating process. We have had reports that heating is done with crucibles (Figures 6 and 7 of Summer 1980 issue of *Gems & Gemology,* Vol. 16, p.318) packed into 55-gallon drums serving as ovens. But we have also heard that sophisticated furnaces and platinum crucibles are used. In fact, one dealer claimed he was present when such an oven exploded in the next room while visiting a supplier in Bangkok.

Asterism can be added by a surface diffusion step as described in U.S. Patent 2,690,630 issued to W. G. Eversole and J. N. Burdick of Union Carbide and Carbon (Linde) in 1954 and also in the Carr and Nisevich patent. This is process 6 of Table 1 but only seems to have been used experimentally. It was not until 1968 that the GIA-GTL, Inc. in New York was shown some of these stones (Figure 12). Since they were never available commercially, we had not seen any since that time until May, 1981 as this manuscript was being prepared.

Three star sapphires (Figure 13) were submitted to the Los Angeles Gem Trade Lab and subsequently forwarded to the New York Lab for study. They were reported to have been a recent purchase in Bangkok. Like the stones we first examined in 1968, the individual star-causing needles are extremely fine and the star unnaturally sharp. The colour of two of the stones is 'not right' and 'bleeding' of colour around pits and fractures indicated colour diffusion (Figure 14), while the fine needles indicate the induced asterism. Two stones showed weak greenish fluorescence under short UV and all showed a weak iron line at 4500Å in the spectroscope. The third stone is a pleasing blue, but the star is 'too

FIG. 12. Asterism added by a surface diffusion step (process 7, Table 1).

FIG. 13. Three star-sapphires with induced asterism. These stars are sharper than they appear in the photograph.

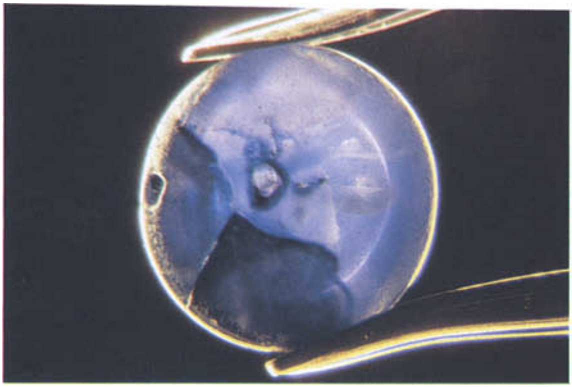

FIG. 14. 'Bleeding' of colour around pits and fractures indicates colour- diffusion.

sharp'. All three stones exhibited iridescent internal fractures. Possibly, such flawed material is not suitable for faceting, hence it is relegated to being processed as star material.

CHANGES IN INTERNAL STRUCTURE (TREATED VERNEUIL SYNTHETICS)

Dealers have tried to secure information on heat treatments for us, for which we are most grateful. One dealer's Bangkok supplier, after many requests, finally sent him three parcels of sapphires purported to be three stages in the heating process. We were delighted to see some heavily colour-zoned preformed 'Ootu' stones before heating, some evenly coloured similar shape preforms presumably heated and some quite beautiful cut stones. However, upon testing the three lots, only the unheated preforms were natural sapphires. The rest were heated Verneuil synthetics, most with induced fingerprint inclusions (Figure 15)! One report states that the heating of Verneuil synthetics (which improves the appearance considerably) is not done in Bangkok, but in California, Japan, and Switzerland. The donor of the crucibles mentioned in the Summer 1980 issue of *Gems & Gemology,* Vol. 16, p.315, says that heating of Verneuil synthetics with induced fingerprint inclusions is carried out in Bangkok. To the jeweller gemmologist who must identify them, it really makes no difference where the treatment is performed. We have noted that a positive Plato test is more difficult to secure since the heating eases some of the strain in the crystal structure in addition to improving the colour immensely. However, we doubt that repeated heating of natural banded sapphires finally causes the bands to curve, as several Bangkok dealers have mentioned in defence of their heat treated Verneuil synthetics!

We have encountered Verneuil synthetic rubies and pink sapphires containing induced fingerprint inclusions (Figure 16). It would seem logical to anticipate similar deceptions with all colours of synthetic corundum. The pink synthetic sapphire shown here was beautifully 'native' cut. It had fingerprint inclusions and repeated twinning lines. However, it also had tiny gas bubbles and characteristic chalky green over red fluorescence under short UV. The diminishing of the curved growth lines of Verneuil rubies and sapphires is process 5 of Table 1, while the unknown process involved in producing fingerprint inclusions is process 6 of Table 1.

FIG. 15. Induced fingerprint inclusion in heated Verneuil synthetic sapphire.

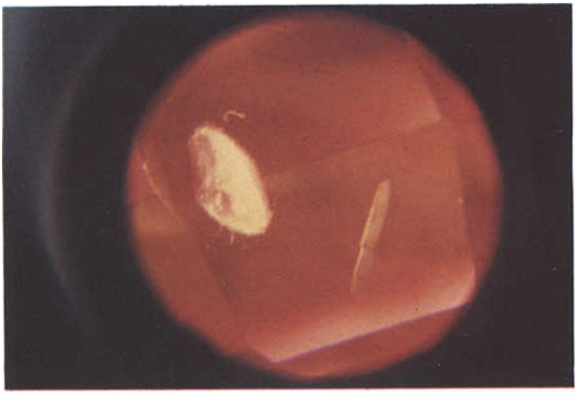

FIG. 16. Induced fingerprint inclusion in Verneuil synthetic pink sapphire.

SUMMARY

The jeweller gemmologist today is confronted with a wide variety of treatments and processes which have complicated the task of identifying many colours of sapphire. A blue or yellow faceted stone that appears to be a sapphire may with careful testing be identified as any one of the following: a natural, unheated stone; a synthetic stone; a simply heat-treated natural stone (lightened or darkened); a heat-treated synthetic stone (with or without induced fingerprints); a natural sapphire with surface colour diffused either when the stone was preformed or finished; an irradiated yellow to orange fading sapphire. When one considers the imminent commercial appearance in the market of flux-grown synthetic blue sapphires to say nothing of garnet and glass doublets and natural/synthetic sapphire doublets, the comparison with heating beryl to produce aquamarine is indeed inappropriate.

Only by becoming aware of all the possible treatments used on corundum can one know for what specific signs to be alert. Unlike the heat-treatment used on aquamarine, it is often possible to detect the heat or diffusion treatments in sapphire.

If diffusion has been used, the effects are limited to a very thin skin at the surface of the stone and can accidentally be removed if recutting becomes necessary. This has become a definite problem for dealers world wide as well as in Bangkok.

Aside from unusual inclusions seen in heated Burma rubies such as rutile needles that have been incompletely absorbed, the evidence of heat treatment is scant.

The first four treatments of Table 1, correspond to processes also occurring in nature. The reason why some of those can be recognized lies in the rapidity of these treatments: since geological periods of time are not available, it is necessary to use somewhat higher temperatures than nature uses and this sometimes leaves evidence in the stones. The last four treatments do not correspond to natural processes and are identifiable; accordingly, it would seem that disclosure of their use is essential.

As a last point, it is clear that corundum from different localities can show considerable variation in its reaction to these treatments.

[*Manuscript received 4th July, 1981.*]

THE FIFTIETH PARALLEL

By A. E. FARN, F.G.A.,

lately Director of the Gem Testing Laboratory of the London Chamber of Commerce and Industry.

Have you ever sat in a train or a bus opposite someone reading a newspaper with intriguing headlines? Have you ever suffered eye strain or neck pains through craning in attempts to wrest more information literally from an appetite-whetting situation? Such was my predicament or position the other day. I was writing a report at my desk on a pearl necklace; I saw across from me my colleagues notes inadvertently displayed. The heading I read (upside down) was: 'What is a gem?' This seemed to me an ideal heading for an article dealing perhaps with etymological derivation, the history of gemmology or some particular facet of the fascinating science we pursue. When I was invited to write something for the fiftieth anniversary-year celebration of the Gemmological Association of Great Britain I felt honoured and frankly flattered. Equally I felt a little concerned.

In earlier years, when renowned gemmologists achieved three score years and ten, special tributes were written in their honour. These well-deserved tributes stemmed from pens of erudite scientists each offering some new finding or item of specialized research. *This* is the kind of worry I have both in this instance and when I attend an international conference—the question or demand arises, in effect, what to contribute?

Far from being a scientist I am a member of the trade, fortunate enough to have secured a job in the Laboratory, a job which I was not seeking but when offered I accepted. I hoped some mistake in identity had not occurred, but if so I hoped I could be kept on. Following this stroke of luck I spent the next thirty-five years at this fascinating job. I met people from all walks of life in the jewellery/gemmological world in its broadest concept. Nineteen eighty-one is the fiftieth anniversary year of the Gemmological Association of Great Britain; it is equally my own fiftieth year of working in the jewellery trade.

I have entitled my contribution 'The fiftieth parallel', because on looking back upon my years in the Laboratory and those of the G.A., I was struck by this parallel aspect. I was surprised upon

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looking at the very close association, friendship and progress made by Harry Wheeler, F.G.A., of the Gemmological Association, and myself in our respective, respected and closely complementary careers.

Just before the War (1939-1945) both Harry Wheeler and myself were students at Chelsea Polytechnic under the tuition of B. W. Anderson, B.Sc., F.G.A., then the director of the Laboratory of the London Chamber of Commerce Inc.; Gordon Andrews, a Tully Medallist, was then secretary of the G.A. and director of examinations. Harry Wheeler and I both passed our first year examinations and received a Chelsea Polytechnic certificate (a collector's item now?). Then followed six years of war service in H.M. forces. In 1946 we both re-enrolled for our second year course in gemmology. B. W. Anderson was still teaching at Chelsea Polytechnic. Both Harry Wheeler and myself passed our second year examination not without distinction—considering six years interruption, a satisfactory result.

Harry continued working with Gordon Andrews at the G.A.'s various addresses in Hatton Garden, Ely Place, and now at Carey Lane. The Laboratory under B. W. Anderson continued at various addresses in Hatton Garden; I was his junior colleague. The laboratory of the London Chamber of Commerce was a gemmological centre. As well as this aspect, the actual work of gem testing for the trade continued. We tested scores of thousands of pearls and scores of thousands of rubies annually as part of our job. Woven inextricably in our everyday conversation would be the G.A., its examinations, the questions, the examiners, the instructors, the presentation of awards, the Goldsmiths' Hall. All would be part of the potpourri of a working day. With B. W. Anderson and Robert Webster as principal instructors and myself as a later assistant at classes, it is small wonder the students thought that *we* were the G.A. laboratory! Certainly we were a gemmological laboratory. Our visitors and friends in those days, it seemed, were gemmologists who were bird-watchers (ornithological mostly) as well as *Times* crossword addicts. Ernest Rutland, Ph.D., F.G.A., was a member of our evening class in 1947. He soon made his mark by becoming an instructor, later examiner. Lunch times in those days would find Ernest Rutland, Robert Webster, C. J. Payne, B. W. Anderson and often Gordon Andrews at one table *devouring The Times* crossword, but otherwise dining normally.

Gordon Andrews had a penchant for anagrams, Ernest Rutland was strong on Shakespeare, C. J. Payne was the history expert and Robert Webster supplied his own broad knowledge culled from a long working life. Anderson was the master.

Later, when erudite gemmological discussions arose, exams were examined, students studied, questions questioned and the results reviewed. This conversation of those eminent men served to keep me in a sort of friendly fringe atmosphere (small fry perhaps). I seldom contributed to the solving of *The Times* crossword! The continued contact of intelligent and intellectual conversation, the proper use of words, etc., did at least help to afford a little polish to my trade knowledge, for which I have been grateful ever since.

On practically every working day at the Laboratory we would receive from or deliver to the G.A. some items of work or the results of enquiries. There was (and is) a continual coming and going of their messengers. The telephone rings daily with calls to and fro bound up with gemmology and its participants. I think the basis of so much understanding stems from the strong links forged over the years between Andrews and Anderson and Webster and Andrews, with Harry Wheeler and myself in the background doing the basic *real* work! In our own manner I would like to think that Harry Wheeler for the G.A. and myself for the Laboratory have continued on that same parallel.

To have been asked to contribute something for this anniversary has provided me with a nostalgic opportunity to look back and reminisce upon my very happy early days in the company of gemmological friends. I can only talk 'shop', since as a child I lived over a jewellers'/pawnbrokers' shop, as a young man I 'lived in' over a jewellers'/pawnbrokers' shop and have been trade orientated all of my working life, Looking back, I think to myself 'Fifty years—it doesn't seem all *that* long.'

Harry Wheeler, now secretary of the Gemmological Association, and myself, now director of the Gem Testing Laboratory,* meet frequently—unlike parallel lines which only *seem* to merge. We have arrived at this our '50th parallel' as a fitting tribute, I hope, to this our anniversary gemmological celebration.

[*Manuscript received 10th January, 1981*]

*Mr Farn retired on 17th March, since this article was written.—Ed.

RECENT OBSERVATIONS ON AN APPARENTLY NEW INTERNAL PARAGENESIS OF BERYLS

By Prof. Dr E. J. GÜBELIN, C.G., F.G.A.
Meggen, Lucerne, Switzerland

That ingenious artist Nature, gifted with highly fanciful imagination, has granted the prolific womb of the pegmatite the prerogative of bringing forth innumerable variations of design and combinations of inclusions in its precious gems. Notwithstanding this immense multitude of varying formations, repeated similarities do occur, and many a pegmatitic species or varieties thereof excel with characteristic internal features which are specifically inherent to these particular gemstones. To mention a few: the growth tubes running through an aquamarine parallel to the *c*-axis (the so-called 'rain') and being filled with one or two fluids or with quartz and apatite and/or epidote respectively; or those partly-healed fractures surrounding a central grain, lying parallel to the basal plane and rendered visible by radially arranged or dendritic residual drops (so-called 'snow-flakes'); or those tell-tale curtains hovering in topazes and consisting of negative crystals in strict alignment with the original prism faces and comprising two immiscible fluids, normally water and carbon-dioxide, as well as the latter in gaseous state; or those unmistakable trichites which faithfully mark tourmalines of all hues and shades and from whatever sources; let alone the well-known golden fibres of byssolite (an amianthus) in demantoid garnets.

With the exception of several elucidating and eloquently illustrated articles by Eppler (1960, 1963, 1964, 1967, 1970a&b), Graziani *et al.* (1979a, b & c, and 1980) and Zwaan (1958), little has indeed so far been reported about the inclusions in common beryls. Their light has always been hidden under the bushel of the gemmologically more enlightening and often locally differing inclusions in the more sumptuous precious stones such as emerald, ruby, sapphire, and also garnet, quite apart from the scientifically highly informative mineral inclusions in diamond.

Strangely enough, the conclusive consistency adding special merit to the above-mentioned gems has not been observed in

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common beryls (i.e. colourless, yellow and green varieties) until recently. Thus it came as a surprise when during the lapse of the last three years, the author time and again noticed an apparently 'new' association of guest minerals in colourless, greenish and bluish beryls. Although the complete paragenesis, as it could be established as time went on, was not always present, two of the component minerals could always be perceived. Curiously enough these various beryls originated from deposits as remote and far apart as Afghanistan, Brazil, Kenya and Switzerland, and it appeared rather striking that all these beryls, although coming from such distant sources, shared at least one guest mineral in common. This consisted either of a large pseudohexagonal colourless or brown crystal and/or brownish-orange isometric crystals obviously belonging to the cubic crystal system. The particularly interesting compositions will be described in brief detail hereafter.

Worth mentioning is a colourless beryl (a so-called goshenite) from Brazil, which had been cut so as to facilitate the inspection of the inclusions. To the unaided eye the host gem exhibited a large brown guest mineral accompanied by numerous small black spots (Figure 1). The large brown inclusion was wrapped in a whitish coat reflecting a silvery lustre, and minute flakes reminiscent of fish scales ejected from it into the clear and transparent body of the goshenite (Figure 2). Under the microscope a few discrete and transparent parcels and single platelets were observed. They possessed a slightly higher RI than the host gem because, upon raising the tube of the microscope, the bright Becke line would move into the alien guests. One of these flakes happened to be exposed at the surface of the colourless beryl, thus allowing a microprobe examination to be carried out. This enquiry revealed the presence of Al (twice as much as in the embracing beryl!), Si, and K. Consequently the parcels and individual platelets were *muscovite.* The large brown inclusion (Figure 2) on the other hand, although also mica, proved to be *phlogopite* on account of the elements K, Mg, Si, and Al, whose presence the microprobe analysis confirmed. The black grains, which under the microscope reflected a strong metallic lustre and iridesced with vivid tarnish colours, indicated the elements Mn, Fe, *Nb* and Ta, and could therefore be declared as *niobite* crystals (Figure 3). The association of muscovite, phlogopite and niobite in one host gem is a new

FIG. 1. Survey of the mineral association (phlogopite, muscovite and niobite) in a goshenite from Brazil. 25 ×

FIG. 2. Detail of Figure 1: cluster of pseudohexagonal crystals of phlogopite accompanied by black grains of niobite. 100 ×

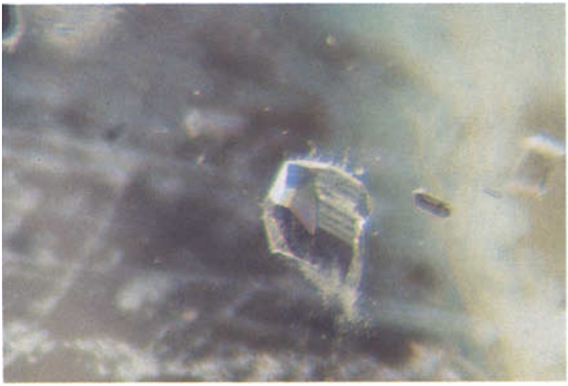

FIG. 3. One well-shaped niobite crystal with metallic lustre and tarnish colours. 50 ×

FIG. 4. Survey photomicrograph of part of the internal paragenesis of the second goshenite from Brazil. We recognize large brownish pseudohexagonal crystals of biotite accompanied by numerous black grains of niobite.

FIG. 5. The truncated, barrel-shaped dark green crystal of Mn-apatite covered by a coat of muscovite in the second goshenite. 20×

paragenesis which has not been previously observed. The presence of mica, but particularly that of niobite, delivers ample proof of a pegmatitic parentage of this goshenite.

Another goshenite, also excavated in Brazil, looked very similar to the afore-mentioned specimen, in that it displayed two very large inclusions of different nature, but also both shrouded in the same kind of sheath with a silvery lustre. They were escorted by numerous black grains or euhedral crystals of metallic lustre or glittering tarnish colours (Figure 4). The assumption that they were *niobite* crystals was again proved correct when the microscope investigation betrayed the combination of Mn with Fe, Nb, and Ta.

The more eye-catching of the two large inclusions was a monocrystal of dark green colour with a distorted hexagonal habit, the prism faces of which were so strongly terraced that it simulated a truncated barrel. The microprobe manifested the elements Ca, P, Mn (and Fe) whose stoichiometric ratio is characteristic for *manganese-apatite* (Figure 5). The other large inclusion was easy to identify by experience and its colour, and the conjecture that it was *phlogopite* (Figure 4) was verified when the electron microprobe responded to the elements K, Mg, Al, Si (and Na). Despite encountering old acquaintances within this second goshenite, we have met with yet another combination of trapped minerals, which supply an equally eloquent testimony as to the origin of the host gem.

The next assays were of three crystals of pale blue, greenish to bluish-green beryls from three different continents. The first sample was a light blue aquamarine which had been found in the gemmiferous province of Nuristan in eastern Afghanistan. Besides a large, colourless and hexagonal prism in its centre, it accommodated several of the above-mentioned brownish isometric crystals. Although most of these were completely enclosed by the aquamarine, a few happened to be exposed at the surface of the host crystal and were thus most enticing for an electron microprobe analysis. This examination registered the elements Mn, Fe, Al, Si (and Ca) in stoichiometric amounts that suggested *spessartine* (Figure 6). Though the cubic morphology of these isometric guest crystals concurred with this result, it seemed at first incredible, since spessartine had not been hitherto known as a regular mineral inclusion in aquamarine. Consequently more analyses were carried out, which nevertheless all led to identical findings. The large, colourless, hexagonal prism was sufficiently big to be visible to the naked eye, and at first sight it was taken for an apatite crystal—mainly so because it displayed several parallel cleavage planes. However, cautioned by a previous publication by Eppler (1964), and using optical means, it was possible to reliably determine this large prismatic crystal to be a pseudohexagonal *muscovite* (Figure 7). This alien crystal was not oriented after the crystallographic directions of the host crystal.

The most elucidating and rewarding specimen of all these beryls was a greenish blue aquamarine from Kenya, which was exceptionally well qualified to confirm the previous observations

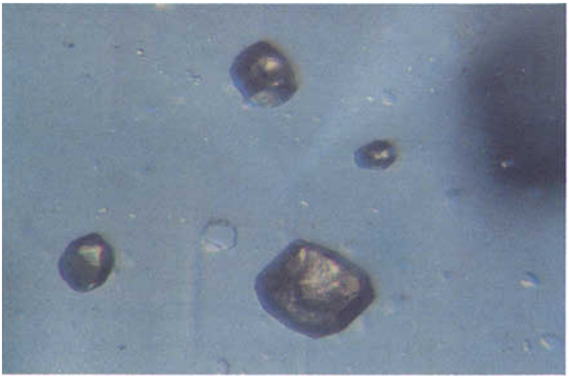

FIG. 6. Brownish spessartine crystals in aquamarine from Nuristan (Afghanistan). 80×

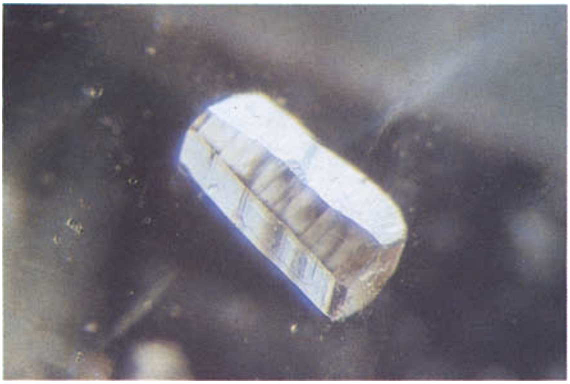

FIG. 7. Large crystal of muscovite distinctly exhibiting pseudohexagonal habit in aquamarine from Nuristan. 40×

and analyses. It turned out to be a true bonanza of abundant inclusions encompassing two very conspicuous clusters of white crystals (Figure 8) (part of which protruded beyond the surface of the aquamarine), several brown isometric crystals again (irregularly disseminated through the host crystal), black grains and needles, and, last but not least, a small cluster of a few well-shaped crystals of green hue. All of these inclusions could be subjected to electron microprobe scrutiny, yielding the ensuing results: the white cluster consisted of the elements Na, Al, and Si, and hence was *albite;* the orange isometric crystals agreed with previous findings manifesting the elements Mn, Fe, Al, Si (and Ca) and therefore were *spessartine* (Figure 9). The presence of Mn-rich garnets suggested that the

FIG. 8. Large white cluster of albite crystals on which an orange spessartine crystal and a black platelet of tantalite are perching. Greenish aquamarine from Kenya. 35×

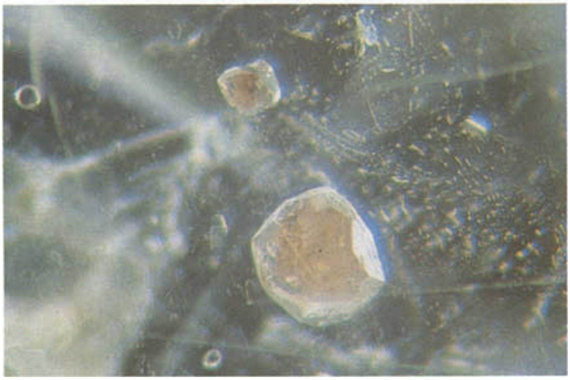

FIG. 9. Orange spessartines complete the internal paragenesis of the aquamarine from Kenya. 100×

black inclusions might be members of the isomorphous columbite series of mixed crystals. Indeed, the elements found, namely Mn, Fe, *Nb* and *Ta,* pleaded for *niobite* or *tantalite.* The tabular crystals (Figure 8) were richer in Nb, while an excess of Ta was responsible for the acicular habits (Figure 10). A further component of this variegated paragenesis was a group of three pseudohexagonal, reddish brown crystals of phlogopite, grown together in parallel arrangement (Figure 11). From the small group of euhedral green crystals near the basal pinacoid, tiny fragments were removed after the basis had been cut down to expose the inclusions. The latter were investigated in an x-ray Gandolfi camera and determined as green *tourmaline* (variety dravite: $NaMg_3Al_6B_3Si_6O_{27}(OH)_3(OH,F)$)

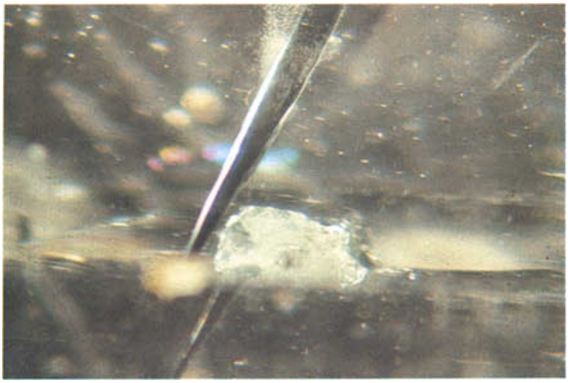

FIG. 10. Two acicular crystals of niobite piercing through the interior of the greenish-blue aquamarine from Kenya. Between the two needles is one of the clusters of albite. 25 ×

FIG. 11. Group of three large pseudohexagonal crystals of phlogopite partly coated by muscovite flakes in close proximity to a large fracture. Greenish-blue aquamarine from Kenya. 35 ×

FIG. 12. A small group of green tourmaline crystals in close contact with gahnite crystals—forming a most unusual internal paragenesis of beryl. 50 ×

in intimate contact with dark green *gahnite* (zinc spinel: Al_2ZnO_4). These two minerals have never before been observed as inclusions in beryl (Figure 12). Thus, this host aquamarine generously granted accommodation to a highly unusual assemblage of guest minerals, namely: albite, gahnite, niobite, spessartine and tourmaline, delivering a quintessence of Nature and proving that she still holds many secrets in store to be discovered by gemmologists.

The presence of mica in pegmatitic gem minerals is quite normal, but the association of mica with albite, spessartine and two varieties of the columbite series was an unexpected surprise.

For the sake of completion, and to emphasize the similarity of the internal paragenesis in beryls from sources far apart, a pale blue aquamarine from Verabbio in the Mesoggio Valley in Switzerland may be referred to as the last item. It housed one relatively large orange isometric crystal (Figure 13), whose faces could effortlessly be recognized as the main growth faces of garnet, and, apart from a few vicinal faces, could be designated by the Miller indices of (110) = garnetohedron and (211) = leucitohedron. In view of this determination and a strong reluctancy to cut down this rare and beautiful host crystal to expose the inclusion, it was decided to abstain from a more elaborate investigation, and to accept the conclusion that this inclusion was another *spessartine garnet* in an aquamarine.

From the various internal parageneses described above, and from their illuminating investigation, emerges the realization that

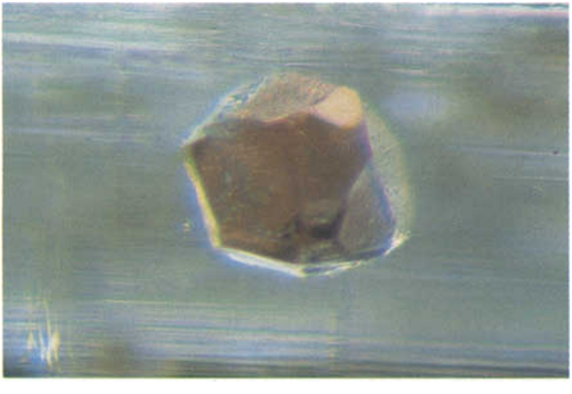

FIG. 13. Large euhedral crystal of spessartine constituting the remarkable internal feature of a pale blue aquamarine from Switzerland. 50×

niobite is the indicative mineral inclusion of paramount importance with regard to unveiling the environment of the host gems in their birth chambers. The growth milieu of niobite is a Mn-rich granitic pegmatite with much albite and lithium-minerals (Klockmann, 1978); consequently it was possible for Mn-rich garnet (spessartine) and Mn-rich apatite to occur and accompany niobite in one and the same host beryl, which itself is a typical product of pegmatite. The large pseudohexagonal mica crystals and their characteristic appearance (marked by cleavage planes parallel to the basal face), represent a most distinctive and unique feature of the internal paragenesis of beryl, by means of which beryls containing them may readily be recognized. In one aquamarine (not described here because of the lack of a picture) a Li-rich mica—a so-called *lepidolite*—was found to form the internal paragenesis together with niobite.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr H. Krupp, Heidelberg, and to Bill Larson, Fallbrook, for their co-operation in finding gems with interesting inclusions; as well as to Prof. Dr M. Weibel, of the Institute for Crystallography and Petrology of the Federal High-school of Technology in Zürich, for the electron microprobe analyses and valuable comments.

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THE PAILIN RUBY AND SAPPHIRE GEMFIELD, CAMBODIA*

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The Pailin gemfield was discovered by Burmese pedlars as late as 1874, in contrast to the Burmese deposits at Mogok which have been known for centuries. Further contrasts are provided by the geology of the deposits, the gems in Cambodia coming from small basaltic bodies whereas the Burmese rubies originate from limestone, and several rocks including types of syenite are the sources of the sapphires. The Pailin gemfield was investigated by the authors in the mid-seventies and the following account is based upon that visit and subsequent laboratory work.

GEOLOGY

The small gem-mining town of Pailin lies athwart a fault zone trending NW-SE and roughly parallel with the main road (see Map 1, facing p.560). This zone separates a northern region of low relief, underlain by the ancient Precambrian Pailin Crystalline Complex and some Devonian and Carboniferous rocks, from a mountainous region in the south composed largely of Triassic sandstones and greywackes. During the Himalayan orogeny of Tertiary times this southern area—the Tadeth mountains—was uplifted by block faulting and small gem-bearing basaltic bodies were intruded in the vicinity of the fault zone with subsequent extrusion of lavas. Subsequent erosion during Tertiary times, especially by the northward flowing rivers, led to the formation and spread of the bouldery sands and clays of the Ancient Alluvium over the area. This has been reworked into the present river alluvium (Recent Alluvium) and outwash fan deposits during Quaternary times.

As a result of this survey the authors were able to show that the rivers which drained from the small basaltic bodies carried gem minerals including ruby, sapphire, zircon and garnet. Rivers rising in other areas were barren unless they were joined by tributaries

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draining from the basalts (see Map 1). Additional proof for the source of the gems was provided by the relatively rich concentrations of gem fragments (the eluvial deposits) in the *in situ* weathered basalt and the soil profiles overlying the basaltic bodies.

The lavas form four separate hills of varying aspect. Phnum O Tang is a breached crater rising some 40-60 m above the surrounding plains with a lobe of lava extending westwards for almost one kilometre. The Phnum Ko Ngoap lavas form a W-SW trending plateau some 20-40 m above the surroundings and cover an area some 3 km by 1 km. Phnum Ko Ngoap itself—the eroded remnants of a volcano cone—rises some 40 m above the plateau. The Phnum Yat lavas form an elongated plateau, about 600 m wide, which extends roughly N-S for approximately 3 km. Pailin town lies on this plateau (see Figure 1) and the volcanic cone of Phnum Yat (254 m), south of the town is surmounted by a Buddhist temple. The fourth lava outcrop seen in a coffee plantation, is only 200 m in diameter and is considered to be a volcanic pipe.

A thin-section study of the lavas from the Pailin and Chantaburi-Trat (Thailand) gemfields (and from other bodies between them) shows that they are all of an essentially similar basic to ultrabasic silica-deficient type. The chemical composition of the Pailin rock (Lacroix 1933) is very similar to the average basanites quoted by Cox, Bell and Pankhurst (1979). Pailin 'basalt' composition with average 'basanite' in brackets: SiO_2 43.50 (44.30), TiO_2 2.82 (2.51), Al_2O_3 13.91 (14.70), Fe_2O_3 3.62 (3.94), FeO 8.50 (7.50), MnO 0.15 (0.16), MgO 8.48 (8.54), CaO 10.78 (10.19), Na_2O 3.30 (3.55), K_2O 2.20 (1.96), H_2O+ 0.78 (1.20), H_2O- 0.43 (0.42), P_2O_5 0.84 (0.74), Rest 1.03 (0.18 etc.), Total 100.34 (99.89).

The main crystal phases of the groundmass appear to be analcime and feldspar, often in the range of oligoclase-andesine. Microlites of augitic pyroxene are sometimes identifiable, but mostly the groundmass is fine grained with low relief and very low birefringence. An x-ray examination of the light fraction ($SG<2.9$) showed major analcime and some feldspar. All rocks are porphyritic with phenocrysts of augite, euhedral olivine (often serpentinized) and feldspar. Vesicles containing opaline and chalcedonic silica, andesine and radiating zeolites were noted. The lavas are tentatively referred to as analcime-basanites.

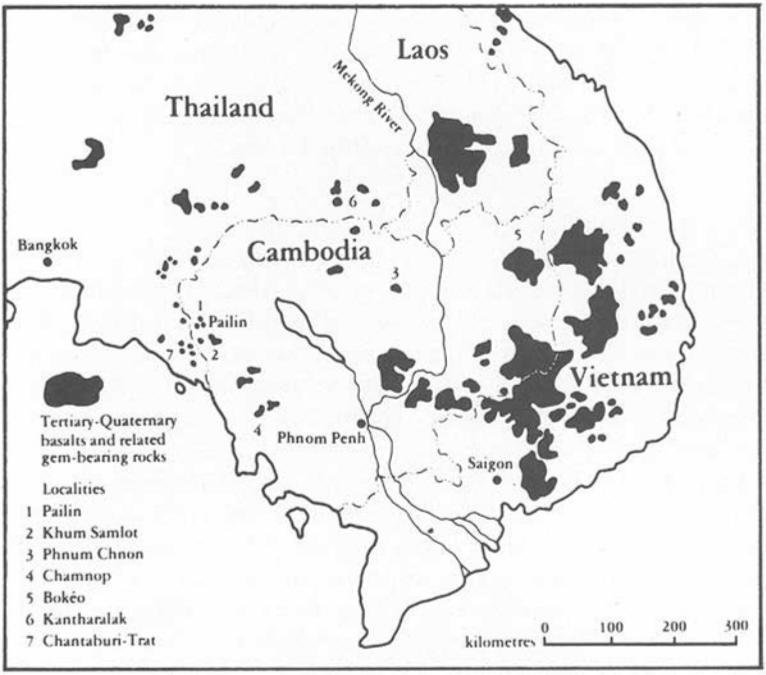
FIG. 1. Pailin looking west: foreground - alluvial workings in O Ta Prang river; middle distance - volcanic vent of Phnum Yat (temple on extreme left) and lava flows extending to north (right); slopes to Tadeth mountain at rear.

The other notable feature of the Pailin lavas is the presence of large megacrysts of magnetite, ilmenite, dark spinel, clinopyroxene, garnet, olivine, phlogopite mica and feldspar. Zircon, ruby and sapphire are found in the gem gravels and have been weathered out of the lava, but we found only one zircon in the lava and only one ruby in matrix was reliably reported although others were reported by the miners. This suggests a sparse distribution of the gem minerals in the lavas, with a marked concentration as a result of weathering. There appears to be an erratic distribution of the megacrysts and not all occur in every outcrop and no rubies, sapphire or zircon were found near the small volcanic pipe.

FIG. 2. Pailin rubies and sapphires (from 1 to 3 ct) showing colour variations, with clinopyroxene xenocryst from the basalt.

A study of the xenocrysts as recovered reveals that many of them, especially the sapphires and clinopyroxenes (see Figure 2), show marked corrosion reminiscent of the ablation marks on meteorites. We suggest that the xenocrysts of corundums, clinopyroxenes, garnets, spinels and others were originally formed at great depth by metamorphism and/or metasomatism on the margins of a basic pluton and were then intruded rapidly with the basic magmas at a later date.

Reference to Map 2 will show that the basaltic bodies in Indo-China may be divided into two broad groups—small and large. The small bodies of the Pailin-Chantaburi type carry ruby, sapphire, zircon and garnet, whereas the larger, and more easterly, bodies are relatively barren save for the zircons at Ratanakiri described by Lacombe (1968-70). Work on the dating of these lavas is still in progress, but determinations on the Pailin lavas have yielded ages between 2.14 and 1.4 million years (U. Pliocene-L. Pleistocene) in contrast to ages for the larger bodies which go up to 12 million years. It may be that the older bodies initially carried gem corundum, but that later outpourings were barren and that gems are buried under later lavas.



MAP. 2. Gem localities and basaltic vulcanism in south-east Asia.

Examining the gem-bearing bodies in more detail shows that the small basaltic plateau (with its two volcanic necks of Khao Ploi Waen and Khao Wua), some 8 km west of Chantaburi, yielded blue, green and yellow sapphires and the so-called 'black star-sapphires'. Some 37 km to the east the workings near Ban Bo Na Wong produce mainly rubies (ruby:sapphire ratio said to be 20:1). Still farther east (and near the Khmer border) the deposits near Ban Thung Chug Ka Chan produce rubies with very small amounts of blue sapphire. The deposits at Bo Rai (some 28 km south of Pailin) are almost certainly ruby producers as are those at Bar Khal Stung (about 9 km NE of Bo Rai and often referred to as Khum Samlot). Finally we have the eastern bodies at Pailin which are ruby producers save for the Phnum Yat body producing sapphires.

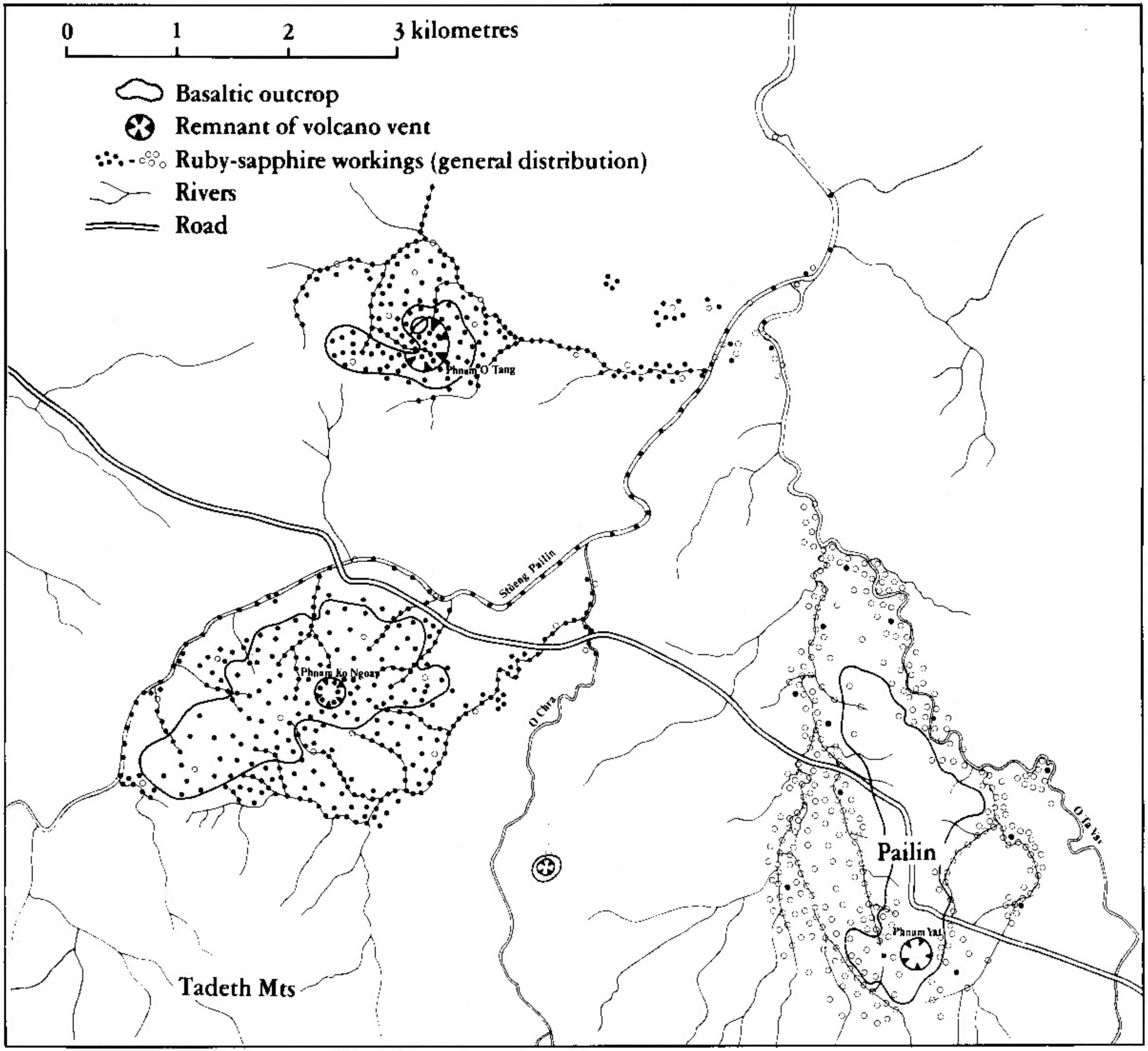
These deposits are all derived from similar basaltic rocks and it is interesting to note the colour changes (and, of course, the colouring agents) from blue/green/yellow in the west through red and back to blue at Pailin where no yellow sapphires were reported.

The reasons for these changes are not immediately apparent—are they connected with the relative ages of the intrusions, with the colouring agents changing as vulcanicity proceeded, are they the result of tapping different levels in the deep-seated magma or has local assimilation of country rocks played a part?

THE GEM MINERALS

Probably the most striking aspect of the corundums of the Pailin area is the virtual absence of colourless, yellow and green stones. None were seen by the authors, and the local diggers and gem merchants could only vaguely recall the very occasional yellow stone. Nevertheless there is considerable range in colour from pink to brownish-red in the rubies of the Phnum Ko Ngoap and Phnum O Tang bodies and from very pale blue to deep blue in the sapphires from Phnum Yat. The rubies may sometimes attain a virtual 'pigeon's blood' or 'Burma ruby' red and these stones become only slightly more red in tungsten lighting; the directional change in colour due to pleochroism is small, the extraordinary ray being only very slightly more yellowish-red. Good colour rubies were reported from the gemfields near Khum Samlot. Paler and more purple stones which occur in all three bodies often show a wider pleochroic change from yellowish-red to purplish-red and there is a noticeable increase in redness when viewed by tungsten lighting. Pronounced colour-change material is not uncommon in the gravels from Phnum Ko Ngoap and to some extent from Phnum O Tang. These stones appear violet when viewed along the optic axis but a pale yellowish-grey in other directions; under tungsten lighting they change colour to deep pinkish-red and pale yellowish-brown, and such stones could be mistaken for reasonable rubies if viewed by artificial illumination. Deep pink and bright red stones show the chromium spectrum normally asociated with ruby, but as the colour deepens with increasing percentage of iron and the reds become brownish or purplish, the chromium spectrum tends to be modified or even swamped by absorption in the green and blue due to iron which is a characteristic of many stones from this area. The sapphires, which were usually of good commercial colours and not of inky hues, show an attenuated absorption spectrum only with a distinct line at 4500Å and a very faint line at 4600Å.

The fluorescence of the Pailin stones under ultraviolet light (long wave 3650Å) is generally weak, the bright red stones



MAP. 1. Distribution of ruby and sapphire occurrences in the Pailin gemfield, Cambodia.

appearing a dull red, whereas the darker and more brownish-red stones are almost inert. Blue stones show no fluorescence and virtually all stones examined were inert under short wave (2537Å) radiation.

The refractive indices of the stones were normal, being in the ranges 1.760 to 1.762 for the extraordinary ray, and 1.768 to 1.770 for the ordinary ray, with a constant birefringence of 0.008. Specific gravities determined were in the range 3.993 to 4.007.

Colour zoning is common in the stones, and many sapphires are quite cloudy due to microscopic inclusions. We were assured that these imperfections and some of the larger inclusions become almost invisible to the naked eye and the colour improved by the heat-treatment process (which often included the use of chemicals) to which a high proportion of the sapphires and rubies are subjected either in Pailin itself or in other marketing centres such as Bangkok.

Zircon, mainly seen as fragments up to 5 cm long, from the Phnum Yat body ranged from colourless through pale straw to reddish-brown and brown in colour. Tiny euhedral, but broken, zircon crystals of a bright orange-red colour were also seen. As with corundum, euhedral material was uncommon and the subhedral and other grains showed much evidence of corrosion in their smooth, very bright surfaces, which appear to be a characteristic of many zircons of basaltic parentage. Freshly broken surfaces were also found, probably due to fracture during river transportation.

Unlike gem zircons from Burma and Sri Lanka which contain uranium and and/or thorium and show rich absorption spectra, the zircons from Pailin hardly show a spectrum although faint lines in the red are sometimes just discernible.

The garnets are invariably an intense brownish-red colour and the grains show their transparency only when held to sunlight or an intense light source. The specific gravities of grains determined are in the range 3.756 to 3.768 and the refractive indices are in the range 1.748 to 1.750. As might be expected from the deep colour, the absorption spectrum is intense with complete absorption of the blue and much of the green part of the spectrum, with a faint line in the orange. These properties indicate that the stones are in the pyrope-almandine range and nearer to the pyrope end of the series. These garnets are mostly too deeply coloured to look really attractive when cut.

The garnets are generally angular to subangular in shape but close examination of some grains shows them to have rounded edges. In addition many surfaces show etch-pits of triangular or lozenge-shaped cross-section which may develop into fine channels commonly crossing at angles which suggest a relationship with the crystallographic symmetry of the mineral. These features point to fragmentation into angular pieces whilst still in the magma, followed by rapid corrosion and etching, which in some instances produces a fine saccharoidal surface pattern. More rounded fragments showing dull water-worn edges are not uncommon in the gem gravels.

Dark brown to black clinopyroxenes are a characteristic heavy mineral of the gravels. Near the vent of Phnum O Tang fragments up to 10 cm in length of these shiny black clinopyroxenes are abundant, and similar material but of smaller size is common in the gravels over the whole gemfield. Specimens derived from gem gravels remote from the vents are usually rounded by abrasion in the fluvial cycle. These clinopyroxenes have specific gravities in the range 3.32 to 3.37, and determination of the refractive indices of one specimen from the Phnum O Tang vent area gave values of α-1.688, β-1.691, γ-1.711.

Other heavy minerals include dull-black magnetite, a black spinel and greyish-black ilmenite, often showing fine striae and lamellar structure and sometimes intergrown with rutile.

Rounded fragments of green olivine are found locally in the gravels and feldspar occurring as xenocrysts in the parent rock appears near the basaltic bodies.

Examination of the surface features of the heavy minerals from the gem gravels gives some idea of their history. The corundums have angular to subangular outlines, but generally have a rounded surface relief with scalloped or fluted features resembling surfaces sometimes seen on meteorites. A high surface polish is common in grains recovered near the vents. Euhedral corundums are rare, and even on recognizable crystals the edges are rounded. The clinopyroxene fragments, frequently have a blocky form, controlled by the cleavage, but again the edges are generally rounded and the surfaces finely etched producing a silky sheen. There is clear evidence of etching out along the cleavage traces on surfaces broadly perpendicular to the cleavage direction.

FIG. 3. Hand working the shallow surface (eluvial) deposits above the 'basalt' on the crater rim. Note sacks of 'rai' (gem gravel) ready for tractor transport. Phnum O Tang body.

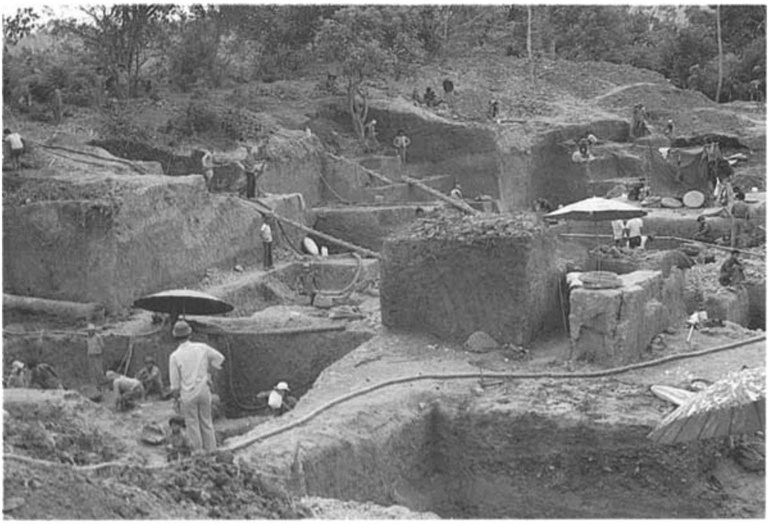


FIG. 4. Open cut workings in alluvium near Pailin. Note the stepped rectangular pattern of excavation, the competent vertical faces of the alluvium and the dumped overburden in the background.

These surface features all point to the fact that the megacryst minerals were in disequilibrium with their surrounding lava environment and were being actively corroded at some stage during their ascent. This is confirmed by the recrystallization of the outer layers of many of the clinopyroxene xenocrysts as seen in thin section.

METHODS OF WORKING

For convenience the methods of working have been divided as shown below but one type may grade with another.

1. Surface clearing
2. River bed working
3. Pitting
4. Open cuts
5. Trenching
6. Mechanized clearing of soil and overburden prior to 4 and 5.

1. Surface clearing of the eluvial deposits was in operation over the crater area of Phnum O Tang at the time of our visit—the whole of the top soil and decomposed basalt being scraped down to bedrock, placed in sacks and transported to the river for washing (see Figure 3).

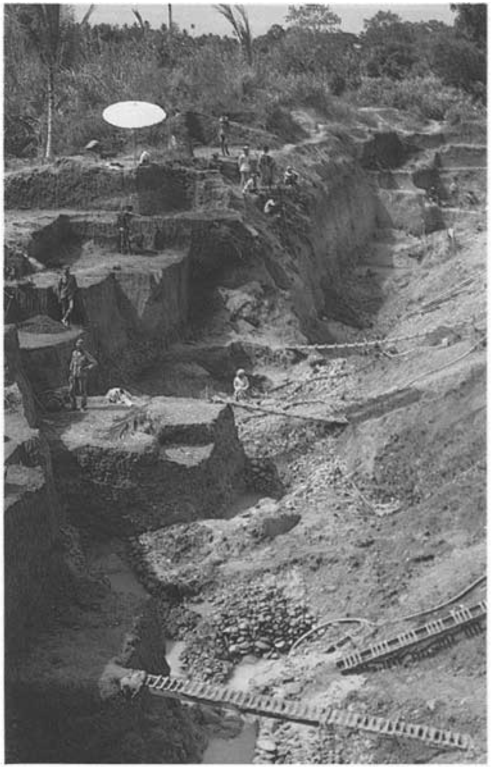
2. Washing of the alluvial deposits in the river beds was widespread—operations mostly completed on the spot using flat baskets and sieves.

3. Pitting is the obvious way to locate a gem bearing horizon at depth and in many areas, especially over Phnum Ko Ngoap, pits (60-90 cm diameter) were sunk to 4 m or more. Spacing might be a mere 2 to 3 m apart.

4. Open cuts were seen at several localities (see Figures 4 and 5). In these workings the overburden is removed over a series of adjacent rectangular areas (possibly concessions) which descend to the gem gravel(s) in a series of irregularly arranged steps with slippery walkways or planks spanning open cuts at various levels. The gem gravel may be recovered over the whole area, but it often seems to require the double handling of quantities of overburden which have to be moved from one place to another. Various classes of worker are often employed, and overburden diggers are sometimes paid by the cubic metre dug out and on a sliding scale which increases with depth.

Left: FIG. 5. Locally made shaking table made of three superimposed screens and driven by an eccentric cam from a diesel motor. The 'rai' (gem gravel) is fed on at the upper end and is washed and sorted into sized fractions. Gems most frequently occur in the ½ inch to ¼ inch and the ¼ to ⅛ inch fractions which emerge separately at the two chutes. Open cut workings near Pailin town.

Right: FIG. 6. Pailin: trench working some 100 m long and 8 m deep in alluvium, O Ta Prang river.



5. Trenching methods over reasonably large sites were only seen at O Ta Prang, but they possibly exist elsewhere in the area or have been operated in the past. At O Ta Prang a long trench to a depth of some 8 to 10 m was opened up along the line of the river for a distance approaching 100 m (see Figure 6). A considerable depth (*c.* 5 m) of overburden was being re-worked so as to reach the lower gem gravels which could not be de-watered for working prior to the advent of the portable motor pump. By this trenching method it is possible to avoid the neutralizing of any gravel, but the re-working of the overburden as at O Ta Prang (because of the two levels of gem gravels) is obviously highly undesirable and could be avoided in future workings by careful planning. Mechanized working had been forbidden by the authorities at the time of our visit, probably since a large pool of cheap labour was available and the men needed the work. However, bulldozers and other mechanical equipment had been used to clear the overburden down to the gem gravel level in the past, and this method has many advantages in time and efficiency if the social aspects are ignored. Working of the underlying gemmiferous layers may best be carried out using an advancing system of trenches.

It is regrettable that highly inefficient and wasteful methods of extraction were in everyday use over the whole of the Pailin gemfield.

MARKETING AND CUTTING

We think we were able to gain a reasonably accurate picture of the local marketing scene during our visit to Pailin, but the international ramifications were less easy to assess. A typical pattern of events might be that a small-scale miner or group would sell the daily output at the diggings to intermediate dealers who were able to reach even the most remote workings on their motor cycles. These dealers, who would buy individually or as a syndicate, would then either trade the uncut stones in the market place at Pailin amongst themselves or offer them to larger dealers. Cutting might take place after any stage in this marketing procedure. At the top there were perhaps 10 to 15 principal dealers some of whom had international connexions and may have had their own agents at the actual workings. From our enquiries it appeared that the highest profits were at the top of the chain, and were principally made when the stones left Pailin and were sold in Bangkok or elsewhere, the transactions often being in the hands of non-Khmer dealers. A very small proportion of stones was exported via Phnom Penh, and little direct revenue was received by the Government. On the other hand the gem industry at Pailin probably supported between 100 000 and 200 000 Khmers who might otherwise have been an embarrassing charge on the Government.

A substantial proportion of the stones produced were heat-treated and cut in Pailin but the treatment was also carried out in Bangkok. The standard of cutting we saw was not always high, but neither was it as poor as cutting in other gemfields of southern Asia where the stones are cut locally. Orientation to produce the best colour from a piece of rough was often very good, but more emphasis was laid upon getting the maximum possible weight rather than upon obtaining the best looking and most symmetrically cut stones.

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[*Manuscript received 15th August, 1981.*]

A BRIEF SUMMARY OF GEMMOLOGICAL INSTRUMENT EVOLUTION*

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President, the Gemological Institute of America

INTRODUCTION

Compared to chemistry or physics or its parent science, mineralogy, gemmology is still in its infancy, and the early instrumentation used by the gemmologist had to be borrowed almost exclusively from mineralogy or physics. For example, the polarizing microscope was primarily a mineralogical tool, and instruments such as the spectroscope came from optical physics. Even gemmological equipment that had been developed much earlier elsewhere was not available for sale in America. Many years ago, the late Robert M. Shipley told me that in 1930 to the best of his knowledge only one gem refractometer existed in the United States.

GEM MICROSCOPES

The monocular petrographic microscope (Figure 1), which was used by most early gemmologists, was not a very effective tool for gemstones. Although highly effective for powders, this microscope did not enable the user to examine effectively the interior of a stone. Lighting the interior of gems being tested was difficult and the result usually poor. In the early days, for practical purposes, magnification was provided either by loupes or by monocular microscopes.

Of the major advances in gemmological instrumentation made by Shipley's son, Robert Shipley, Jr, probably the most important was adapting dark-field illumination and stereoscopic magnification for the study of gemstones. A patent on the combination, which was called the Diamondscope, was granted in 1938 (Figure 2). There were two great advantages to the combination the younger Shipley chose: (1) with the stone lighted from the side, inclusions appeared as bright objects against a dark background; and (2) the stereoscopic magnification provided a large field of view with upright images, as well as a great depth of

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*Note: This article refers only to instruments used for gem identification. It does not discuss instruments designed for grading the colour, clarity or proportions of diamonds.

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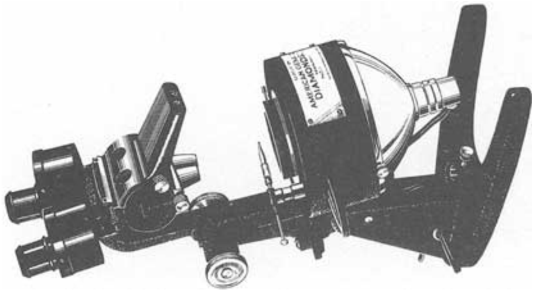
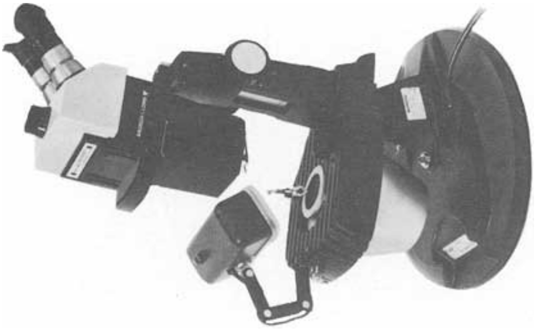
FIG. 1. Petrographic Microscope.



Left. FIG. 2. An early Diamondscope.



Right. FIG. 3. Custom B Gemolite with zoom.

focus. This contrasted with the inverted images, small field, dark objects against a light background and small depth of focus of the monocular petrographic microscope.

Another distinct addition to the microscopy of gemstones was the mechanical stone holder that young Shipley devised. He worked on this with an old French tool-and-die maker named Raoul Francoeur, who also built the first polariscope for him (Figure 5). This stone holder is still in use on 1980's microscopes—without any significant change (Figures 3 and 4).

In the early days of gemmology, the principal means of distinguishing singly refracting from doubly refracting materials was the polarizing microscope. For gemstones of more than a fraction of a carat, this instrument was very awkward to use. After Edwin Land developed the efficient polarizing sheet film he called Polaroid, Robert Shipley, Jr, was immediately intrigued and soon developed the first gem polariscope. It had Polaroid plates in place of the complicated Nicol Prisms which the polarizing microscope used. The Nicol Prisms were much more expensive and had size limitations the Polaroid material did not have. Shipley's earliest polariscope used small squares of Polaroid, but later instruments used large circular pieces. This instrument is still important for determining optic character; the details of its use are not within the scope of this article.

The dichroscope, another instrument for determining single and double refraction, uses a different material: Iceland-spar. The function of the dichroscope is to determine the differential absorption of light between different vibration directions in doubly refracting coloured stones. This small instrument uses the strong birefringence of calcite to separate the two polarized vibration directions in a dichroic gem. Early dichroscopes contained an elongated cleaved section of calcite, usually ground and polished flat on the opposite small ends, with a square or rectangular aperture at one end. A lens at the other end is focused on the aperture, which appears doubled. The calcite separates light into two polarized rays that have vibration directions at right angles to one another. Pleochroic coloured stones show different colours in the two images of the aperture; often the colours are distinctive.

Another form of dichroscope uses two or four pieces of sheet Polaroid. If two are used, the two vibration directions are set at right angles, to one another. If four are used, pairs are lined up

FIG. 4. Stone-holder.

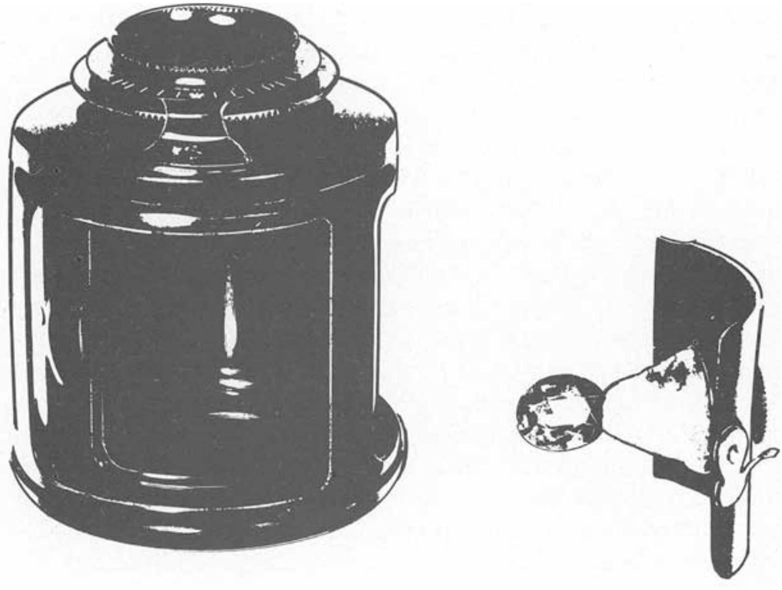


FIG. 5. An early polariscope.

parallel in diagonally opposite quadrants and at 90° to the vibration direction in the other two quadrants.

The increasingly serious shortage of Iceland-spar forced G.I.A.'s subsidiary, Gem Instruments Corporation, to go from the original Iceland-spar dichroscope to sheet Polaroid around 1977. Gale Johnson, a Vice-President for Gem Instruments Corporation, produced an ingenious device that permitted the use of much smaller pieces of Iceland-spar to get the same effect as when large sections were used.

REFRACTOMETERS

Before the advent of the jewel refractometer (or the total reflectometer, as it is sometimes called), the only reliable means of determining refractive index readily available to the gemmologist was the polarizing microscope using calibrated index liquids. The first refractometer designed to measure the refractive indices of gemstones was designed by the late G. F. Herbert Smith of

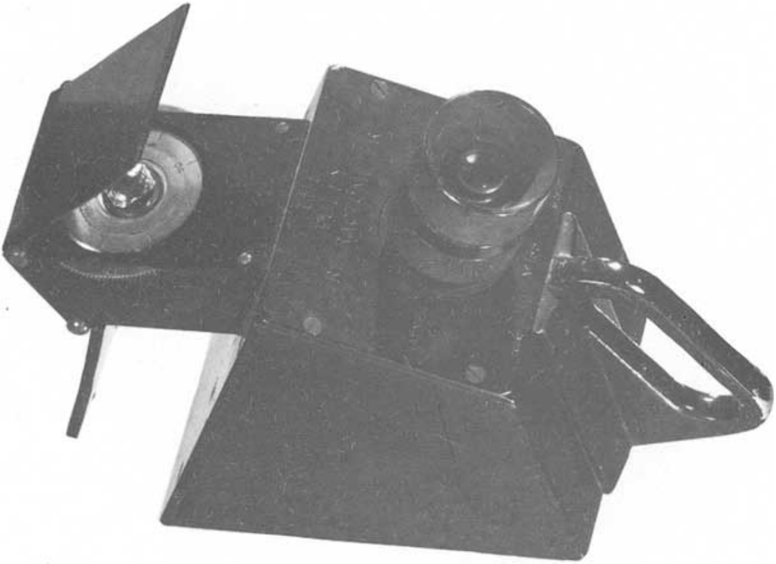


FIG. 6. Tully Refractometer.

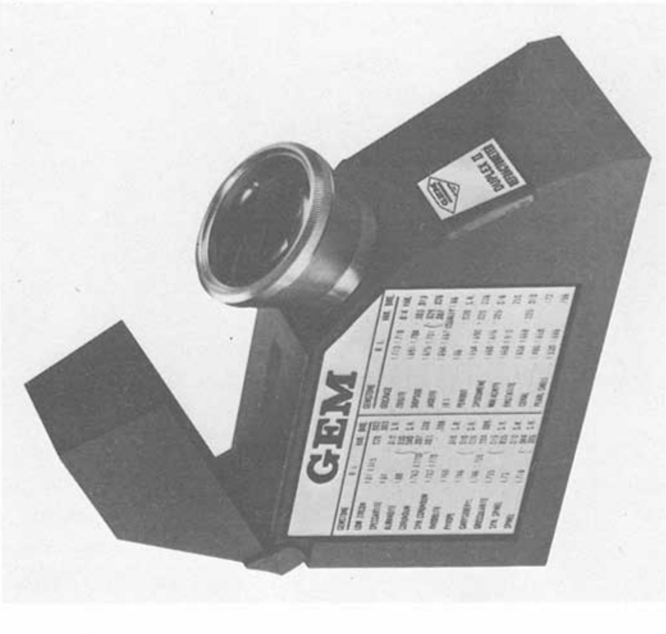


FIG. 7. The Duplex II Refractometer.

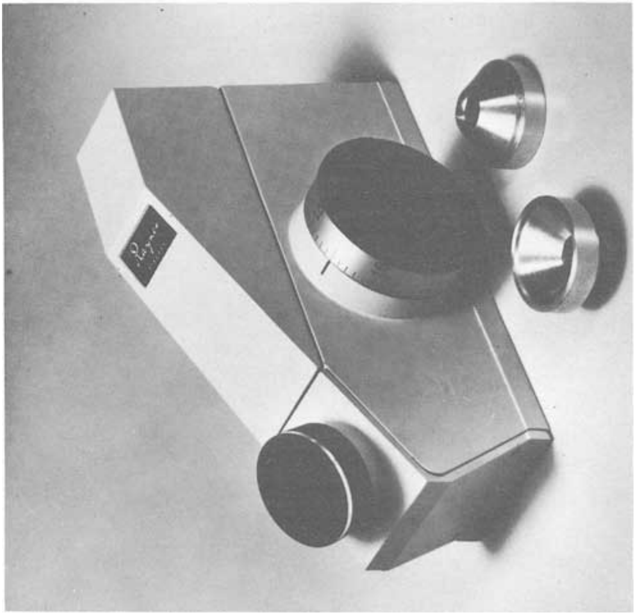


FIG. 8. The Rayner Dialdex Refractometer.

England, the author of the famous *Smith's Gemstones.* His first one, made in 1903, did not have a scale, but a model made two years later did. This was followed by the Rayner and Tully (Figure 6) refractometers, which were also made in England. Rayners, at the suggestion of Basil Anderson, also produced refractometers with a diamond contact prism and others with synthetic spinel and zinc blende.

In the United States, the Erb & Gray refractometer was made for G.I.A. shortly after World War II. There were two models, one with a rotating hemisphere and the other with a stationary hemisphere. A few years later, Robert Shipley, Jr, made the tiny Gem Refractometer. G.I.A. later developed the Duplex Refractometer (Figure 7), the first instrument designed specifically to take advantage of the spot, or distant-vision, method for taking refractive index readings on curved surfaces or tiny flat facets. This method was discovered by the former Director of Research at G.I.A., the late Lester B. Benson, Jr.

In recent years, the Rayner refractometer has been redesigned. The first new model was the Dialdex (Figure 8), which has an exterior dial that gives the refractive index reading. A second model has an interior scale. Rayner-type refractometers are also now made in Japan.

The most recent developments in conventional refractometry are a new design by Cornelius Hurlbut, Professor Emeritus of Mineralogy at Harvard, using a cubic zirconia hemicylinder in a G.I.A. Duplex Refractometer, and the newly announced Krüss refractometer with a refractive index upper limit of about 2.2. The latter uses a strontium titanate prism and a solid contact material. A solid contact material must be melted to make the optical contact between gem and hemisphere. Our analysis of this contact material showed thallium, a highly toxic ingredient.

TOOLS FOR DETERMINING SPECIFIC GRAVITY

One measurable property used widely, particularly in the early days, is specific gravity. The specific gravity of gemstones is obtained either through weighing the stone both in air and in water, or by observing the results when loose stones are dropped into heavy liquids of known densities. Both heavy liquids and the hydrostatic methods are very appealing in that they provide useful information relatively quickly and inexpensively. Unfortunately, specific gravity tests are useless with mounted stones.

1. Heavy liquids

The most versatile heavy liquid is methylene iodide, which in pure form at about 70 °F has a density of 3.32. It is relatively safe to use, compared with most other liquids. Bromoform, at the slightly lower specific gravity, of 2.89, was widely used until it was discovered to be a dangerous liquid; prolonged inhalation may be very harmful.*

Many other high-density liquids have been used in gem testing. Perhaps the most useful of the high range is Clerici's solution. However, it includes thallium malonate and thallium formate; these thallium salts are highly toxic, so the liquid is dangerous to use. In saturated solution at room temperature, it has a density of about 4.15. When diluted with distilled water, its specific gravity (SG) is easily determined by taking its refractive index (RI), since the relationship is linear, as pointed out by Anderson, Payne, and Webster. (At RI 1.56, the SG is 3.10; at 1.61, the SG is 3.52; and at 1.668, the SG is 4.0.) The solution should be used with extreme caution to avoid contact with the skin.

2. Balances

Almost any balance used for weighing gemstones can be equipped to weigh the stone while immersed in water as well as in air. A number of balances have been designed expressly to test specific gravity. The Berman balance is a torsion balance designed by a Harvard professor to give accurate specific gravities for stones of less than one-third carat, for which measurements are likely to be very inaccurate when using the normal balance.

There have been a number of direct-reading balances such as the Westphal, the Penfield, and the Hanneman. On these, the stone's weight in air becomes a zero setting. Then when the stone is weighed in water, the resultant reading is the specific gravity. With today's sophisticated gemmological testing procedures, specific gravity is used less frequently perhaps, but it remains a very useful test.

HARDNESS

Determining a stone's hardness has some value in testing.

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*See *J.Gemm.*, 1979, XVI(6), 430, lines 7-14.—Ed.

However, testing hardness is very likely to damage the gemstone being tested. The usual tool for this determination is a set of hardness points commonly in whole numbers from 5 to 10 on the Mohs Scale. To test an unknown stone with a hardness point would leave a scratch, so it really has no place in the testing of fine gemstones. Perhaps better suited for this purpose is a set of hardness plates over which the girdle of the unknown can be drawn. If this is done carefully the gemmologist is able to determine the hardness of the material relative to the Mohs Scale with somewhat less chance of damage.

TOOLS FOR DISTINGUISHING CULTURED FROM NATURAL PEARLS

When, in the early 1920s, cultured pearls began to reach the market in some quantity, it became imperative to develop a means by which they could be distinguished from the very expensive natural pearls. At that time almost the only effective means (other than indications such as determining the slight differences in specific gravity or the use of the 'pearl compass'), was a careful examination of the drill hole. The examiner looked for the usually darker conchiolin layer between the mother-of-pearl bead and the nacreous layers of the cultured pearl. This is a reasonably effective test even today.

In the mid-twenties René Bloch, of Paris, a pearl dealer, devised the ingenious endoscope in which a hollow needle was cut in a manner that provided two mirrors set at 90° to one another and at 45° to the length of the needle. Light passing through the needle (actually a syringe needle) would strike the first mirror, pass through the concentric layers of nacre on a natural pearl, and thus reach the second mirror and show a flash of light to the eye through a microscope focused on the end mirror. Since the nacreous layers of the large mother-of-pearl bead in a cultured pearl are parallel instead of concentric as in the natural pearl, the cultured pearl did not display a flash of light. This test worked only for drilled pearls, and it required cutting a necklace entirely apart so each pearl could be tested individually, a laborious and time-consuming task.

In 1938, Dr A. E. Alexander, of the Pearl Associates Laboratory in New York City, (later turned over to what is now the G.I.A. Gem Trade Laboratory) devised a means by which x-rays could be used to identify and distinguish cultured from natural pearls without cutting the strand. He found that natural salt-water pearls did not fluoresce to x-rays, while cultured pearls with fresh-water mother-of-pearl beads did. X-ray fluorescence indications can be confirmed by x-radiography, and the whole strand can be recorded on film at once. The layer of rich conchiolin that surrounds the bead of the cultured pearl before nacre starts to be added is readily discernible on the x-radiograph, because of its greater transparency to x-rays. There is another x-ray method which can only be used for testing individual pearls—the Lauegram method. It is very useful when the nacre layers make up less than one half of the pearl's diameter. A collimated x-ray beam passing through the centre of the pearl is deflected in a manner that creates a spot pattern on a film. Since the pseudohexagonal aragonite crystals in the concentric layers of nacre in a natural pearl are arranged in a spoke-like pattern, the beam traverses their length. This produces a six-sided spot pattern. There is only one direction in a cultured pearl in which the mother-of-pearl bead would produce that pattern—in most directions a four spot pattern is seen. Confirmation of the hexagonal pattern in a natural pearl is provided by a second shot taken after the pearl is rotated 90°.

INSTRUMENTS FOR DETECTING DIAMOND SIMULANTS

The advent of a number of fairly realistic diamond simulants such as gadolinium gallium garnet (GGG) and cubic zirconia brought forth new instruments to distinguish between diamonds and simulants. The first one of importance was the reflectivity meter.

1. Reflectivity Meters

All other things being equal, the higher the refractive index, the greater the surface reflection, that is, the higher the percentage of light striking a gem's surface that is reflected back to the sensor. Unfortunately, this percentage also depends on other factors in addition to refractive index; the quality of the polish, the flatness of the surface and cleanliness of the stone also affect reflection. Because of these variables, reflectivity meter results tend to be much less dependable than those obtained from the conventional gem refractometer. As a result, gemmologists usually tend to use the meter only for materials with indices above the refractometer's upper limit (1.81).

The early reflectivity meters used an infrared light source that was a good match with a sensor that could pick up the reflections. A variety of reflectivity meters have appeared on the American market and recently European and Japanese instruments have been offered.

Two other instruments designed to distinguish between diamonds and simulants were introduced in the late 1970s. One is the Ceres Probe, which tests heat conduction: Diamond's unsurpassed heat conduction distinguishes it from any simulant. The other is the Diamond Pen, developed by the Gem Instrument Corporation, which differentiates simulants and diamonds by the behaviour of a special liquid that spreads on the surface of a diamond but beads on simulants.

THE SPECTROSCOPE

The spectroscope was of little consequence in gemmology until Basil W. Anderson of the Gem Testing Laboratory of the London Chamber of Commerce proved how valuable it could be for gem identification. His pioneering work was of enormous importance to the field. He investigated some of the findings of an earlier scientist, Arthur Church, and studied the spectra of garnets, rubies, zircons and various other gemstones using a hand spectroscope. From the viewpoint of his fellow gemmologists, Anderson's findings introduced a new era in testing.

The spectroscope is somewhat more difficult for the novice to learn to use effectively than some of the other instruments, but the results are particularly rewarding. There are many types of spectroscope available, including hand and wavelength types, as well as spectrometers. Anderson hand-held a Beck spectroscope over a microscope tube, through which a strong light was directed from below through the gemstone being examined.

Robert Crowningshield used the wavelength type on the G.I.A. Spectroscope Unit (Figure 9) in his discovery of a means to distinguish between irradiated and naturally coloured diamonds, and between naturally coloured and dyed green jadeite.

ULTRAVIOLET RADIATION, X-RADIATION, AND FLUORESCENCE

Short- and long-wave ultraviolet radiation was added to the gemmologist's instrument arsenal relatively early. Long-wave radiation (at about 3660Å) excites bright fluorescence in more gems than short-wave (at about 2537Å), but both are useful in gem identification. Since the strength and colour of fluorescence often depend on the presence of small amounts of impurities or colouring agents (such as chromium), and are subject to dampening in the presence of other impurities (such as iron), fluorescence is less dependable than many other tests.

For those who have x-ray equipment, fluorescence caused by x-radiation also may provide useful information. The fluorescence of transparent diamonds to x-rays is so dependable that it is used to separate diamonds from heavy mineral concentrates in diamond recovery from ores. Several other gems, such as translucent green grossularite and kunzite also have distinctive x-ray fluorescence.

FIG. 9. Gem spectroscope unit with Beck Wavelength model.

Another test used occasionally to separate natural emerald from synthetic is transparency to short-wave ultraviolet radiation, a characteristic of synthetic emerald. One quick way to make the test is to direct a short-wave ultraviolet lamp at the unknown, which is placed so it completely covers an opening in an opaque shield. Below the opening is placed a piece of scheelite, which will fluoresce only under short-wave ultraviolet radiation. If the scheelite fluoresces, the unknown passes ultraviolet at least down to 2537Å.

SPECIAL-PURPOSE INSTRUMENTS

There have been many special-purpose or minor instruments developed over the years. The thermal reaction tester, a tiny, electrically heated metal point, was developed specifically to detect paraffin treatment of turquoise (it causes the paraffin to melt and well up to the surface), but other uses soon became apparent. One is the easy separation of amber from plastic substitutes by odour.

The conductometer was developed when it was found that colourless diamonds subjected to electron bombardment turn blue. In nature, only Type IIb diamonds are blue, and they conduct electricity; treated blues do not. The conductometer determines whether an unknown blue stone conducts a current.

Occasionally, scintillometers or geiger counters are used to detect radioactivity in an ekanite or a radium-treated diamond.

The Luminoscope permits binocular magnification of the luminescence caused by an electron beam. Its effect is to make structural oddities obvious, and differences between the reactions of synthetic and natural materials may become apparent.

FILTERS

Various colour-filters have been employed in gem testing with different degrees of success. Undoubtedly the best of them is the Chelsea Filter (also known as the Emerald Filter). Basil Anderson and C. J. Payne of the London Chamber of Commerce Laboratory noted that the light-transmission curve for emerald is unusual for a green stone: a portion of the yellow-green is largely absorbed, but most of the deep red is transmitted. They prepared a filter that transmitted the deep red wavelengths but absorbed the green—except in the yellow-green sector. Most (but not all) natural and synthetic emeralds appear red through the filter, but most green substitutes do not. This filter has a few other uses, but generally provides more of an indication than a proof of identity.

Anderson also devised an interesting way to check red fluorescence—particularly that caused by chromium. Light is directed through a saturated copper sulphate solution (cutting out the red end of the spectrum) and then through a gem. The emerging light is passed through a red gelatin filter. Stones coloured by chromium appear bright red, because the fluorescence is triggered by wavelengths not absorbed by the copper sulphate. Other filters are used to sharpen refractometer readings and for other less important purposes.

Other minor tests include refractive index determination by the appearance of facet junctions when gems are immersed in a liquid of known refractive index, reaction to acids, and fade tests for irradiation.

ADVANCED RESEARCH INSTRUMENTATION

A number of advanced techniques are used for gem identification in research laboratories. Probably the most widely used is x-ray powder diffraction. A tiny amount of gem material powder is picked up with cement and placed in a spindle, which is rotated in front of the collimated x-ray beam. Reflections of different planes of atoms are recorded on a strip of film, usually in a camera with a film diameter of 114.7 mm. The intensity and spacing of the lines representing these reflections are characteristic for each gem mineral. (G.I.A.'s Charles Fryer is able to obtain excellent results using so tiny an amount of powder (scraped from the girdle of a fashioned stone) that no weight change is measurable on a balance that is accurate to less than 0.01 carat).

The combination of a scanning electron microscope, with its enormous magnifications, and an electron microprobe or an energy dispersive unit enables the tester to determine fairly accurately the chemical composition of an unknown material. With the energy dispersive unit, no damage is done to the gem material. Electron spin resonance is another source of information for the fully equipped, modern research laboratory, but such equipment is too expensive and bulky for any but the largest laboratory. Several other types of equipment present possible uses in gemmology.

INSTRUMENTS FOR THE FUTURE

Several new and even revolutionary instruments are on the drawing boards, or have recently been produced at Gem Instruments Corporation. The new Colormaster duplicates the hue, tone and intensity or saturation of a coloured stone on an image selected in the general shape and facet pattern desired. Calibrated dials are adjusted to increase or decrease each of three primary colours individually, providing a numerical reading for the combination that best matches the colour of the original gemstone. With this instrument, it would be possible for an appraiser to describe a colour to a supplier and determine the current cost of a matching stone from its reading. It also would be possible to order stones in this fashion or to provide the desired colour for a customer who is not quite satisfied with the colour of an emerald, ruby, sapphire, or other stone in stock. (It requires little imagination to conceive of further uses.)

Generally speaking, the 1980s promise exciting developments in gemmological instrumentation. There may well be a parade of ingenious new aids to identification and grading in the next few years. In view of the rapid pace in the development of new forms of treatment to improve apparent quality and new simulants or synthetics, the gemmologist will need as much help as possible. The prospects are exciting and challenging.

[*Manuscript received 10th July, 1981.*]

STAR INCLUSIONS IN DIAMOND

By R. KEITH MITCHELL, F.G.A.

From time to time apparently six-rayed star inclusions are found in diamonds, usually in crystals, since such blemishes are not acceptable in the cut stone. They seem to be quite rare and, since they all have common characteristics, could possibly originate from a single source. One example, showing only part of the formation in a cleavage flake, was possibly Indian.

Figure 1 illustrates the star in a crystal lent to me by Christopher Cavey, then of Roughgems Ltd, now of Cavey McCallum Company Ltd. This is a good example of the phenomenon and shows the darker star-form as an ill-defined formation or cloud, with more pronounced ribs of deeper colour making a definite star. Between the arms of this dark star is another six-rayed star, which is effectively of clearer material and therefore appears white.

I have said 'apparently' six-rayed stars. Careful examination of the actual crystal shows that the six-rayed phenomenon is seen identically through each of the octahedral faces. It follows therefore that the formation must, in fact, have eight arms, although it has not been possible to find a viewpoint from which all eight arms can be seen at once. Looking directly down on any octahedral face one is looking straight down one pair of arms and these two are not visible in the photograph, or indeed in visual examination, unless the crystal is searched carefully for other indications of the structure.

My second example is shown in Figure 2 and is a crystal which came into my possession some twenty years ago and was irretrievably lost not long afterwards. It was appreciably larger than Mr Cavey's crystal and the star inclusion is much denser and was much more complex, generally grey in colour. Its complexities can still be related to faint features seen in the first crystal. The morphology of both stones was essentially the same, a combination of the octahedron and cube forms with the former slightly predominating. But my stone had two dodecahedral faces, one of which was sufficiently clear to allow photography through it. The cube form consisted entirely of octahedral peaks which ended approximately where a cube plane might be expected to occur.

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FIG. 1. Diamond cubo-octahedron crystal with star inclusion. *(Photo by E. A. Jobbins)*

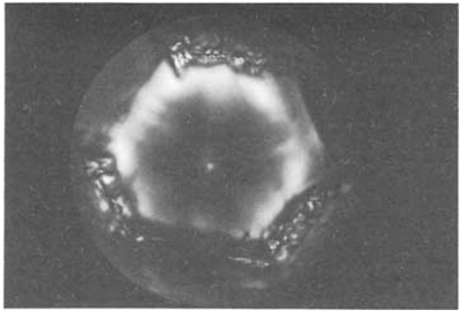

FIG. 2. Funnel or 'hopper'-shaped inclusion in another cubo-octahedron crystal, focused at top of the funnel. Seen through (111) face.

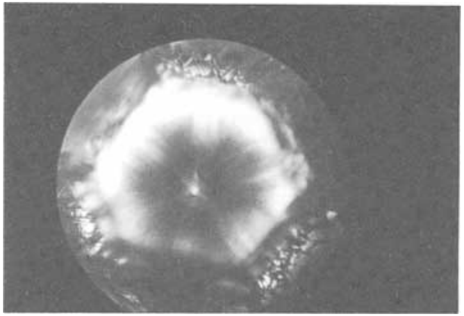

FIG. 3. The same funnel, but with focus near the centre of the diamond crystal. (111) face.

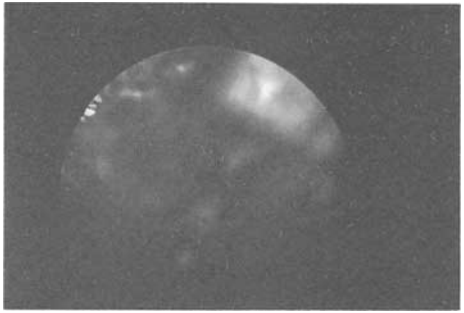

FIG. 4. Two funnel inclusions meeting in the centre of the crystal, seen through the one clear dodecahedral face on the diamond. (110).

This stone had the inclusions sufficiently developed and dense enough to allow one to see clearly those which have been surmised in my third paragraph, and, looking down into the octahedral faces, one sees that each arm of the eight is triangular in outline, with the triangle in opposed position to the octahedral edges, and the whole shape under each face is that of a hopper, in that it tapers towards the centre of the crystal. If one realizes that the three smoother edges in this figure are the octahedral edges (the very rough ones are those of the cube form) then the distorted triangular outline of the top of the 'hopper' can be seen in relation to the octahedral face. In this the inclusion resembles the orientation of trigons on the normal growth surface.

Focusing through the stone one comes to the opposite octahedral face and another triangular end to that arm of the inclusion, but both are reversed in position relative to the nearer ones. The original print of the Cavey crystal shows centrally a very faint curved triangle, which reveals that a similar structure is present and that we are dealing with practically identical formations. In Figure 2 it will be seen that the distorted triangular top edge of the 'hopper' shows evidence of having a double outline with clearer material between the two layers; the centre in this instance is filled with coarser inclusions which do not extend down into the crystal.

In Figure 3 I have focused approximately at the centre of the crystal. Some unidentified inclusions are to be seen, but this view shows the essentially star-shaped mass of sub-microscopic dust inclusions which give the main star effect. It has to be remembered that each arm is a triangular pyramid pointing its blunt end towards a different octahedral face. Thus in this view we have three arms diverging towards faces forward of the point of focus and a further three diverging towards three such faces beyond the focal plane. The two funnels directly in the line of sight are more or less lost by the change of focus. Absolutely sharp focus is impossible, partly because of the diffuse nature of the total inclusion and rather more because the total effect is three dimensional and impossible to bring to focus in one plane at this magnification. A better idea of the total inclusion was to be obtained by raking the focus back and forth through the whole crystal. Figures 2 and 3 were both taken through the same face. Other octahedral faces gave similar glimpses of the star structure but were marred by surface growth lines and trigons and would not photograph even with this degree of clarity. The density of the dust cloud masks the star effect, and it is seen rather in the form of six 'brushes' as opposed to the more clear-cut line effect seen in the Cavey stone.

Figure 4 gives the view through the one dodecahedral face and shows two of the 'hopper' structures in profile, meeting at the centre of the crystal. It was difficult to photograph and I can only hope that the points I want to make will reproduce sufficiently well in printing to make my meaning clear. Other branches of the star are there but are not clearly identifiable. The broad ends of these formations point directly to opposed octahedral faces, in one of which one can see the triangular outline of the end of the funnel shape.

Going up to about 250×, the limit available on my Koritska microscope of those days, I was just able to see that the dust cloud consisted of short rod-like particles mostly oriented in a direction vertical to the octahedral face. In all there must have been millions of the tiny things. The 'hopper' structures did not come right to the surface on any of the faces. In Figure 3 structural lines of inclusions may be detected if it has printed reasonably well.

It is now possible to arrive at some conjectural interpretation of the star as seen in Figure 1. I have already said that the dark star, which is fairly well defined, fades in density as one moves away from the darkest lines. Having established that the dust-like inclusions are formed into eight hollow three-sided pyramidal 'hoppers', other points may be made. First, the particles are less densely aggregated towards the centre of the crystal, i.e. the phenomenon became progressively more intense as growth proceeded, until for some reason it stopped altogether, and secondly there appears to be a greater concentration of the dust particles in the angles of the 'hoppers'.

We now have to explain why, in Figure 1, there are vague areas of darker colour separated by an ill-defined white star and concentrating in a central 'rib' of grey which is the most marked feature of each arm of the dark star. The white star can, I think, be dismissed as the result of the comparatively clear centre of each 'hopper'. Similar questions arise in the case of the second crystal, which is even more complex and therefore less easy to interpret.

In an effort to arrive at a reasonable explanation of this apparent concentration of the dust particles into definite star forms

I constructed a hollow model of the octahedron from thin transparent plastic sheet and then threaded coloured silks through it to represent the approximate edges of the 'hopper' structures. Looking vertically through an octahedral face of this model, it was at once evident that the position of each arm of the eight-fold star is one in which four 'hopper' edges are fairly close together directly in the line of sight and that two of each set in fact superimpose. The view from a dodecahedral direction was also as expected from Figure 4.

Looking again at Figure 1, it has to be remembered again that the star form is not in one nice convenient plane, easily focused in what is a very shallow field indeed. Its arms diverge from the sharp centre both forward and back from the focal point, alternating in direction. The two faces parallel to the line of sight have to be ignored, although their 'hopper' edges almost certainly contribute to the final star.

In Figure 4 we are seeing two edges of each of two tapering forms converging in the centre of the crystal. Why no third edge is seen is not easily explained, but my model, which regrettably is too crude to give usable photographs, does show that these two formations are more or less in one plane, although not sharply so. Indeed scarcely any features of the stars are other than diffuse in structure.

To summarize, this is a diamond inclusion which is both rare and very interesting and, in the second crystal, quite complex. The accurate interpretation of the directions of the darker arms or brushes is exceptionally difficult, especially from two-dimensional photographs. Any contribution these observations may have made towards the interpretation of diamond growth is even more obscure to the writer.

[*Manuscript received 15th December, 1980.*]

AFRICAN STAR CORAL, A NEW PRECIOUS STYLASTERINE CORAL FROM THE AGULHAS BANK, SOUTH AFRICA

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INTRODUCTION

The use of the stylasterine corals for personal adornment is not new. Most standard texts on gemmology mention it in passing but Bolman(2) specifically makes two references of historic merit. Firstly, it was harvested and used by the Polynesians of the Samoan Islands to adorn themselves with unworked fragments of the red, blue and violet varieties of the coral; secondly, the stylasterine coral *Allopora subviolacea* was an important and highly prized commodity in Cameroon, off the West African Gulf, before the eighteenth century. Here the blue and violet varieties were fashioned into necklaces as well as being used for adorning clothes and weapons. It was locally known as 'Akori' (coral). However, its popularity waned, and by the beginning of the eighteenth century it was no longer sought after. All that seemed to have remained is the term 'Akori coral' which has since been used indiscriminately, not only to describe the original stylasterine coral, but also a variety of beads fashioned from coral and coral simulants.

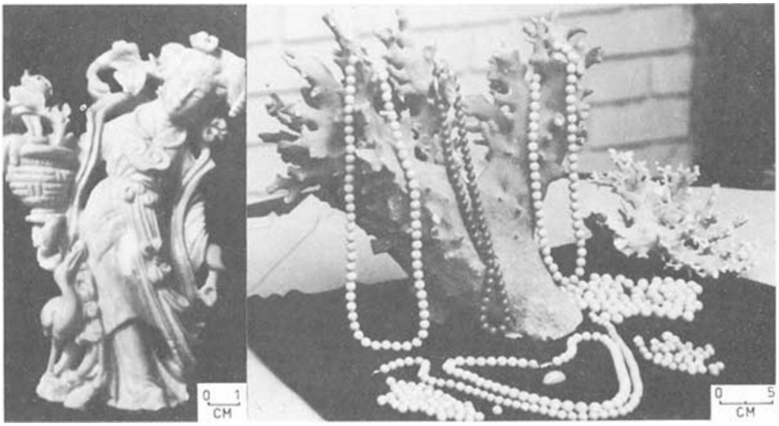

FIG. 1. Stylasterine coral—worked and unworked.

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During the past two years, another stylasterine coral *Allopora nobilis* has reappeared on the world market as 'African Star Coral'. Presently it is being exported from South Africa to Asia, Europe and the Americas in the form of polished beads and unworked slabs and cylinders. The latter are especially in demand for the manufacture of engraved cabochons and carvings (Figure 1).

GEOGRAPHIC DISTRIBUTION AND ZOOLOGICAL DESCRIPTION

Allopora nobilis was originally discovered at a depth of 55 metres in False Bay, near Cape Town, and described by Kent in 1871(1,8). It has been found to exist in both the colder polar Benguella and the warmer equatorial Mozambique ocean currents, from Saldanha in the west to East London in the east (Figure 2).

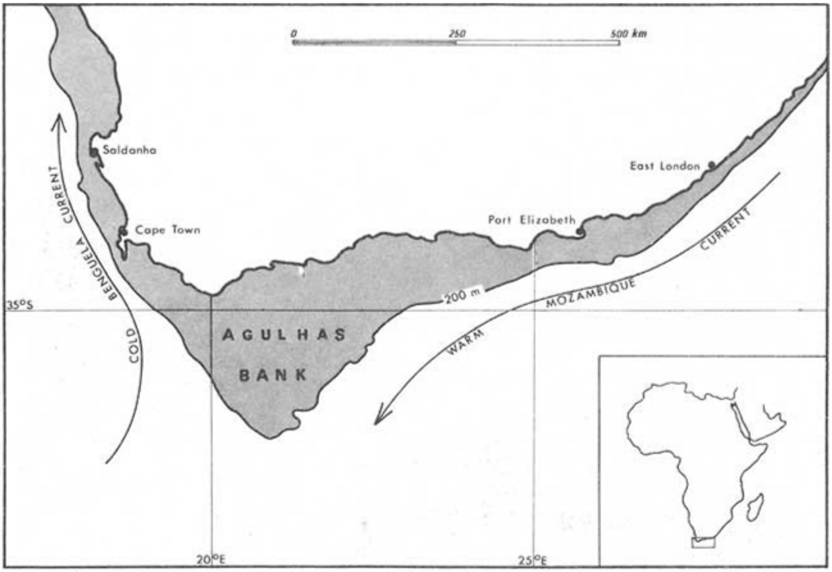

FIG. 2. Locality Map of the Agulhas Bank, South Africa.

The organism seems to be photosensitive and lives in crevices and caves at depths greater than 15 metres on the Agulhas Bank, which is the local geological expression of the continental shelf. Taxonomically it may be classified as follows(1,7):

DIVISION	CLASSIFICATION	EXPLANATION
KINGDOM:	*Animalia*	An animal
SUBKINGDOM:	*Metazoa*	with cell differentiation
BRANCH:	*Eumetazoa*	organized into organs,
SUB-BRANCH:	*Radiata*	having a radial symmetry
PHYLUM:	*Coelenterata*	and tentacles with stinging cells, situated around a mouth.
CLASS:	*Hydrozoa*	A gullet-lacking polyp
ORDER:	*Stylasterina*	arranged into discrete star-shaped groupings of polyps—the central polyp developing a prominent stylus—
GENUS:	*Allopora*	with other openings
SPECIES:	*nobilis*	and is precious

The hydrozoans are a class of coelenterate or polyp that has the ability to reproduce in two different ways. Asexual reproduction, a process of cell-division and of budding, leads to the formation of a colony. This colony of polyps is housed in a porous exoskeleton which in turn is harvested for ornamental use. Budding allows certain polyps to break off from the colony and develop into unisexual medusae which reproduce sexually to produce larvae. These larvae attach one of their ends to a rocky ledge and in turn commence to reproduce through cell division, thus forming a new colony.

The *A. nobilis* colonies are found as squat, dense, arborescent structures which are supported by a central, thick-set, asymmetrical cylindrical trunk—somewhat reminiscent of a miniature baobab tree (Figure 3). The branches tend to be aligned in a flat plane which usually coincides with the direction in which the current flows. On average, single *A. nobilis* trees having a trunk diameter of 25 mm, a height and spread of 200 mm, and a mass of 1.5 to 2 kg, are harvested. Yet specimens of up to 10 kg are regularly encountered. To date the largest single colony found had a mass of just under 50 kg and a trunk diameter of approximately 150 mm.

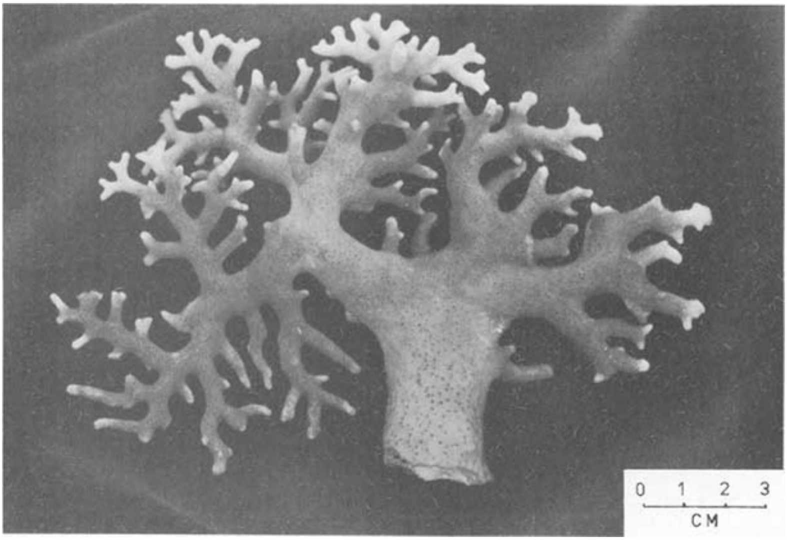

FIG. 3. Typical arborescent form of a stylasterine coral colony.

The calcareous exoskeleton is coloured by a yet undetermined organic pigment. Colours found include yellow-orange, pink, deep salmon pink and rarely amethyst-violet. The violet material is highly prized and seems to occur sporadically with the other colours in crevices on the rocky terrains as well as in caves that specifically mouth away from the prevailing ocean current. Furthermore, the tips of the branches are white and have a rounded and stubby appearance. Divers report that these tips fluoresce and phosphoresce in the light emitted by their underwater diving lamps.

The natural surface of the polyp colony is hard and even, but slightly harsh to the touch. This abrasive sensation is caused by small concentric groupings of cavities, breaking the surface in randomly spaced pimple-like mounds of about one millimetre. These pinholes are biologically referred to as 'pores'. They are the chambers that house specialized individuals of the polyp colony and from which or into which they are extended or retracted, respectively. Each grouping of pores is characterized by a large central gastropore which has a central stylus, and which measures on average 0.35 mm in diameter. It houses the gastrozooid or feeding polyp. The gastropore is surrounded concentrically by five to seven circular dactylopores, each with an average diameter of 0.1 mm. These pores in turn house the dactylozooids or food-collecting and protecting polyps (Figure 4). This star-like arrangement of groups of dactylopores around a central stylus-bearing gastropore is diagnostic for this class of *Hydrozoa,* and hence the name *Stylasterina.*

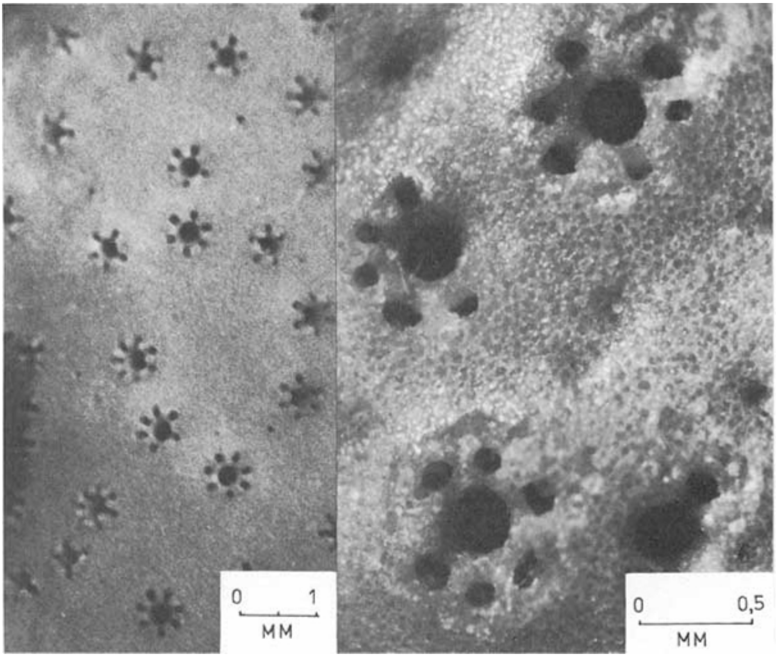

FIG. 4. Natural surface of a stylasterine coral displaying cyclosystems of gastropores and surrounding dactylopores.

The porosity of the hard exoskeleton seems to change as the polyp colony enlarges itself. Microscopic examination of cross-sections of branches reveals that the white central zone (also finding expression in the white tips of the branches) is the area of maximum porosity. Lateral thickening is associated with the addition of the organic pigmentation together with a lessening of porosity. The least porous areas are found, on average, to be the outer 5 mm, while the surface itself is covered by a very thin organic layer (Figure 5).

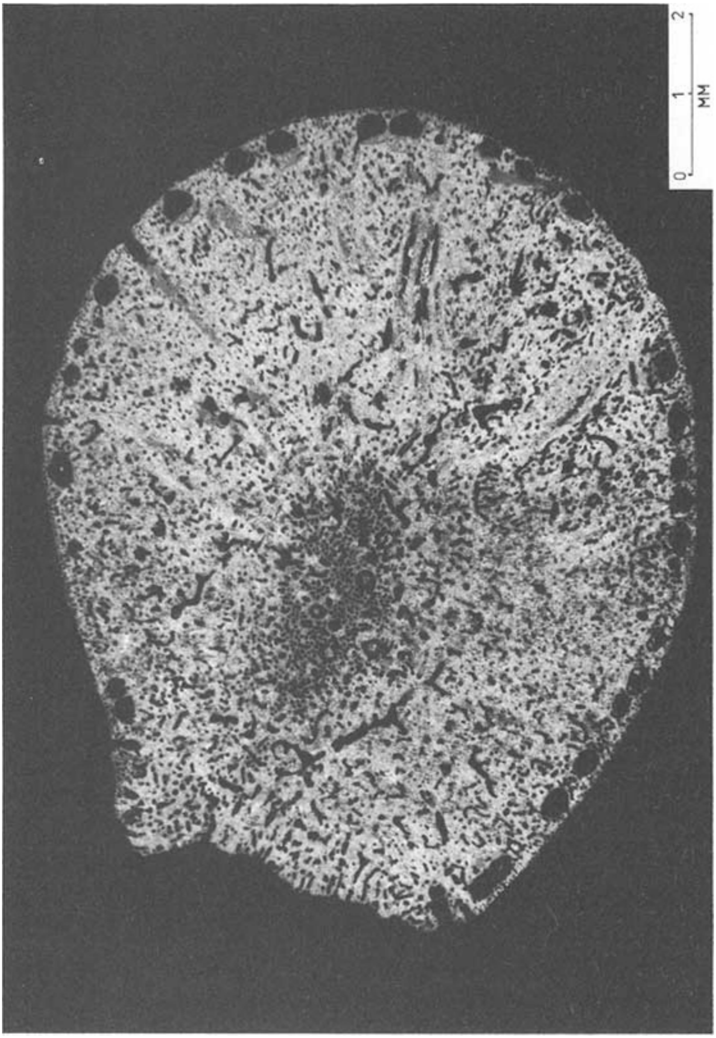

FIG. 5. A cross-section of a stylasterine coral branch (crossed polaroid filters) showing structure and porosity.

EXPLOITATION, RECOVERY AND TREATMENT

Although the presence of the precious stylasterine coral *A. nobilis* has long been known to occur off the South African coast, it has only been successfully exploited since November 1978, when a group of divers, working from Port Elizabeth, were granted a concession from the Ministry of Agriculture and Fisheries to do so. The concession restricts the harvesting to certain prescribed areas and a maximum of 25 metric tons (wet mass) is permitted annually. Moreover, only polyp trees with a trunk diameter greater than 20 mm may be gathered by divers using scuba equipment. No other means of recovery may be used. The coral occurs at depths greater than 15 metres, but the present restriction limits harvesting to between 25 metres and the 60 metre depth contour. The quality of coral improves with depth; the shallower coral being more porous. Usually, the material suitable for gem use is reported to have been collected at depths of 35 to 45 metres.

Once brought ashore, the coral trees are cleaned and desalinated by washing them repeatedly in fresh water. Thereafter they are treated with a vigorous oxidant to remove any biological or organic remains and to ensure that the pores are open. Then they are allowed to dry on racks placed either in the sun or in large desiccating rooms. The next step includes sorting and sawing into large segments, slabs or cubes, depending on whether the coral will be used for carvings, engraved cabochons or beads respectively. A slightly acid cutting fluid is used to ensure that the pores remain open.

Now the coral is ready for the so-called 'stabilizing' treatment. The treatment is a vacuum-impregnation technique whereby a critical mixture of methyl and butyl methacrylate monomer is allowed to infuse into the open pores throughout the coral and undergo subsequent polymerization, aided by a catalyst (benzoyl peroxide), into a tough co-polymer plastic. Final shaping and polishing are carried out in accordance with the usual techniques prescribed for ornamental stones.

Further treatment may include bleaching or dyeing. The pink coral is sometimes bleached with peroxide to produce a pale, whitish pink product which approaches 'angels' skin' quality. The yellow-orange coral in turn is sometimes dyed a deep red, duplicating the 'moro' coral tint prized in the Orient. When used, dyeing is incorporated with the plastic monomer in the stabilizing process.

CHEMISTRY AND PHYSICAL PROPERTIES

The chemical composition of *A. nobilis* is similar to that of *Corallium rubrum* in being $CaCO_3$ with a small percentage of organic material, and reacts similarly with acids. However x-ray diffraction studies indicate that the $CaCO_3$ has crystallized as platelets of orthorhombic aragonite.

The hardness varies from 3 to 4 (Mohs's scale) while the toughness could be described as excellent. The natural friability resulting from the platey nature of the aragonite exoskeleton is eliminated by the methacrylate impregnation.

There is no fluorescence when exposed to either 254 nm or 365 nm ultraviolet irradiation; but specimens that were dyed to imitate 'ox-blood' or 'moro' coral fluoresce brilliant scarlet under 365 nm irradiation.

Refractive index values are difficult to determine. At best a vague spot reading of 1.65 is possible on a gemmological refractometer. A twinkling effect seen through a rotating polarizing filter confirms the strong double refraction expected from aragonite.

Relative porosity measurements on the unstabilized coral gave values of up to 18 per cent, the white areas being the most porous. After impregnation with the methacrylate polymer ($RD = 1.18$ to 1.20), the relative density of the stabilized coral is 2.41 ± 0.08.

Thermal tests applied with a red-hot needle do not induce 'sweating' on the surface of the treated coral, but a fruity aroma characteristic of the plastic does become apparent. Continued heating chars the surface.

A microscopic examination of the surface exhibits the following three diagnostic features which reflect the biological organization of the polyp colony:

(a) *Parallel concentric growth banding* (not unlike the growth rings seen in wood) resulting from the accretion of the exoskeleton (Figure 6);

(b) *White star-like spots* consisting of a central concentric double circle surrounded usually by five or six smaller, symmetrically placed, satellite circlets—collectively having the appearance of a small star (Figure 7). (The large central double circle is the expression of a cross-section through the central stylus within

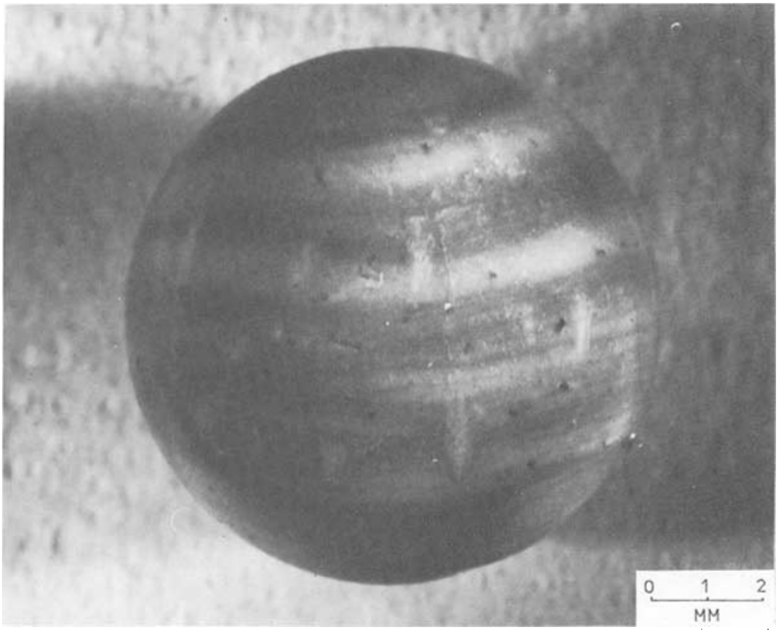

FIG. 6. Parallel concentric banding of stylasterine coral.

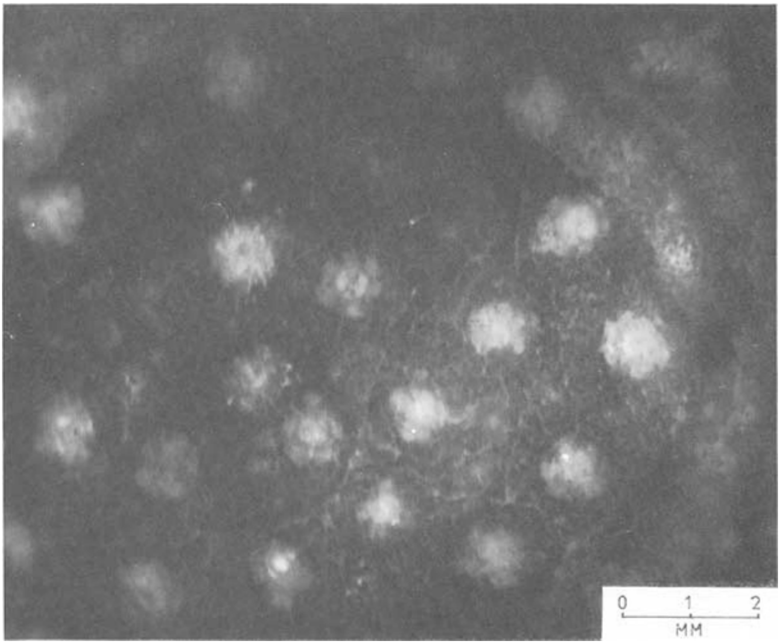

FIG. 7. White star-shaped inclusions in stylasterine coral

the gastropore, while the satellite circlets represent cross-sections through the smaller dactylopores, respectively).

(c) *White 'comet-tails'* with a fluted appearance that usually cut across the concentric growth banding (Figure 8). (This feature is caused by longitudinal cross-sections through the canals connecting the various groupings of gastrozooids and dactylozooids with each other).

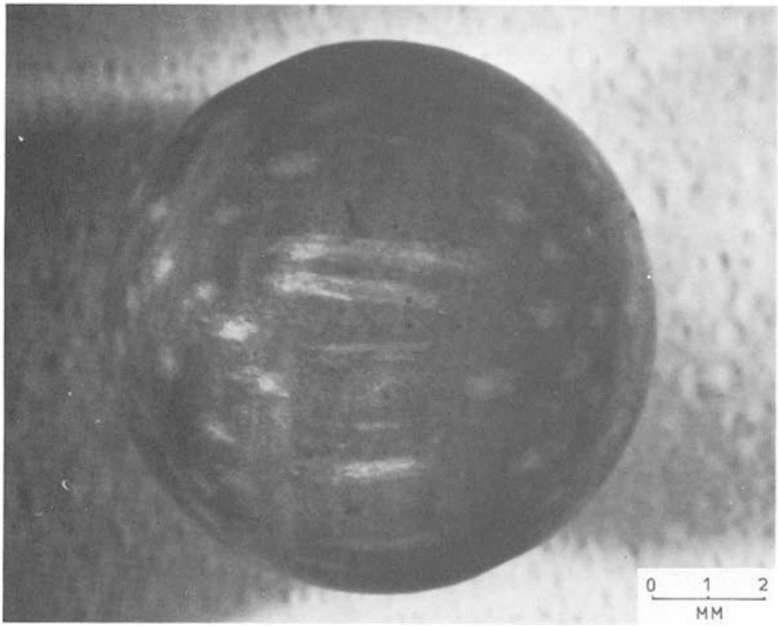

FIG. 8. 'Comet-tail' inclusions in stylasterine coral.

Moreover, the relative positions of these three characteristic features allow one to reconstruct the orientation of the polished gem in relation to the original polyp branch from which it was polished. The white star-like spots are found on planes parallel to the growth banding, while the 'comet-tails' are orientated perpendicularly to both the stars and the banding.

THE CORAL CONFUSION

A certain amount of confusion seems to have been caused by the proliferation of the different 'corals' that are used for ornamental purposes. Although it has clearly been shown (4,7) that the reef-building corals are not to be associated with those commonly occurring as gems, there still seems to be a great confusion when discussing corals in general. Moreover, taxonomically speaking, one is confounded by the conflicting classifications encountered in the literature. Ideally, it should be possible to identify and name each coral by its genus and species. But presently this is almost impossible because of the uncertainty that still exists amongst taxonomists.

Alternatively, it is possible to group the corals in terms of common denominators and to create a useful terminology for gemmology which is in keeping with zoological taxonomy. One such common denominator is that all corals belong to the Phylum, *Coelenterata.* These coelenterates in turn are divided into three Classes, namely, *Hydrozoa, Anthozoa* and *Scyphozoa.* Corals are found amongst the hydrozoans and the anthozoans but not in the schyphozoans. Although the corals start diversifying rapidly beyond this level of classification, it is still practicable to use the next taxonomic subdivision, namely, the Order, to make a meaningful grouping (Figure 9).

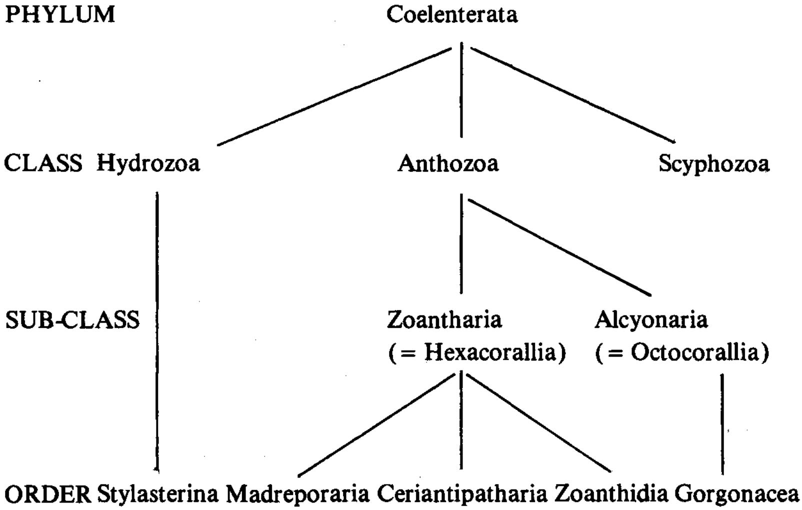

FIG. 9. Taxonomic Classification of Coral.

1. GORGONACEAN CORALS

Genus and Species	Appearance	Common Name
Corallium rubrum	red, pink, white	Precious coral
Corallium secundum	pink	,, ,,
Corallium japonicum	red,	,, ,,
Corallium konojoi	white	,, ,,
Corallium elatius	pink	,, ,,
Keratoisis sp.	yellow-brown	Bamboo coral
Gorgonia sp.	black	False black coral

2. STYLASTERINE CORALS

Allopora subviolacea	blue, violet	Akori coral
Allopora nobilis	red, pink, violet, yellow-orange	African star coral

3. CERIANTIPATHARIAN CORALS

Antipathes spiralis	black	Black coral
Cirrhipathes sp.	yellow	Golden coral

4. ZOANTHIDIAN CORALS

Gerardia sp.	yellow	Gold coral

5. MADREPORARIAN CORALS

All the reef-building corals

FIG. 10. Proposed Gemmological Classification of Coral.

The gemmological subdivision shown in Figure 10 is proposed as a possible means of minimizing the confusion. Presently five groups are sufficient to differentiate between the existing types of coral(3,4,5,6). However, should a new discovery be made which does not fall within the present scheme, an additional group could be created and added by using the taxonomic Order to generate it.

ACKNOWLEDGEMENTS

I wish to thank Messrs Transvaal Tigerseye Industries (Pty) Ltd, Johannesburg, and Laroc Manufacturing Company (Pty) Ltd, Port Elizabeth, for supplying specimens and relevant information for this study, as well as the technical staff of the Department of Geology, Stellenbosch University, for the photographs, maps and the processing of the manuscript.

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

REPORT ON COLOURED CUBIC ZIRCONIA

By PETER G. READ, C.Eng., F.G.A.

Several manufacturers of cubic zirconium oxide (ZrO_2) are now growing crystals of the material in a range of attractive gem colours, in addition to the colourless variety used as a diamond simulant. In March, 1980, the writer received a batch of coloured zirconia specimens from the Ceres Corporation, of Waltham, U.S.A., which illustrated not only the range of colours now available in this material but also the distinctive profiles of the crystals as grown by the skull crucible process (Figure 1).

To check the subjective effect of zirconia's high dispersion (0.06) in the various colour-varieties, the writer had a sample gem cut from a crystal of each colour. Although some of the resulting brilliant-cut gemstones could have been confused at first glance with natural stones such as amethyst or topaz, their high dispersion was easily detectable as 'fire' through the body-colour of the stone. Indeed, the only stone that might have served as a simulant was the light olive-green variety, whose colour and dispersion made it similar in appearance to sphene.

FIG. 1. Seven coloured cubic zirconia crystals (courtesy of Mr J. F. Wenckus, of Ceres Corporation), and seven polished specimens (courtesy of Mr J. F. Turner, of Glenjoy Lapidary Supplies).

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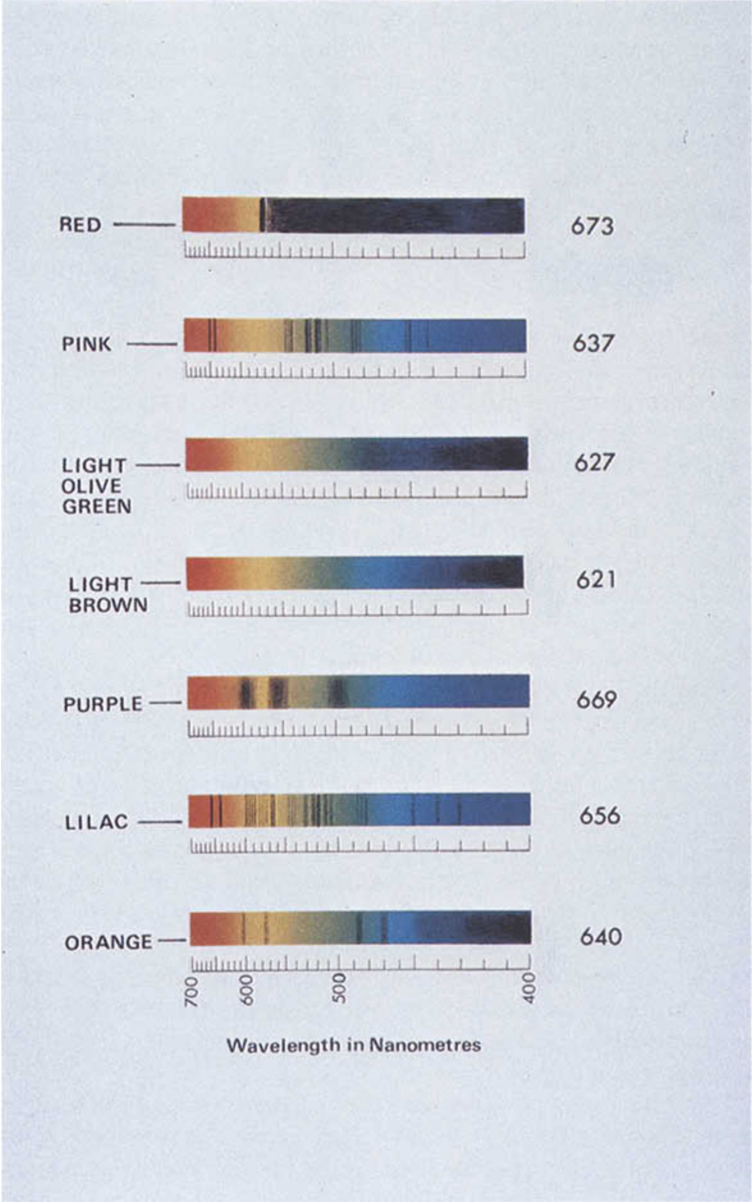

FIG. 2. Absorption spectra of the seven coloured cubic zirconia crystals. The figures on the right-hand side are the Ceres process numbers.

In the Ceres crystals, the dopants used to produce the various colours consist of transition metal ions and rare earths, both as individual additives and in multiple combinations. Irradiation techniques aimed at inducing or modifying colour in the crystals have also been tried experimentally by this company, but the resulting hues were prone to fading when the crystals were exposed to strong UV or subjected to low temperature annealing.(1)

The use of rare-earth dopants in some of the stones is immediately apparent on viewing their absorption spectra (Figure 2). In the pink and lilac crystals, the prominent fine line spectra are caused by oxides of erbium (Er_2O_3) and neodymium (Nd_2O_3) respectively. Cerium oxides (CeO_2 and Ce_2O_3) are responsible for the colour in the orange and red varieties, the latter being very heavily doped with Ce_2O_3. No information is available on the remaining colours, but the purple colour may be due to the presence of ferrous oxides, and the light olive-green and light brown shades may also be caused by one of the transition elements. Other manufacturers have used oxides of thallium (Tm_2O_3), holmium (Ho_2O_3) and terbium (Tb_2O_3), the latter as a stabilizer, to produce various shades of green; praseodymium (Pr_2O_3) has also been used to produce an amber colour.(2)

Under LW UV, the pink crystals fluoresced a yellow-green, the orange crystals fluoresced red, and the lilac crystals fluoresced a bright peridot green. The remaining crystals were inert. Under SW UV both the pink and the lilac crystals exhibited a faint green fluorescence, and the orange crystals fluoresced pink. The light olive-green and the light brown crystals fluoresced pale green and pale brown respectively. The remaining crystals were inert. None of the crystals showed any signs of phosphorescence under LW or SW UV.

When tested on a reflectivity meter, all the polished samples had a lustre which was slightly, but consistently, lower than that obtained with colourless specimens (these readings were, however, still appreciably higher than that for GGG).

Specific gravity tests on the crystals (using hydrostatic weighing) gave figures which varied from 5.95 to 6.06 (for comparison, a 646 carat colourless crystal of cubic zirconia had an S.G. of 5.95). However, the specific gravity and refractive index constants of cubic zirconia are reported(3) to be influenced mainly by the concentration of the stabilizer (Y_2O_3 in the Ceres product) rather than by the colouring dopants. The specific gravity of cubic zirconia can, for example, range from 5.54 to 5.95, and its refractive index from 2.09 to 2.18. Some variation in these constants can also be expected within a single specimen, as the stabilizer concentration tends to vary along the length of the crystal.(1)

A comparative test of the thermal conductivity of the coloured crystals (by adjusting the calibration trip point on a Rayner Diamond Tester) showed that this was virtually the same as for the colourless variety (i.e. somewhere between glass and lithium niobate).

Because of their high dispersion, gems cut from coloured cubic zirconia do not qualify as effective simulants of any natural gem (except maybe for sphene or even diamond fancies), but with a hardness of 8-8½ and a lustre approaching that of diamond they will no doubt find a worthwhile niche as attractive and durable man-made gems.

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[*Manuscript received 15th October, 1980*]

NOTES FROM THE LABORATORY

By KENNETH SCARRATT, F.G.A.

London Chamber of Commerce and Industry Gem Testing Laboratory

After a visit to the Laboratory in October of last year, Pierre Gilson, Jnr, as he had promised, sent to us samples of his latest production of synthetic white opal. Of the eight samples we received, M. Gilson informed us that three (two pieces of rough and one cabochon cut) were plastic impregnated. We were not, however, told precisely which of the specimens these were.

So far as commercial gem testing is concerned the fact that a 'synthetic' opal has been plastic impregnated is not the most important factor to ascertain, the main object being the recognition of the stone's synthetic origin. The importance of recognizing such treatment, though, increases when the stone appears to be natural.(1,2,3)

A short time prior to our receiving the samples from M. Gilson, during the course of our normal gem testing function, one particular natural black opal had been giving us cause for concern. Examination under the microscope revealed that the stone was a little unusual in its colouring, just enough to arouse one's suspicions. The SG was calculated to be 1.76, which, if this stone were an untreated gem opal, would be extremely low, and it would be expected to be of the porous variety,(4) which this stone to any great extent was not. With this information and a refractive index in the region of 1.47, we were sure that this stone had been plastic impregnated. Naturally as this was a relatively important stone, the client was less than enthusiastic about the applying of any tests during which there was a possibility of damage occurring. Time also, as always, being a relevant factor, on this occasion proof positive eluded us. Certainly nowadays it is foolish to attempt the identification of an opal of apparent natural origin whilst it is mounted. Having been a little frustrated with this stone, when M. Gilson's samples arrived, it was felt that it would be a useful exercise if we were to examine these closely with a view to identifying those which had been impregnated.

The results of this examination are given in Table 1. The SGs were obtained by hydrostatic weighing, using distilled water. No

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TABLE 1

Specimen		CT Weight	SG	Luminescence			Reaction to Thermal Probe *	Reaction on Heating in A Test Tube	Structure
				X-ray	Long Wave Ultraviolet	Short Wave Ultraviolet			
1.	Untreated specimens	5.76 (Rough)	2.22	Strong blue with blue phosphorescence. Discoloured in the area where the beam passed.	Dull blue with a weak phosphorescence in the area where the x-ray beam had passed.	Bright strong green on three surfaces otherwise almost inert. Moderate to strong phosphorescence.	No reaction.	Colourless residue. No smell or Condensate.	See Figure 2.
2.		4.94 (Rough)	2.22	As for specimen No. 1.	As for specimen No. 1.	Very bright strong green on four surfaces otherwise almost inert. Phosphorescence where x-ray beam had passed.	As for specimen No. 1.	As for specimen No. 1.	See Figure 2.
3.		1.48 (Cabochon)	2.24	As for specimen No. 1.	Almost inert. Moderate to strong phosphorescence where the x-ray beam had passed.	Almost inert. Weak phosphorescence where the x-ray beam had passed.	As for specimen No. 1.	Not tested.	See Figure 2.
4.		2.36 (Cabochon)	2.12	Moderate light green which changes to a light blue. With phosphorescence.	Dull green. Very weak phosphorescence.	Bright green. Weak phosphorescence.	As for specimen No. 1.	Not tested.	See Figure 1.
5.		1.88 (Cabochon)	2.17	As for specimen No. 4.	Almost inert. Weak phosphorescence.	As for specimen No. 4.	As for specimen No. 1.	Not tested.	See Figure 1.
6.	Treated specimens	3.48 (Rough)	1.91	Inert.	Bright strong blue. Fast fading (2 sec.) phosphorescence.	Strong blue. Strong phosphorescence where the x-ray beam had passed, otherwise weak.	Surface is marked. See Figure 3.	Red-brown residue. Strong smell of burning plastic. Condensate on wall. (Fig. 4).	See Figure 2.
7.		1.50 (Cabochon)	1.92	Slight blue.	As for specimen No. 6.	As for specimen No. 6.	As for specimen No. 6.	Not tested.	See Figure 2.
8.		3.10 (Rough)	1.93	Inert.	As for specimen No. 6.	As for specimen No. 6.	As for specimen No. 6.	As for specimen No. 6.	See Figure 2.

*The thermal reaction tester, as manufactured by the Gem Instruments Corporation.

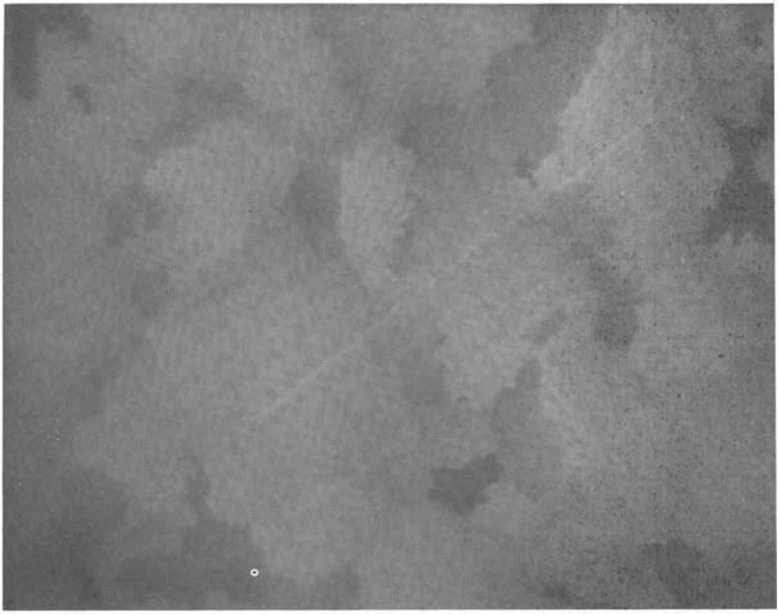

FIG. 1.'Lizard skin' structure in Gilson synthetic white opal (SG 2.12-2.17).

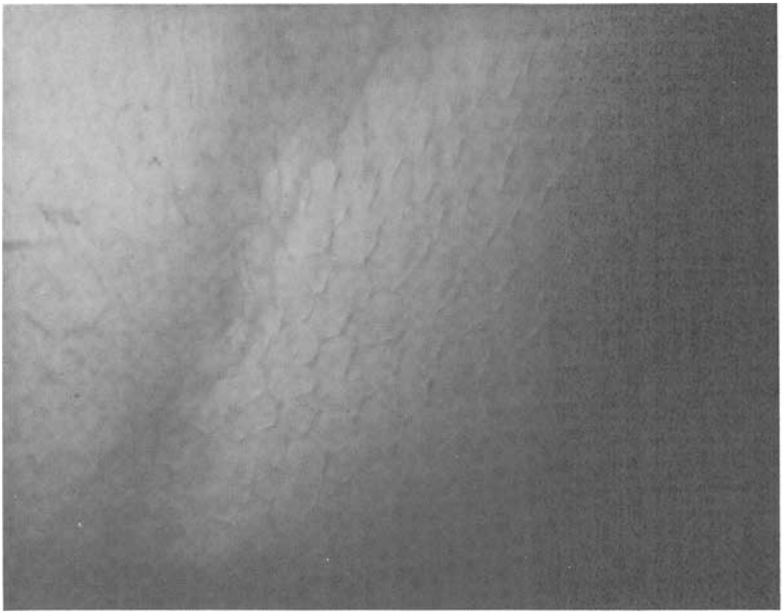

FIG. 2. 'Chicken wire' structure in Gilson synthetic white opal (SG 2.22-2.24 and 1.91-1.93).

significant porosity was noted. The SG range for the untreated opals was found to be from 2.12 to 2.24, whereas the plastic impregnated opals ranged from 1.91 to 1.93. This latter lower SG reminded me of the 'porous variety' M. Gilson placed on the market in 1975,(5,6)—possibly a good reason for plastic impregnation! Of the untreated samples, there appeared to be a relationship between the SG and the internal structures. The two stones with the lower values (2.12 and 2.17) revealed the 'lizard skin' structure in Figure 1, whilst the three with the higher values (2.22 and 2.24) revealed the 'chicken wire' structure in Figure 2. The treated stones also revealed the 'chicken wire' structure.

Naturally, destructive tests are of no use under normal gem testing conditions; however, they were employed in this examination to confirm our suspicions that the samples with the lower SGs were the treated stones. Only small fragments were required from the rough samples to observe the reactions recorded in Table 1 under the heading 'heating in a test tube' and in Figure 4. The test tube in this case was held in the flame of a spirit lamp. It was necessary to place the tip of the thermal probe lightly on to the surface of the impregnated synthetic opal to obtain the reaction recorded in Table 1 under the heading 'reaction to thermal probe' and in Figure 3.

* * *

Heat treated blue sapphires(7) have been a fact of life for some time. On occasions it is possible to identify these stones but often one can only be suspicious. In either case positive identification is not required, for under a C.I.B.J.O. ruling these stones are placed in a category along with such stones as zoisite and aquamarine(8).

A departure from this 'normal' heat treatment is a new type of 'treated corundum', warnings about which have been issued by the French delegation to the C.I.B.J.O. Coloured Stone Commission, in recent months(9). The colour of these stones is produced by coating what could be a colourless corundum with a 'chemical dye', heating the stone so that the colour is diffused into the surface and then repolishing. The Coloured Stone Commission decided that these stones should be described as 'treated corundum'.

We have had the opportunity to examine two of these stones and feel that identification is not difficult once the examiner is

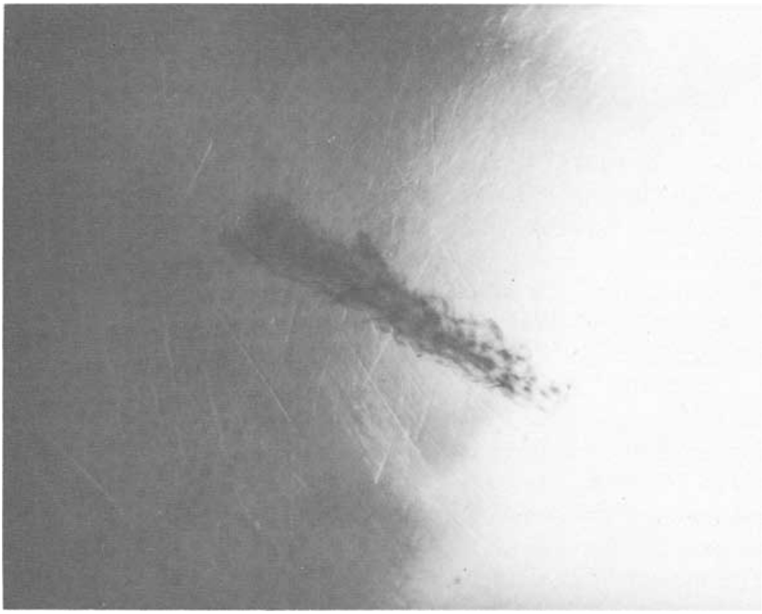

FIG. 3. The mark produced when the surface of the plastic-impregnated synthetic white opal is lightly touched with the tip of the thermal reaction tester.

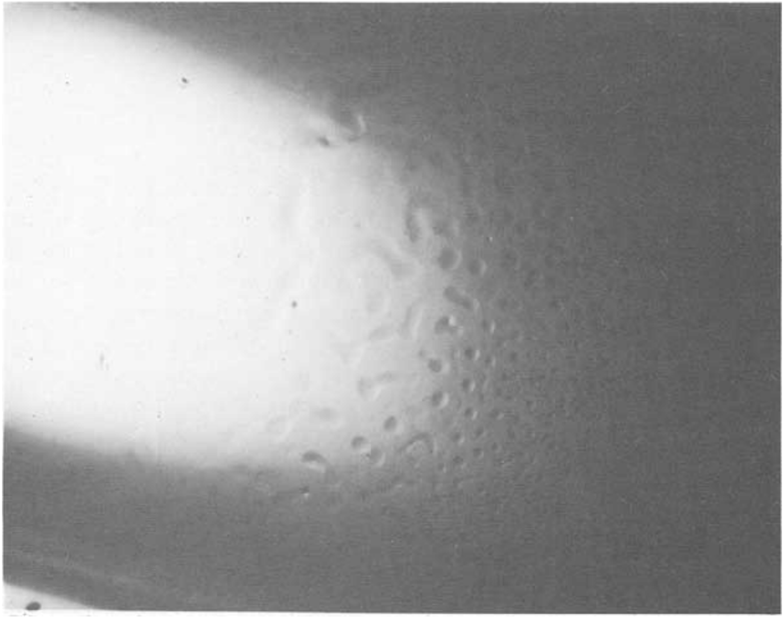

FIG. 4. The condensate on the inside wall of the test tube after small fragments of the plastic-impregnated synthetic opal had been heated.

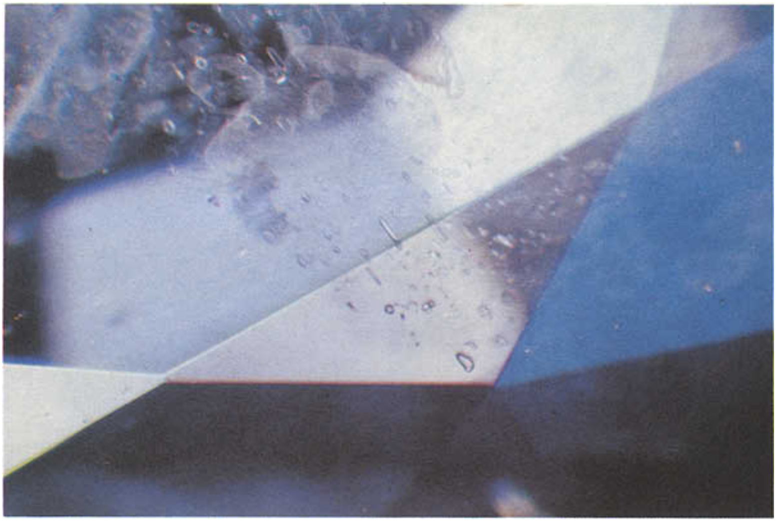

FIG. 5. 'Ceylon feathers' in a blue treated corundum.

FIG. 6. The patchy colour-zoned appearance of a normal heat-treated blue sapphire.

FIG. 7. The 'glassy' or 'watery' centres to Ceylon feathers, which are so characteristic of many heat-treated sapphires, seen here in a treated blue corundum.

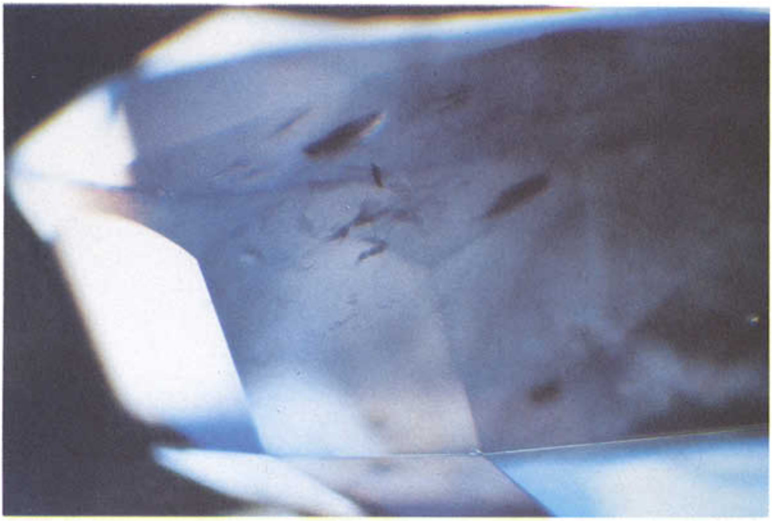

FIG. 8. The colour concentration in feathers which reach or come close to the surface in a treated blue corundum.

made aware of what to look for. Mistakes could occur, though, where the stone or stones are set in an item of jewellery and are only given a cursory examination under the normal lighting conditions of a retail outlet, for these stones can contain the 'Ceylon feathers' so characteristic of natural sapphires from Sri Lanka (Figure 5).

Both of the stones examined were a good over-all blue with none of the patchy or colour zoned appearance seen in some of the heat treated stones (Figure 6). The first was oval and faceted weighing 2.84ct and the second was a round cabochon cut stone weighing 4.58ct. None of the fluorescence characteristics proved to be of any aid to identification and the refractive indices for the faceted stone were normal for corundum. An indication that the stones were not all they purported to be, was the absence of any absorption in the 450 nm region as observed with the hand spectroscope. Natural sapphires of this colour should at the very least show some weak absorption in this area.

It is however the observations made through the microscope that give the examiner the proof necessary for identification. The first impression gained, from the examination of the inclusions in the faceted stone, was that they were typically Sri Lankan in appearance. Upon closer examination of the feathers, the 'glassy'

FIG. 9. The colour concentration at the surface of a treated blue corundum, seen here as a royal blue rim following the girdle line.

or 'watery' centres (Figure 7) which are so characteristic of many of the heat treated sapphires could be seen. Further examination of those feathers which came close to, or reached the surface, revealed that there was a colour concentration within them (Figure 8). The most important identifying factor though was found to be the colour concentration at the surface. This could be most easily seen when the stone was immersed in benzyl benzoate, so that the girdle area could be inspected with the crown facets uppermost (Figure 9), when a royal blue band could be seen just inside, and following the girdle line. As the colour of a cut stone is normally a little darker in this area, care should be taken when coming to a decision, but if the effect seen in Figure 9 is visible, then this is enough to identify such a stone as 'treated corundum'.

It is with pleasure that I acknowledge the continued generosity of Pierre Gilson, Jnr, and thank E. A. Thomson Ltd for allowing us to examine the treated corundum. Figures 5-9 were produced by Mr E. A. Jobbins, whom I thank for these and his many valuable comments.

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UNSTABLE COLOUR IN A YELLOW SAPPHIRE FROM SRI LANKA

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Among the many cases of routine testing in a laboratory, from time to time there comes an enquiry for ascertaining colour-stability of gemstones under daylight or other conditions. In keeping with gemmological rules of non-destructive testing, the possibilities are rather limited, especially for large or very valuable gems, unless the owner accepts the risk of a possible loss of value for the sake of knowledge, in giving permission to carry out an adequate investigation.

Such a case occurred some time ago, being worth mentioning in consideration of the large size of the faceted yellow sapphire involved, weighing 45 carats, of rectangular shape, 20 mm in length, a very pleasant gem of a good saturated yellow colour, matching approximately the colour hue 2:6:1 of the DIN 6164 system. Together with clear-cut physical properties for natural corundum, this sapphire proved its origin from Sri Lanka through tell-tale inclusions, as well as the usual, strong, orange fluorescence under 365 nm ultraviolet radiation.

The owner said that the sapphire had been sent on consignment, and, after it was returned, he had got the impression that the colour had slightly faded. As he suspected that the stone might have originally been submitted to some kind of treatment to improve its colour, he asked to have it checked for colour-stability, giving the laboratory permission to carry out appropriate tests. Rather than relying only on the impression of the eye to judge the colour, in order to get a better comparison basis, the transmission was first recorded on a two beam spectrophotometer, resulting in a curve as shown by the plain line in Figure 1. The following features are to pointed out:

—a rather even and broad transmission between 800 and 550 nm;

—a steep decrease below 550 and 0% transmission limit at about 340 nm.

In the condition as received the dichroism was weak, the colours being yellow and pale yellow.

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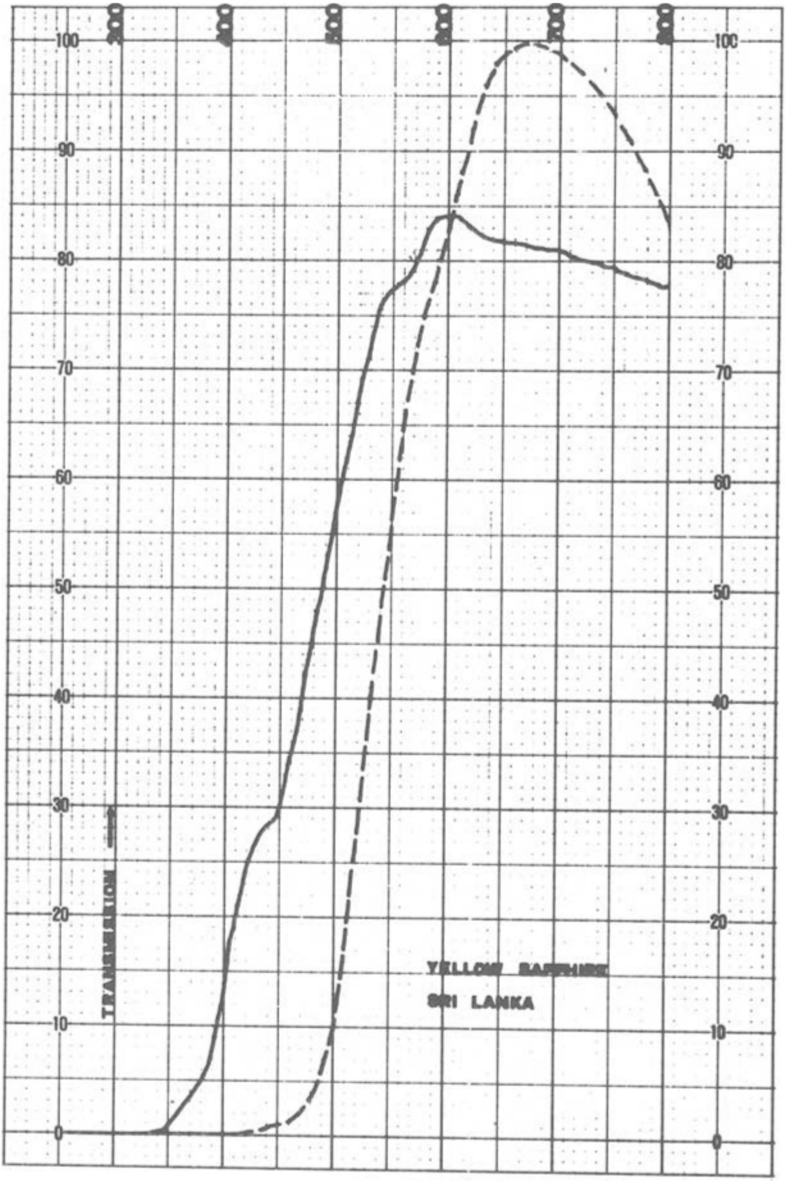

FIG. 1. Spectrophotometric recording of colour transmission in a 45 ct yellow sapphire from Sri Lanka.
Plain line, condition as received.
Dotted line, after irradiation under x-rays, 60 kV 25 mA during 3 hours.
(Photograph by the author)

To duplicate the possible bleaching action of daylight through part of the ultraviolet radiation it contains (however, in a shorter period of time), the sapphire was left for 36 hours under the 365 radiation of a B-100 A ultraviolet lamp made by Ultraviolet Products Inc. The result was a considerable loss of the colour-saturation. At this point, it was already clear that the colour was not lasting.

The next step involved was trying to impart the colour again, by means of irradiation by x-rays at a rate if 60 kV 25 mA for a period of 3 hours in a Siemens Kristalloflex x-ray unit. The deepening of the colour in one-hour steps was easily recognizable to the eye. At the end, the hue had turned to a saturated, orangy yellow colour, the dichroism being then more distinct, in colours of yellow and pale yellow. To increase the appreciation of the colour-change, a colour transmission recording was made again, as per the dotted line in Figure 1, featuring the following changes:

—a shift of the main transmission as a broad peak culminating at about 675 nm

—a more drastic decrease under 600 nm to a 0% transmission at about 420 nm.

Comparing both curves renders the colour-change quite evident, the conclusion being that x-rays have a definite action of deepening the colour. In order to avoid possible damage we did not try to

FIG. 2. Yellow sapphire from Sri Lanka, 45 ct. Original size, length 20 mm.
Orangy yellow part induced by x-rays; faded part after exposure to 365 ultraviolet radiation.
(Photograph by the author)

influence or stabilize the colour by heating. Microscopic examination proved the colour-change to be throughout the stone.

Due to previous experiments with other yellow sapphires, we know that the colour-activation through x-rays may be reversible under ultraviolet radiation. This was tried again, and to make the effect more obvious, the sapphire was partly wrapped in aluminium foil, about one third only being left uncovered under the action of the same lamp as before, under similar conditions. The colour-fading at one end of the stone is quite striking, as shown in Figure 2. Our tests prove that, under these conditions, the colour would fade and might be reactivated at will, confirming our former experience.

In consideration of this situation, a few words of caution to people dealing in yellow sapphires might seem appropriate, because of the commercial consequences involved with unstable, artificially-induced colour.

The phenomenon discussed here is different from the artificial colour-change met with in sapphires of various shades as a thin skin of deeper colour—induced superficially, with the result that these might be expected to lose part of their colour if recut.

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THE CARAT WEIGHT

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For many people the word 'carat' is partly a mystery. Frequently it is somehow associated with quality, but usually confused with size. There is some foundation for both conceptions, for quality with regard to gold and for size in so far that a larger stone in most cases weighs more than a smaller. Two gems of equal size may, however, have different weights, depending on their SG and how they are proportioned.

One carat is today a weight unit equal to one fifth of a gram, i.e. 200 milligrams. But this was not always the case. The history of our carat weight will therefore be related here in detail, since a complete compilation never seems to have been published yet. The association of carat with the various gold standards will be discussed as well.

When originally the flow of diamonds into the Western world began, much of the traditions and conceptions were taken over from India, the one and only source of supply. However, neither the tandula* nor any other oriental weight unit was adopted. At the source diamonds were obviously weighed and valued for taxation purposes, but the prices quoted and accepted respectively were no doubt based on size and beauty alone. For the importers' inventory and marketing purposes the gems eventually had to be weighed and their respective weight expressed in terms generally understood by everybody, specially by the prospective customers.

In those early days the smallest weight units used in commerce were specified seeds. In England and on the Continent north of the Alps 'the least portion of weight' was the grain, usually the weight of the local grain of wheat. By Robert Recorde (1542)† this is quoted as 'a grayne of corne or wheate, drie, and gathered out of the middle of the eare'. But the weight of a grain unfortunately varied considerably. There were various 'diamond grains', 'pearl grains' and, of course, 'grains troy' and 'grains avoirdupois', and in other countries still other grains. Eventually (probably in the

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*See Lenzen, 1970, pp.41-5.

†Robert Recorde, *The ground of artes, teachynge the worke and practise of arithmatike.* — Ed.

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sixteenth century) a 'carat grain' was most fortunately introduced all over Europe. This now compared with the carat weight and became equivalent to 1/4 of a carat. We will revert to this later in the text, after having first discussed the carat weight.

Since the trade routes from the Far East to Europe for diamonds, pearls and coloured gems ended in the Mediterranean region, a local and abundantly available seed with a weight as small and as constant as possible had to be chosen.

The long established pearl and gold merchants already had at their disposal an accepted, suitable weight. It was the bean of the locust pod or carob tree (*Ceratonia siliqua*), which produces a curved fruit, something like a horn. Inside the pod is a sweet syrup and many small seeds (St John's bread*). These seeds are remarkably constant in weight and those taken from the ends of the pulpy pods are not smaller than those from the middle. Whether dry or affected by humidity the weight of every seed remains practically the same. Some recent authors have, however, found even considerable differences, but these observations are in all probability due to some specific trees from a remote region, different from the normal ones. The small differences in weight normally met with were surely too small to have been measurable by the simple balances available to the traders of the time. As far as they could judge, such seeds were absolutely identical, and this fact is a remarkable tribute to the astuteness of the ancient pearl and gold dealers. In this connexion it must be remembered that the original carat weight was not subdivided into fractions, although obviously a seed may occasionally have been cut into two or even four equal pieces.

The term *carat* is derived from the old Greek word *keration* (*κεράτιον*), which refers to the horn-like shape of the fruit-pod. The equivalent in Arabic was *quirrat* or *qīrāt*, and became *quirate* in old Portuguese; it is now *quilate* both in Portuguese and in Spanish alike. In English it was originally (according to Thomas Nicols, writing in 1652 in *A Lapidary)* written *ceratium*, in plural *ceratia*. Around 1677 (*The Merchants Map of Commerce*, by Lewis Roberts) the spelling was *carot*, but simultaneously also the present *carat*. This term is practically universal, with some slight variations like *carato*, *karaat*, *karaatti*. Formerly abbreviations like C and Ca were common; now it is agreed to read 'ct'.

*See Matt. iii, 4.—Ed.

As commerce in gems increased, various countries began to standardize the carat in relation to their own unit of weight, which also varied. Simultaneously the carob seed was exchanged into metal weights in a sequence, as for instance 1, 2, 3, 4, 8, 16, 32, 64, 100, 200, 300, 500 carats, thus permitting individual stones and lots of any intermediate weight to be quickly calculated. Furthermore, smaller weights—fractions of a carat—were introduced, the smallest of which was 1/64th of a carat. Following the then normal subdivision of units a diamond weighing (say) exactly 1 ct and 63/64 was described as 1 carat 1/2c, 1/4c, 1/8c, 1/16c, 1/32c, 1/64c—indeed taking up much space and cumbersome to interpret, but easy when just adding continuously smaller weights on the scale. This awkward habit survived even after the metric system began to gain ground, and it is not long since, e.g., carpenters often preferred to divide the inch in that way and wrote (say) 1/2, 1/8, 1/16 for 11/16. In 1884 Jacobs & Chatrian listed weights slightly over 205 milligrams as, e.g., 205 milligr. 1/10^e 1/2.

Some jewellers adopted a decimal notation of the fraction of an old carat, but in most cases we find a reluctance to use the smaller fractions and instead a remark like 'just over' or 'just below'. In many instances the weights were indicated in 'carat grains'. One good example is to be seen in the catalogue of the Hope collection, which was exceptional in that the grain was subdivided up to 1/32, corresponding to 1/128 ct! Another example is the Green Vault, where the grain was used throughout.

Even though the carat weight was well established, it varied in different trade centres. It also varied from one period to another and from one dealer to another. However, as a rule a carat was pretty close to 205 milligrams. In Bologna, Florence and Amboina it was below 200, and in Madras, Turin and Leghorn well over 205 mg. Exact values have been quoted by many authors, but the figures vary too much between themselves to be worth listing. As a rule of thumb it may be suggested that an old carat weight of say 10 ct corresponds with 10.25 of our modern metric carats.

As a warning against blind conversions it may be said that in principle a London carat was different from a Paris carat and both were different from, e.g., a Venice carat. But at least six different carat weights have been observed in England alone. Another observation is that the Florentine diamond by Tavernier was said to weigh 139 1/2 ct and by the Austrians only 133 1/5. This indicates the fact that carat weights of 196.8 and 206.1 mg respectively were used. In 1884 Jacobs & Chatrian checked the carat weights with four famous French jewellers and found them to weigh 205, 205.3, 205.45 and 205.5 mg respectively. As late as in the 1890s M. D. Rothschild wrote to three prominent balance-makers in the United States for their carat standards and found that they all differed.

It was therefore not surprising that a first step towards standardization was taken. A syndicate of Parisian gem dealers in 1871 suggested 205 mg as the new standard. An agreement was reached in 1877, as a result of a conference between diamond merchants of London, Paris and Amsterdam and followed by most other countries. The small differences between individual dealers and retail jewellers, however, remained. No wonder, therefore, that discussions went on. At the International Congress of Weights and Measures in 1893 Dr G. F. Kunz suggested that the carat be incorporated with the metric system and reduced to the nearest metric equivalent, 200 milligrams. This would depreciate the '205' ct by a little less than 2.5% to the advantage of the dealers, and it would above all involve new weights, the correctness of which would be easily and rapidly checked against metric standard weights. In order to facilitate the abolition of the old carat, the new one should be called 'the metric carat' and the weights stamped with C.M. or a similar abbreviation. The first resolution, recognizing the advantages to the international trade in gems by a metric carat and suggesting this, was universally adopted. The legalization in the various countries was unfortunately a long and laborious procedure, and prior to World War I only the following countries introduced this unity: Spain, in 1908; Japan and Switzerland in 1909; Bulgaria, Denmark, Italy and Norway in 1910; Holland, Portugal, Romania and Sweden in 1911; France in 1912; Belgium and U.S.A. in 1913, and Great Britain in 1914. The rest of the world handled the question first after the War and either legalized the metric carat or considered it unnecessary to do so, since it could well be used under the metric system already in force.

The metric carat is obviously the one and only international unit for weighing gemstones and in universal acceptance. The intermediate usage, when it was agreed to indicate the difference from the earlier units by saying metric carat and writing m.ct., c.m., etc., is no more necessary. Instead there is a kind of gentleman's agreement to quote gem weights of past times in fractions, e.g. 1 1/2 instead of 1.50 ct.

Modern carat weights are now internationally written with two decimals, even if the second is a zero. If weighed with precision balances a third decimal may be quoted, but in brackets, for instance 1.50 (1.508). The third decimal is thus neglected and serves only the purpose of an easier identification.

THE GOLD CARAT

Since we know that the carob seed was the commonly used smallest weight in the Mediterranean region long before our Christian era, it is not surprising that the weight of old Roman coins was fixed in 'carats'. Thus the Roman emperor Constantine the Great in the year 312 A.D. minted a gold coin named *solidus,* weighing the equivalent of 24 carats at 190 mg, or 4.55 g. This replaced the depreciated *aureus* introduced by Caesar* and soon became the currency of the civilized world. However, inflation forced Valentinian I already in 367 to reduce the content of fine gold from the full value of 24 units to 20 1/2. In the year 700 it was further reduced to 20 units.

During this period the alloy thus sank from 24 down to 20 carat and later to 18. A numismatist will eventually be inspired to make a more detailed investigation and write a paper on how the gold caratage was introduced and generally accepted. Today it is replaced by metric figures stating how many thousandths of the total weight of an alloy is pure gold.

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*C. Julius Caesar (102-44 B.C.).—Ed.

SPHENE, ANOTHER GEM MINERAL FROM SRI LANKA

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INTRODUCTION

In the past Ceylon has been of considerable interest regarding the production of different gemstones and in the future it seems Sri Lanka will continue to be so. Those gemmologists who visit the island regularly will be impressed by the enormous developments the country has made in this field in a short time. This is undoubtedly due to the great influence of the State Gem Corporation, which is promoting the improvement of cutting and is educating the people dealing with gemstones. It, therefore, is no longer easy to buy parcels of tourmaline in which rare stones like kornerupine, ekanite and sinhalite may be discovered. It is even so that rare and unusual gemstones will be sold under their own correct name. The valuable activities of the State Gem Corporation do also promote the discovery of new gemstones in Sri Lanka. Some years ago kornerupine cat's-eyes were mentioned for the first time (Korevaar & Zwaan 1977) and now they are rather common on the market in Sri Lanka. The occurrences of axinite near Balangoda and fibrolite at Paradise Tea Estate in the Ratnapura area are not yet officially reported. Very recently gem quality sphenes from Sri Lanka were first described (Zwaan & Arps 1980), while a dark brown cut sphene of 4.48 ct from Sri Lanka has been reported by Gunawardene & Hänni (1981).

In October 1980 the author visited Sri Lanka and bought three beautifully cut sphenes from the well-known gem dealer Faust A. Saheed in Colombo. According to Mr Saheed they originated from the Tissamaharama area in the southern part of the island. Although the occurrence of sphene near Galle was known since the early fifties, and the sphene described by Gunawardene & Hänni is ascribed to the same area, the stones mentioned above belong to the first sphenes of good gem quality found in Sri Lanka. Gem mining started about a year and a half ago in the Tissamaharama area, and a good production may be expected based on the results of the exploration during the last years.

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In February of this year the author visited Sri Lanka again and went to the above mentioned area. The main places of interest are Amarawewa (Figure 1), situated about six miles from Tissamaharama along the road to Kataragama and Kochipadana, which is about half an hour's drive by landrover from Kataragama in a easterly direction (Figure 2).

People are not yet familiar with gemstones in the area. Material for cutting is sent to Colombo and Ratnapura. Until now it has been found in alluvial deposits only. The ways of mining and washing are similar to those applied in other gem mining areas of the island (Figure 3). As these activities were started recently, no deep levels have yet been mined; on the contrary only many reconnaissance pits up to about one yard deep may be observed, a gem-bearing zone being situated at about that depth. This is especially the case in Kochipadana (Figure 2). The occurrence of sphene in this part of the country, in particular in Amarawewa, has been confirmed by the Scientific Division of the State Gem Corporation.

Since October 1980 five cut sphenes, weighing together 10.02 carats, have officially been exported to the United States of America and another five cut stones were brought to Holland for

FIG. 1. Gem mining in Amarawewa.

FIG. 2. Gem mining in Kochipadana.

FIG. 3. Gem washing in Amarawewa.

further investigation by the above-mentioned gem dealer in March of this year. Three of them are stored in the collection of the Rijksmuseum van Geologie en Mineralogie, Leiden, the total amount of cut sphenes from Sri Lanka in that collection now being six. The are registered with numbers prefixed with RGM.

Refractive indices were measured with a refractometer provided with a cubic zirconia prism and a scale recalculated by the author. Due to the high figures for sphene only α could be observed.

Specific gravity measurements were carried out by means of a hydrostatic balance using both ethylene dibromide and alcohol as immersion liquids. The data obtained are the average of repeated measurements.

X-ray powder photographs were made using Fe-radiation and a Debye-Scherrer camera of 114.6 mm. Since cut stones only were available for investigation, use was made of the 'sphere' method of Hiemstra (1956), to restrict the damage of the investigated stones as much as possible.

Electron microprobe analyses were performed at the electron microprobe laboratory of the Instituut voor Aardwetenschappen, Vrije Universiteit Amsterdam, with financial and personal support by ZWO-WACOM (Research Group for Analytical Chemistry of Minerals and Rocks, subsidized by the Netherlands Organization for the Advancement of Pure Research).

From the gemmological point of view not very much has been published on sphene. Cassedanne & Cassedanne (1971, 1974) reported on sphene of gem quality from Campo do Boa, Capelinha municipality, Minas Gerais State in Brazil. In these papers crystallographic properties are given besides density data, details about accompanying minerals and a comparison with other sphene deposits in the world. Chemical data of sphene from Capelinha have been published by Higgins & Ribbe (1976).

In their recent paper Zwaan & Arps (1980) gave preliminary results of an investigation of the three cut sphenes purchased in October 1980. The properties of these stones were compared with those of sphenes from Capelinha, Brazil, belonging to the collections of both the museum and the Netherlands Gem Laboratory (NEL), which is housed in the museum. In their very recent paper Gunawardene and Hänni (1981) describe one sphene, which is said to originate from a remote area near Galle in Sri

Lanka. Microprobe analysis and absorption spectrum data are given in detail. The properties of the stone are compared with those of sphenes from three other localities and are found to be very similar to them.

The aim of the present paper is to draw attention again to the discovery of this new gem quality mineral in Sri Lanka and to give additional data on the origin of the cut sphenes.

PROPERTIES

Available for investigation were six cut stones; their properties are given in Table 1. With the exception of RGM 151 856, the colour of these sphenes is honey-yellow to brown. All have a strong pleochroism in tones of yellow-green and orange-brown. Due to the enormous birefringence in all stones, double facet edges at the base side are to be observed while looking through the table, in some cases even with the naked eye. Although use is made of a refractometer provided with a cubic zirconia prism, which makes it possible to get readings up to about 2.06, it was only possible to get a shadow-edge near 1.910, which is apparently the lowest figure, more or less corresponding with α. One of the stones (RGM 151 863) gave the two readings 1.908 and 1.940 on the table facet. These can only be related to the double refraction in the direction of observation.

The stones have distinct absorption spectra, due to the content of rare earths, with sharp intensive lines at 586 and 582 nm, in particular specimen RGM 151 854 has a very well developed spectrum. In these sphenes five lines can be seen in the yellow part of the spectrum at 599, 586, 582, 580 and 575 nm, while three absorption lines may be observed at 534, 530 and 528 nm, the strongest of them being the two lines in the yellow as mentioned above and the 530 nm in the green.

This 'didymium' spectrum, due to the presence of the rare-earth elements neodymium and praseodymium, is less developed in the yellowish green sphene RGM 151 856. It has ill-defined lines in both the yellow and the green part of the absorption spectrum. It is evident, moreover, that the quality of the spectrum is not only due to the colour but also to the intensity of that colour.

In Table 2, x-ray powder diffraction data are given for two sphenes from Sri Lanka and Brazil respectively. There are hardly any differences between these data, which indicates that these

TABLE 1.
Properties of six cut sphenes from Sri Lanka

Number	*Colour*	*Style of Cutting*	*Weight in ct*	*Size in mm*	*D (measured)*	*n (α)*
RGM 151 854	brownish-yellow	oval faceted	4.94	11.8 × 9.5 × 6.1	3.535	1.912
RGM 151 855	honey-brown	mixed	6.48	11.7 × 11.7 × 6.8	3.538	1.910
RGM 151 856	yellowish green	mixed	4.60	10.3 × 10.3 × 6.4	3.528	1.910
RGM 151 862	honey-yellow	trap	4.17	8.6 × 8.3 × 6.4	3.529	1.910
RGM 151 863	honey-yellow	trap	1.30	7.4 × 5.3 × 3.7	3.536	1.908
RGM 151 864	honey-yellow	trap	1.25	7.4 × 5.2 × 3.7	3.535	1.913

TABLE 2. X-ray powder diffraction data for two sphenes

	RGM 151 855 Sri Lanka		RGM 151 858 Brazil	
hkl	*d(obs.)*	*I*	*d(obs.)*	*I*
$\bar{1}11$	4.93	1	4.91	½
111 002	3.22	10	3.21	10
$\bar{2}02$	2.98	8	2.98	8
200	2.84	1	2.84	½
$\bar{2}21$ 022	2.59	9	2.59	9
$\bar{1}13$ 220	2.36	½	2.34	½
112 $\bar{1}32$	2.27	6	2.27	6
131	2.22	½	2.21	½
$\bar{3}12$	2.11	½	2.11	½
311	2.06	5	2.06	5
221	1.972	½	1.972	½
$\bar{3}13$	1.942	2	1.942	2
$\bar{2}04$ 310	1.850	½	1.850	½
042 $\bar{2}41$	1.802	½	1.802	½
$\bar{3}32$	1.741	1	1.741	1
$\bar{2}24$	1.703	6	1.704	6
$\bar{3}33$	1.641	7	1.641	7
151 241	1.553	4	1.553	4
043 $\bar{1}34$	1.528	2	1.527	2
133	1.492	7	1.495	7
400	1.419	5	1.418	5
	1.345	5	1.345	5
	1.303	4	1.303	3
	1.272	3	1.271	3
	1.223	1	1.223	1
	1.201	½	1.202	½
	1.143	½	1.143	½
	1.133	4	1.133	4
	1.114	1	1.114	1
	1.107	4	1.107	4
	1.077	2	1.076	2
	1.063	½	1.063	½
	1.040	½	1.040	½
	1.029	½	1.028	½
	1.014	½	1.014	½
	0.997	½	0.997	½

TABLE 3.
Electron microprobe analyses and unit cell contents of two sphenes from Sri Lanka and one from Brazil.

	RGM 151 854 Sri Lanka		RGM 151 856 Sri Lanka		VUA Brazil	
CaO	28.4		28.7		28.6	
MnO	0.07		0.04		0.04	
TiO_2	38.4		38.6		38.2	
Al_2O_3	1.25		1.11		1.37	
Fe_2O_3	0.70		0.60		0.41	
Cr_2O_3	0.015		—		0.015	
SiO_2	30.4		30.4		30.4	
total	99.2		99.5		99.0	
	Unit cell contents on the basis of 19 O					
Ca	3.80	3.81	3.84		3.84	
Mn	0.01		—		—	
Ti	3.61	3.86	3.62	3.85	3.60	3.84
Al	0.18		0.17		0.20	
Fe	0.07		0.06		0.04	
Cr	—		—		—	
Si	3.80		3.79		3.81	
total	11.47		11.48		11.49	

stones have very similar properties although their colours are different. The sphene from Sri Lanka is honey-brown, while the Brazilian stone, originating from Capelinha, is yellow-green. It is not unlikely that the contents of rare earth and other trace elements will make it possible to differentiate between stones from the two sources.

The results of electron microprobe analyses of three sphenes are given in Table 3. Two of them are from Sri Lanka; one is from Malacacheta near Capelinha, Brazil and is in the collection of the analyst Dr P. Maaskant.

Standards used were olivine (Mg,Fe,Ni), gehlenite (Al), diopside (Si,Ca), ilmenite (Ti,Mn), spinel (V, Cr,Zn) and V_2O_3 (V). For Si and Ca reference standards were gehlenite, åkermanite and andradite. If present, the contents of Na, Mg, Ni and Zn are less than 0.01%. Analyses on three different spots per stone did not reveal significant differences in major and minor element contents of the sphenes. The results of the major element analyses compare well with those in the literature (e.g., Deer *et al.*, 1962; Higgins & Ribbe, 1976; Gunawardene & Hänni, 1981)

Trace element analyses, e.g. rare-earth and other elements, could not be performed without damaging the faceted stones. As soon as rough specimens from the Tissamaharama area are available, they will be carried out. These additional data are necessary, because the present data of the sphenes do not give distinct differences between stones from the two sources.

INCLUSIONS

The most striking type of inclusions are liquid feathers comparable with those occurring in tourmalines. This may especially be observed in sphene RGM 151 854. Another type of liquid inclusion is very similar to the liquid feathers which are characteristic for corundums from Sri Lanka. They can be seen in sphene RGM 151 856.

Figure 4 shows inclusions in sphene RGM 151 855. It is

FIG. 4. Liquid inclusions in sphene RGM 151 855, ×25. Note the strong doubling of the inclusions.

FIG. 5. Crystal inclusions, probably apatite, in sphene RGM 151 863, ×25.

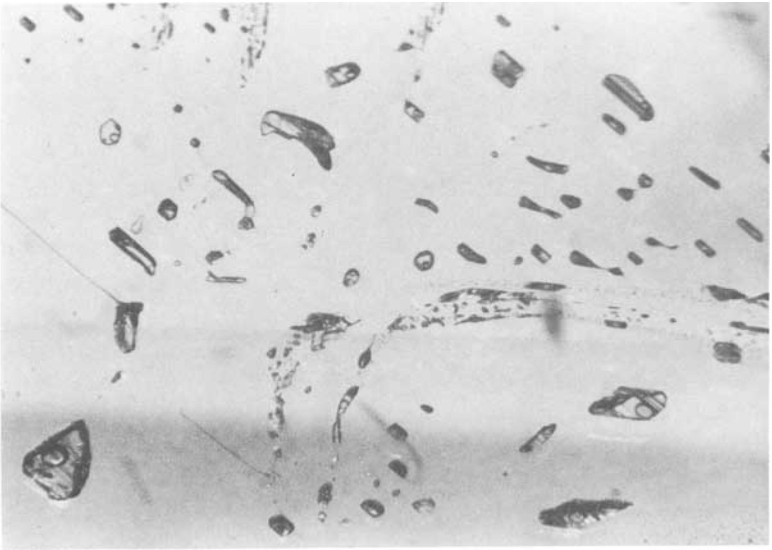

FIG. 6. Two-phase inclusions in sphene RGM 151 862, ×25.

difficult to identify the nature of them, but they most probably are both liquid inclusions and healed fissures, the strong doubling of the inclusions, due to the enormous birefringence of the stone, being very striking. Similar inclusions can be seen in sphene RGM 151 864.

Sphene RGM 151 863 contains some very small crystals which from their habits and optical properties, as far as these could be observed, are very likely apatite crystals (Figure 5). Apatite is a rather common inclusion in several gemstones from Sri Lanka, like corundum, almandine garnet and spinel, but naturally not described before as such in sphene.

In sphene RGM 151 862 superb two-phase inclusions occur. They resemble the type of inclusion which is characteristic for pegmatite minerals, like topaz and spodumene (Figure 6). However, these observations do not allow us to draw a conclusion on the mode of origin of these sphenes.

CONCLUDING REMARKS

The physical properties of the available sphenes from the Tissamaharama area in Sri Lanka are very similar to those of investigated sphenes in the collections of both the museum and the Netherlands Gem Laboratory (NEL), which are said to originate from Capelinha in Brazil. In their recent paper Zwaan & Arps (1980) state that also from electron microprobe analyses it is clear that the compositions of the sphenes are very similar. However, these 'Brazilian' sphenes were bought by the author in February 1978 as 'Brazilian tourmalines' in Singapore. Now the question whether these stones are really from Brazil is becoming very interesting, because those sphenes in the collection of the museum which are undoubtedly from Brazil, like specimen RGM 151 858, have a different colour, that is yellow-green, and a less distinct absorption spectrum. It is not unlikely, therefore that the stones which were bought in Singapore are also from Sri Lanka. The author discussed this problem with both gem dealers and members of the State Gem Corporation staff in Colombo. They are all of the opinion that, although official mining started about two years ago in the Tissamaharama area, stones from that area came on the market much earlier. They were apparently exported in a rough state, because they are all machine-cut, a technique not commonly used in Sri Lanka in and before 1978. Anyway, further work on more material will be necessary to draw more definite conclusions. Moreover one may hope that the expected good production of this very attractive stone will be realized.

ACKNOWLEDGEMENT

The author is much indebted to his collegue Dr C. E. S. Arps for his valuable advice and for critical reading of the manuscript.

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[*Manuscript received 6th June, 1981*]

GEMMOLOGICAL ABSTRACTS

BAMBA (T.). *Chrome-diopside jade from Chisaka, Hidaka Province, Hokkaido.* J.Gemm.Soc. Japan, 7, 1, 9-13, 4 figs, 1980.

A material similar to nephrite in colour but consisting of chrome diopside, uvarovite, chromite and pectolite has been found in the central part of Hokkaido, Japan. It is found as networks cutting the boundary between serpentine and rodingite. M.O'D.

BUCHANAN (K.). *Fresh water pearls.* Lapidary Journal, 35, 1, 76-9, 10 figs, 1981.

Describes pearls found in some of the rivers in Oklahoma. M.O'D.

DILLON (S.) ed. *Gem News.* Gems & Gemology, **XVII**, 1, 56-7, 1981.

Reports on the Afghanistan situation and lapis lazuli; diamond exploration in Australia, India, China, U.S.A., and U.S.S.R.; ruby in Kenya, Australia and Pakistan; sapphires in Kashmir and North Queensland; a gem-cutting enterprise in Sri Lanka and (from Tucson Gem & Mineral Show) aquamarine from Idaho; red beryl from Utah; synthetic red beryl; sugilite or 'Royal lavulite' (a new gem mineral); pink fluorite from Peru; and Brazilian topaz. R.K.M.

FOLGUERAS-DOMINGUEZ (S.), BARBOSA (J.-E. C. A.), YANEZ-LOZANO (S.). *Fluorescence des topazes aux rayons u.v.* (The fluorescence of topaz under ultraviolet light.) Revue de Gemmologie, 66, 10, 1981.

Topaz may show a slight alteration in fluorescence after heating above 200 °C. The change is most noticeable in some rose-coloured stones. M.O'D.

FRANKS (M.). *The deadly lure: a story from the Lightning Ridge opal fields.* Lapidary J., **34**, 12, 2664-70, 1981.

Anecdotal account of a field trip to Lightning Ridge, New South Wales. M.O'D.

FRYER (C.) ed., CROWNINGSHIELD (R.), HURWIT (K. N.), KANE (R. E.). *Gem Trade lab notes.* Gems & Gemology, **XVII**, 1, 40-6, 23 figs (16 in colour), 1981.

A carved bead cut from trapiche-type aquamarine is illustrated and described. Cyclotron treated diamonds, others with natural radiation stains on unpolished crystal surfaces left at girdles of brilliants, yet more diamonds with strangely shaped inclusions, all described and illustrated. A faceted golden cube of diamond also shown. Type II diamonds distinguished from Type I by photographic transparency test using short-wave UV in two second exposure to show that Type II is highly transparent at this wavelength, while Type I is comparatively opaque. An emerald had varying transparency at different angles; a synthetic emerald of Russian manufacture had needle-like inclusions and a cavity filled with yellow liquid as well as normal synthetic 'veils' and 'Venetian blind' banding.

Cultured pearls: a necklace with one shell bead completely without its nacreous layer; other cultured pearls of various colours reported, including dyed bronze and drop-shapes.

Chatham flux rubies showed angular silk-like inclusions as well as expected flux 'fingerprints'. A Verneuil synthetic had induced healed-crack inclusions. Sapphires are being 'packed in chemicals' and heated to diffuse colour into their surfaces. Short-wave UV reveals patchy fluorescence. Polishing removes the colour. Two spinel stars showed 4 and 6 rayed effects respectively. R.K.M.

GARCIA-GUINÉA (J.). *Les beryls espagnols d'un intérêt gemmologique.* (Spanish beryl of gemmological interest.) Revue de Gemmologie, 66, 2, 3 figs, 1981.

Some green and blue beryl is found in Spain, two important locations being at Sierra de Jurès and Pereña. Constants are given. M.O'D.

GÜBELIN (E.). *Zabargad: the ancient peridot island in the Red Sea.* Gems & Gemology, **XVII**, 1, 2-8, 6 figs in colour, 1981.

An excellent first-hand account of the most anciently known source of peridot, once called 'topazos', on this 4.5 km^2 island, which Dr Gübelin visited in 1980. No longer a viable source. Some account of the gem's history from classical Greek times is given. [Atlases use 'Zebirget' spelling; alternative name is 'Isle of St John'.] R.K.M.

HAAS (L. M.). *Venezuelan pearls of Margarita Island.* Lapidary J., **35**, 1, 114-16, 6 figs in colour, 1981.

Describes a visit to Margarita and experiences of pearl buying. M.O'D.

HOBBS (J.). *A simple approach to detecting diamond simulants.* Gems & Gemology, **XVII**, 1, 20-33, 18 figs (17 in colour), 1981.

Starting with careful observation of see-through effects, dispersion, facet edges, girdle defects, grain and polish lines, Ms Hobbs goes on to identify the simulants by SG tests, relating SG to size, and then immersion techniques, before touching on fluorescence, which is of minimal value. She then deals with the diamond pen and the diamond probe. [For some reason the infrared reflectometer is omitted.] R.K.M.

JONES (B.). *Blue ball azurite.* Rock & Gem, **10**, 9, 48-81, 4 figs (1 in colour), 1980.

Small nodules of azurite with some malachite are found in the Pinal Mountains south of Miami, Arizona, U.S.A. Some of the nodules are sufficiently hard to take a good polish. M.O'D.

KOIVULA (J. I.). *The hidden beauty of amber: new light on an old subject.* Gems & Gemology, **XVII**, 1, 34-6, 6 figs in colour, 1981.

An interesting and beautifully illustrated account of some inclusions to be seen in amber, using crossed polars to reveal strain caused by insect death-struggles which occurred millions of years ago. R.K.M.

KOMOTAUER (S. K.). *Granat.* (Garnet.) Mineralien Magazin, **5**, 5, 198-207, 17 figs in colour, 1981.

A short but well-illustrated survey of the garnet family of minerals. M.O'D.

Kraus (P. D.). *A visit with the Maui divers.* Lapidary J., **35**, 1, 118-34, 34 figs (7 in colour), 1981.

Maui divers of Hawaii are a company founded in 1958. Pink and other varieties of coral are found and sold and a description of their fashioning is given. M.O'D.

Nassau (K.). *Artificially induced color in amethyst-citrine quartz.* Gems & Gemology, **XVII**, 1, 37-9, 3 figs in colour, 1981.

More on this new particoloured type of quartz and information on the irradiation used to alter similarly twinned and segmented amethyst quartz to produce the same combination of colours. R.K.M.

Nassau (K.). *Cubic zirconia: an update.* Gems & Gemology, **XVII**, 1, 9-19, 9 figs (4 in colour), 1981.

An authoritative and very thorough account of this man-made simulant of diamond, the most successful so far. It has been found occurring naturally but has no mineral name. R.K.M.

Nassau (K.). *Natural, treated and synthetic amethyst-citrine quartz.* Lapidary J., **35**, 1, 52-60, 8 figs (7 in colour), 1981.

Crystals in which amethyst and citrine colours exist side by side have been available for some time, but there is no single method by which this effect can be obtained, nor is there any test by which artificially irradiated and heated stones can be distinguished from those occurring naturally. M.O'D.

Pressy (M. R.). *Amethyst prospecting in the second Appalachian range.* Lapidary J., **34**, 12, 2528-44, 20 figs (12 in colour), 1981.

An account of the location and recovery of amethyst from Georgia, U.S.A. M.O'D.

Ramsey (J. L.). *Buying faceting rough.* Lapidary J., **35**, 1, 30-50, 9 figs in colour, 1981.

A very general outline of the major gem materials with notes on the selection of rough pieces for faceting. Illustrations show finished stones only and so are unhelpful; surprisingly little is given on selection points. M.O'D.

Rice (P. C.). *Alluring amber.* Lapidary J., **35**, 1, 64-70, 4 figs, 1981.

This is a brief overview of amber, loosely extracted from the author's *Amber, golden gem of the ages.* M.O'D.

Rolandi (V.). *Les gemmes du règne animal: étude gemmologique des sécrétions des Cnidaires.* (Gems from the animal kingdom: gemmological study of the secretions of the Cnidaria.) Revue de Gemmologie, 66, 3-9, 4 figs (1 in colour), 1981.

The family *Cnidaria* includes the corals and their relatives and this study examines those with an ornamental significance. Constants are given. M.O'D.

Shindo (I.). *Growth of modified cat's-eye gemstones $MgTiO_3$ solid solutions by the floating zone method.* J.Gemm.Soc. Japan, **7**, 1, 3-8, 8 figs, 1980.

A chatoyant material with gem application has been manufactured by preparing boules of $MgTiO_3$ by the floating zone method of crystal growth followed by annealing to lighten the colour. Crystals of up to 8 mm diameter and 100 mm length have been grown. M.O'D.

SOLANS HUGUET (J.), DOMÉNECH (M. V.). *Defectos reticulares y color en las gemas.* (Lattice defects and colour in gemstones.) Gemologia, **13**, 47/48, 9-22, 2 figs, 1980.

Colour in gemstones may be caused by defects in the crystal lattice, by which energy is absorbed in the visible region. There are three types of defect, involving vacancies, interstitial atoms and substitutional atoms. Amazonite, topaz, diamond, fluorite and quartz are discussed with brief notes on other minerals. M.O'D.

STÄHLIN (W.), WOLFENSBERGER (R.). *Gadolinium gallium garnet.* Chimia, **35**, 4, 147-52, 8 figs, 1981.

GGG is grown by the Czochralski pulling method and dislocation densities as low as $0.5/cm^2$ can be obtained. Details of apparatus used are given. M.O'D.

VENDRELL SAZ (M.), PAGÈS (A.), ALBAR-FONTE (F.). *Electrogem: equipo para la medición de indices de refracción a partir de la reflectancia. Descripción tecnica.* (Electrogem: equipment for the measurement of refractive indices on the basis of reflectivity. Technical description.) Gemologia, **13**, 47/48, 5-8, 1 fig, 1980.

Electrogem is the trade name of a reflectivity meter measuring in refractive indices and with two scales divided at the point 1.81. The method of operation is described. M.O'D.

WÜTHRICH (A.), WEIBEL (M.). *Optical theory of asterism.* Phys.Chem.Min., **7**, 53-4, 2 figs, 1981.

A simple explanation of chatoyance and asterism is given in terms of physical and geometrical optics. The basic phenomena resolved are the scattering of light by thin cylinders and its refraction by curved surfaces. To substantiate this theory, it is shown that the star can also be observed in asteriated stones having a plane surface. P.Br.

YU (R. M.), HEALEY (D.). *A note on the 'black pearls' of the Philippines.* Lapidary J., **35**, 1, 80-1, 6 figs, 1981.

Material offered in the Philippines as 'black pearl' is neither pearl nor the black variety of coral with an SG of 1.35; the material examined had a cross-section consisting of mother of pearl and a brownish-black coral-like substance whose exact nature has yet to be determined. It has an SG of about 2.6. M.O'D.

ZEITNER (J. C.). *Amber and jet.* Lapidary J., **35**, 1, 92-9, 10 figs, 1981.

Gives a list of localities for both materials in the United States. M.O'D.

ZEITNER (J. C.). *Organic gems.* Lapidary J., **35**, 1, 16-28, 24 figs (11 in colour), 1981.

Amber, pearl, shell and other well-known ornamental materials of organic origin are described briefly. Hardwoods are also mentioned. M.O'D.

£225,000 diamond. The Times newspaper, No. 60936, p.10, 25th June 1981.

The South African Press Association says that a diamond digger has discovered a 148 ct diamond, said to be flawless and worth £225 000. J.R.H.C.

NOTE: the Spring 1981 issue of Gems & Gemology is the first of Volume XVII, which now appears in a new and enlarged format (8½" × 11") with a minimum of 64 pages: a section of Gemological Abstracts is now included as well as Book Reviews.

BOOK REVIEWS

BALITSKII (V. C.), LISITSYNA (E. E.). *Sinteticheskie analogi i imitatsii prirodiykh dragotsennykh kamnei.* (Synthetic counterparts and imitations of natural precious stones.) Nedra, Moscow, 1981. pp.157. Illus. in colour. 1.20R. (In Russian.).

This is a completely new survey of synthetic and imitation gemstones with a bibliography of 410 entries. All the major stones are covered and there is a long section devoted to the manufacture of quartz. General gemmological notes concerned mainly with standard testing methods are also given. M.O'D.

BLÜCHEL (K.), MEDENBACH (O.). *Zauber der Mineralien.* (Wonder of minerals.) Ringier AG, Zürich, 1981. pp.287. Illus. in colour. 45Fr.

This is a book composed almost entirely of photographs with some explanatory text. The quality of the pictures is quite superb—even the scale is given—and the text forms a general introduction to the mineral kingdom. There is a short bibliography, a list of locations for the minerals depicted and an index. Not a book for the student but for one looking for a subject with which to fall in love. M.O'D.

MCNEVIN (A. A.), HOLMES (G. G.). *Gemstones.* 2nd edn. Geological Survey of New South Wales, Sydney, 1980. pp.119. Illus. in black-and-white. Price on application.

This useful compendium on gemstones found in New South Wales forms no. 18 of the series 'Mineral Industry of New South Wales'. Naturally much information is provided on opal, but diamond and corundum also feature largely. A map of New South Wales with gemstone occurrences is provided. M.O'D.

PAGEL-THIESEN (V.). *Diamond grading ABC.* 7th edn. Rubin & Co., Antwerp, 1980. pp.275. Illus. in black-and-white and in colour. 950Fr.

This well-known manual has been completely reworked to take into account the recent developments in grading consequent on the CIBJO version of grading standards. The latest testing instruments are described and the bibliography is updated. As always the illustrations provide the chief reason for buying the book.

M.O'D.

ASSOCIATION NOTICES

GIFTS TO THE ASSOCIATION

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

Mr D. W. Chase, Yelverton, Devon, for a collection of cut specimens suitable for students, including jet, agate, sapphire, jadeite, nephrite, peridot, amber, emerald, aventurine quartz, moonstone, coral.

Mr R. Holt, F.G.A., London, for one step-cut emerald weighing 50.48ct, one cabochon-cut blue aquamarine weighing 48.97ct, one rough piece of aquamarine and one rough piece of ruby crystal.

Dr J. B. Nelson, Ph.D., F.R.M.S., F.Inst.P., F.G.S., F.G.A., for four books entitled *The Optical Performance of the Light Microscope* by H. Wolfgang Zieler, Microscope Publications Ltd., London, part 1 1972, part 2 1973; *Teaching Microscopy* by John Gustav Delly, Microscope Publications Ltd., London, 1976; *Polarized Light Microscopy* by W. C. McCrone, L. B. McCrone and J. G. Delly, Ann Arbor Science Publishers Inc., Ann Arbor, Mich., U.S.A., 1979.

Mr Per Paulin, B.Sc., F.G.A., Uppsala, Sweden, for 16 cut and polished garnets weighing 14.5ct, all showing typical inclusions and spectra.

Professor Dr Pieter Zwaan, F.G.A., for a copy of *Scripta Geologica,* No. 58, 'Sphene, Sri Lanka's Newest Gemstone'.

NEWS OF FELLOWS

On 6th May, 1981, the following Fellows of the Association were granted the freedom of the Worshipful Company of Goldsmiths—Mr J. P. Astley-Sparke, Mr T. J. O'Donoghue and Mr J. A. Styles.

On the 6th May, 1981, Mr M. J. O'Donoghue, M.A., F.G.S., F.G.A., gave a talk entitled 'Man-made crystals', with emphasis on non-gem materials, to the West Midlands Mining and Mineralogical Society, and on the 30th June, 1981, Mr O'Donoghue gave a talk entitled 'Some rare gemstones' to the Amateur Geological Society in London.

OBITUARY

Queene Alice (Renée) Lady Walton, widow of the late Sir James Walton, K.C.V.O., M.S., M.B., B.Sc., F.R.C.S., L.R.C.P., F.A.C.S., F.G.A. (Chairman, 1955), died on 6th June, 1981, at Lindfield, Sussex. Lady Walton was elected a Vice-President of the National Association of Goldsmiths in 1955.

MEMBERS' MEETINGS

North-West Branch

On 7th July, 1981, a social evening was held at the Northern Cricket Club, Thornton, Liverpool.

South Yorkshire & District Branch

On 28th May, 1981, a meeting was held in the City Museum, Sheffield, when Mrs V. E. Duke, a resident of Brazil, showed her extensive collection of gemstones from that country, both cut stones and crystals.

COUNCIL MEETING

At the Meeting of the Council held on Wednesday, 9th May, 1981, at Saint Dunstan's House the business transacted included the following:

1. Honorary Fellowships

The following were elected Honorary Fellows in recognition of their distinguished services to gemmology:

Mlle Dina Level, late of Laboratoire des Pierres Précieuses et Fines et des Perles, Paris.

Mr Richard T. Liddicoat, jnr, President of the Gemological Institute of America.

2. Examinations—Prizes

In 1980 Professor Dr Hermann Bank, F.G.A., of Idar-Oberstein, offered to give a sum of money for a prize to be linked with the name of Mr Basil Anderson. As a result the Council reviewed all the prizes to be awarded in the gemmology examinations and the money provided by Professor Dr Bank, to whom the Council expressed the Association's grateful appreciation for his generous gift, is to be used for an Anderson/Bank Prize and also for an Anderson Medal. It was decided that as from the examinations held in 1981 the following would be awarded:

Tully Medal

To be awarded to the candidate (trade and non-trade) who submits the best set of answers in the Gemmology Diploma Examination which, in the opinion of the Examiners, are of sufficiently high standard to meet the award.

Anderson/Bank Prize

A prize to be awarded to the best non-trade candidate of the year in the Gemmology Diploma Examination. The prize to be books, selected by the winner, to the value of approximately £120.

Rayner Diploma Prize

A prize to be awarded to the best candidate of the year who derives his/her main income from activities essentially connected with the jewellery trade. The prize to be Rayner instruments, selected by the winner to the value of approximately £120.

Anderson Medal

A silver medal to be awarded to the best candidate of the year in the Gemmology Preliminary Examination.

Rayner Preliminary Prize

A prize of a Rayner Refractometer to be awarded to the best candidate under the age of 21 years at July 1st of the year of the examination, who derives his/her main income from activities essentially connected with the jewellery trade.

3. *Membership*

The following were elected to membership:

FELLOWSHIP

Cook, Graham A., Dundee. 1980
Huizinga, Jeroen, Amsterdam, Netherlands. 1980
Perkins, Joanna C., London. 1980
van Kalleveen, Allard, Paris, France. 1980

TRANSFERS FROM ORDINARY MEMBERSHIP TO FELLOWSHIP

Berkowitz, Joseph, Toronto, Ont., Canada. 1980
Clarke, Donald H., Cadiz, Spain. 1979

ORDINARY MEMBERSHIP

Anavil, Sriraj, Cerritos, Ca, U.S.A.
Andreasson, Ralph R., Akersberga, Sweden.
Athauda, Weerasinha A., Warrington.
Beauchamp, Wayne, Breitenbach, Tyrol, Austria.
Bilkoski, Tannis M., Calgary, Alta, Canada.
Blenkinsopp, Robert J., York.
Borrill, Kathleen M., Hull.
Bottom, Ian, Chesterfield.
Bramley, Patrick F., Carlow, Ireland.
Buddington, Jeff, Hyannis, Mass, U.S.A.
Burbidge, Norma P., New Plymouth, N.Z.
Carpenter, Thomas D., Yelden.
Champness, Peter T., Bury St Edmunds.
Currie, Lynnette J., Auckland, N.Z.
del Rey, Mario, S. Caetano do Sul, Brazil.
des Baux, Jeanne R., Romsey.
de Silva, John I., Trier, W. Germany.
Desmond, Jerry, Welwyn Garden City.
Dye, Reginald E., London.
Eickhorst, Manfred, Hamburg, W. Germany.
Gabel, John A., Toronto, Ont., Canada.
Glatt, Rodney D., Johannesburg, S. Africa.
Hall, Michael D., Derby.
Hayashi, Wataru, Kumamoto, Japan.
Hee Kim San, Vincent, Singapore.
Horton, David R., London.
Hutton, Michael P., South Benfleet.
Ikuwa, Daniel N., Voi, Kenya.
Jalaludin, Syed, Kuala Lumpur, Malaya.
Kaneko, Fumiya, Tokyo, Japan.
Kularatnam, Samuel K., Colombo, Sri Lanka.
Kyle, Alan J., Neilston.
Laladia, Cashyap L., Dubai, U.A.E.
Lee, Eric, Singapore.
Macdonald, Roy W., Glasgow.
Mangrolia, R. D., Bolton.
Mangrolia, Ved Lata, Bolton.
Melleck, Joel, Harrow.
Monaghan, Neil, Umtali, Zimbabwe.
Monogyios, George, Athens, Greece.

Morris, Roy B., London.
Moussaieff, Tamara, London.
Murphy, Jack, Newry, N. Ireland.
Myers, Robert, London.
Nasser, Shertaz, Northwood.
Pattani, Rasiklal A., London.
Peebles, Kathleen W., Johannesburg, S. Africa.
Petrillo, Nicholas J, Scranton, Pa, U.S.A.
Porter, James W., Coventry.
Purcell, Jeremy C., Brighton.
Roberts, Charles, McAllen, Tex., U.S.A.
Sakamoto, Kanichi, Kumamoto, Japan.
Schofield, Nichola J., Huddersfield.
Smith, Barry K., Fielding, N.Z.
Smith, Margaret S., Dana Point, Ca, U.S.A.
Stephanides, George, Nicosia, Cyprus.
Suzuki, Schoichiro, Ibaragi-Ken, Japan.
Veera, Rajesh, Port-Louis, Mauritius.
Waller, Myra L., Victoria, B.C., Canada.
Waterworth, Eileen, Hong Kong.
Watson, Gordon, Lanark.
Weare, Richard M., York.
Webber, Michael, Macclesfield.
Wehrly, Tony, Sligo, Ireland.
Winiecki, Halina, London.

ANNUAL GENERAL MEETING

The 50th Annual General Meeting of the Association was held at Saint Dunstan's House, on 20th May, 1981, at 6.30 p.m., and was attended by thirty-five members.

Mr David Callaghan, the Chairman, welcomed all those attending and said how nice it was to have a larger number than usual present. Sincere thanks were expressed to all members of Council for their support during the year, to the Branch Chairmen and Secretaries for the help that they gave, and to the Examiners and Instructors who were doing so much for gemmology as a whole. The special Committee concerned with the review of examinations-prizes was specially thanked for its work. Mr Callaghan praised the quality of the *Journal of Gemmology* and its high standing in the gemmological world and said how fortunate the Association was to have Mr John Chisholm as its Editor, together with his Assistant, Mrs (Mary) Burland. Due to the excellent guidance of the Treasurer the Association's finances were in good order. Lastly he thanked the staff for the work done throughout the year, in particular the Secretary, Mr Harry Wheeler. Although not specific to the year in question, he made reference to the fact that this year (1981) we were celebrating our Fiftieth Anniversary. A Committee had been formed to make all the arrangements, and the events planned for October should do justice to the Association and the work it has done for so many years.

The Treasurer then reported on the Accounts which showed a surplus of £31314 and said that the reserves which had accumulated would allow the Association to undertake its Fiftieth Anniversary celebrations without financial problems. He thanked the Assistant Secretary, Mr Douglas Wheeler, for his good work during the year in ensuring that all available funds were invested to obtain the maximum amount of interest.

The Chairman moved that the Audited Accounts and Report of the Council for the year ended 31st December, 1980, be adopted and Mr Ian Lewis seconded the motion, which was carried *nem. con.*

Sir Frank Claringbull was re-elected President, and Messrs D. J. Callaghan, N. W. Deeks and F. E. Lawson Clarke were re-elected Chairman, Vice-Chairman and Treasurer respectively. Messrs A. J. French, D. Inkersole, D. M. Larcher, P. W. T. Riley and C. H. Winter were re-elected and Dr J. B. Nelson and Mr W. Nowak were elected to the Council.

Messrs Hard Dowdy, Watson Collin & Co. were re-appointed as auditors to the Association.

G.A. FELLOWSHIP TIE

Together with other Jubilee celebrations the Council has decided to have a new design for the Fellowship tie. The tie is made of polyester material and is available in two colours—dark blue *or* maroon. The Coat of Arms of the Association is attractively woven in colour (red, silver, blue and gold) in the centre of the tie.

Price—U.K. (including postage & V.A.T.)	£4.40
Overseas (including air mail)	£4.60

The enamelled badge brooch of the Association's Coat of Arms is still available. Pin fitting makes it suitable for female and male dress.

Price—U.K. (including postage & V.A.T.)	
metal gilt	£15.50
9 ct gold	£66.60
Overseas (including air mail postage)	
metal gilt	£15.00
Overseas (including air mail Regd post)	
9 ct gold	£60.00

Year Diploma was awarded must be stated with each order.

Orders to Gemmological Association.

EXAMINATIONS 1982

Examination dates for 1982 are as follows:

Gem Diamond Examination:
  Theory, Monday, 7th June
  Practical, Monday, 7th and Tuesday, 8th June.
Examinations in Gemmology:
  Preliminary: Tuesday, 29th June
  Diploma:
    Theory, Wednesday, 30th June
    Practical, Thursday, 1st July, and Friday, 2nd July.

The *last* date for receiving examination entry forms is Wednesday, 31st March, 1982.

I.M.M. GEMSTONES MEETING

The Institution of Mining and Metallurgy is arranging a one-day Gemstones Commodity Meeting at Goldsmiths' Hall, Foster Lane, London, E.C.2., on the 3rd December, 1981. The Meeting will start at 08.45 and end at approximately 18.00 hours. Subjects to be covered by well-known experts include—

> 'The World of Gemstones', 'Emeralds at Sandawana', 'Production of Diamonds in Southern Africa', 'Opals and Sapphires in Australia', 'Production and Identification of Synthetic Gemstones', 'Detection of Treated Diamonds', 'East African Coloured Gemstones', 'Diamond Discoveries in the

Kimberlies, Western Australia', 'Recent Discoveries in the Transvaal and Botswana', 'Prospect of Diamonds in the Southwest Pacific' and 'Marketing and Trends in Coloured Stones'.

The cost to non-members of the Institution is £60 (including V.A.T.) and interested persons should apply direct to the Institution at 44 Portland Place, London, W.1. (tel: 01-580 3802).

CONFERENCE IN COLOMBO, FEBRUARY 1982

Notice has been received of the First International Coloured Gemstones Conference and Gem and Jewellery Exhibition which is to be held on 1-2 February 1982 at the Bandaranaike Memorial International Conference Hall, Colombo. Dr E. Gübelin is to speak on the first day. Further information may be obtained from the Organizers, Conventions (Colombo) Ltd, P.O. Box 94, Colombo 1, Sri Lanka (telephone 21124).

G.I.A. INTERNATIONAL SYMPOSIUM

The Gemological Institute of America invites those who have earned its Gemologist or Graduate Gemologist Diploma and others from the world-wide gemmological community to its first International Gemological Symposium to be held at the Century Plaza Hotel, Los Angeles, from Friday, 12th February to Monday, 15th February, 1982.

As a culmination of its 50th Anniversary celebrations, G.I.A. has announced this gathering of gemmologists for a series of lectures and discussions to be led by speakers of international repute on subjects to include the most recent findings in research of diamonds and coloured stones, including treatments, synthetics and substitutes, with reports on important sources, changing patterns of supply, marketing, retailing and instrumentation. The proceedings will be published.

Members interested in attending the symposium should communicate with the Gemmological Association of Great Britain, Saint Dunstan's House, Carey Lane, London EC2V 8AB—telephone 01-606 5025/6.

INDEX FOR VOLUME XVII

The Index for Volume XVII (1980-1981) will be issued with part 1 of Volume XVIII in January 1982.

LETTERS TO THE EDITOR

From Mr Dan E. Mayers, M.Sc., A.I.M.E., A.G.A.

Dear Sir,

I refer to the note entitled 'Japanese Synthetic Emeralds?' by R. Keith Mitchell, in the *Journal,* January 1981 (XVII, 5, 290-1).

The stones in question, sold under the Crescent Vert trade name, are indeed manufactured in Japan by Kyocera. In addition I examined, at their factory last month, samples of excellent quality Ruby, Padparadsha Sapphire, and Alexandrite. All are made by the standard Gilson procedure.

The only real challenge yet to be surmounted is that of growing Jadeite. I would be surprised if we have long to wait.

Yours etc.,
DAN E. MAYERS.

5th May, 1981.
Crystals S.A., Geneva-2, Switzerland.

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

Dear Sir,

I read with interest the Gunawardene and Hänni paper in this *Journal,* XVII (6), 381-5, on what they claim to be the first gem sphene found in Sri Lanka. Without wishing to detract from what is an unusual find in that country, I would point out that Paul Desautels, in his book 'The Mineral Kingdom', published in 1968, lists sphene among the gems which may be found in Ceylon illam. Also that the late Louis C. Siedle, of Colombo, found a very fine green sphene among faceted Ceylon gems as long ago as the early 1950s. He sent this stone to me for confirmation, and I eventually mentioned it in a letter to Dr Edward Gübelin. It was undoubtedly sphene.

In 1974, after the untimely death of this old friend and fellow Tully Medallist, I was able to purchase the stone from Mrs Eunice Siedle. Its weight then was 5.47 carats, and it was a very bright and pleasing green colour, showing considerable dispersion. The green was less dense than that normally seen in the Baja Californian (Mexican) green sphenes. The stone eventually went to a Swiss buyer.

While writing, I would mention that early in 1968 I bought two parcels of light green sphenes, which had been sent from an Indian source. Two stones, which were sent as 'peridot', weighed 9.84 carats and 8.66 carats respectively, while a second parcel of 15 stones, sent as 'zircon', weighed a total of 43.75 carats. All these were gem quality but very crudely cut and polished, and it is reasonable to suppose that the rough was of Indian origin and cut by a local and inexperienced cutter. On this reasoning, this was evidently a new source of gem sphene and I now wish to record it, albeit vaguely. The supplier died shortly after these stones were purchased and no further information on their exact provenance can be obtained. The colour of both parcels was a light peridot green with one or two of the smaller ones tending to a brownish green.

Yours etc.,
R. Keith Mitchell.

27th May, 1981.
Orpington, Kent.

CORRIGENDA

On p.400 above, in Table 2, for 'SiO_2 44.87 wt%' read 'SiO_2 48.87 wt%'.

On p.433 above, in lines 11 and 10 from bottom, for '53¼ carats' read 53½¼ carats' (=53¾ ct. For this method of recording weights, see page 516 above, lines 10-33, and page 621 above, lines 1-17.)

On page 433 above, in the bottom line, and on page 434 above, in lines 18 and 26, for 'Jejeebhoy' read 'Jeejeebhoy'.

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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Compiled by Mary Burland

Alphabetical arrangement is letter-by-letter.

Names of authors are printed in capitals, pages of abstracts and book reviews in italics.

Special usages:

above and *below* in cross-references indicate that the reference is to another subheading under the same heading, not a separate heading.

bis or *ter* immediately following page references indicates that there are two, or three, separate references to the subject on the page.

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