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IDENTIFICATION OF THE NEW SYNTHETIC AND TREATED SAPPHIRES

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The fact that the new techniques of synthesis are now being applied to the production of sapphires is not surprising when one considers the imposing success attained recently by Chatham, Kashan and Knischka in synthesizing rubies.

Although the new synthetic sapphires have not yet reached the market in such overwhelming quantities as those new synthetic rubies, it is nevertheless high time for gemmologists to arm themselves with some knowledge of how to distinguish them from their natural counterparts.

SYNTHETIC BLUE SAPPHIRES

The experiments which led to the production of synthetic sapphires by the new flux-growth method lasted for many years, and in 1980 Messrs C. and Th. Chatham introduced their first samples of synthetic sapphire of gem quality to the trade. These

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early productions by Chatham contained a great number of inclusions, some of which were of totally unnatural nature, and these stones were therefore clearly distinguishable from natural sapphires, thus making them incompatible on the market. However, having attained a certain degree of success, Chatham & Son have improved their product to such an extent that the latest synthetic sapphires to enter the market from this source have considerably less inclusions. The author was able to acquire a good number of samples of each generation of these synthetic Chatham sapphires, and a thorough examination revealed the fact that with some experience these can be readily distinguished not only from natural sapphires, but also from synthetic Verneuil sapphires. The results of these examinations are therefore presented forthwith for the benefit of all readers of this *Journal* interested in this field of gem-testing. As was expected, the physical properties differed very little from those of natural sapphires.

General Appearance. Both crystals and cut specimens were available for the examinations. All the crystals were remarkable for their irregular coloration: dark blue patches alternated with pale blue and even colourless zones, the latter often being tinted with yellow. The cores of the crystals were also mainly yellow (Figure 1). As cut stones, these synthetic Chatham sapphires bore some resemblance to natural sapphires from Australia (see also Figures 22 and 23). The crystals were rhombohedral in their main forms; medium sized rhombohedra and rhombohedral dipyramids combined with truncated prism faces, while the basal planes were so well developed that the crystals displayed a pronounced tabular habit (Figure 2). Many smaller crystals had grown together in clusters.

The refractive indices varied for n_ϵ from 1.758 to 1.762, and for n_ω from 1.766 to 1.770, with an absolutely constant birefringence of $n_\Delta = -0.008$.

The density ranged from 3.942 to 4.05 g/cm^3 and appeared be strongly influenced by the inclusions.

The dichroism showed twin-colours: pale greenish-blue for the extraordinary ray and dark blue for the ordinary ray.

The spectro-optical examination revealed no absorption lines at all for the blue area of the stones, but the yellow zones showed a very weak suggestion of a delicate band at 450 nm, only visible with a blue filter.

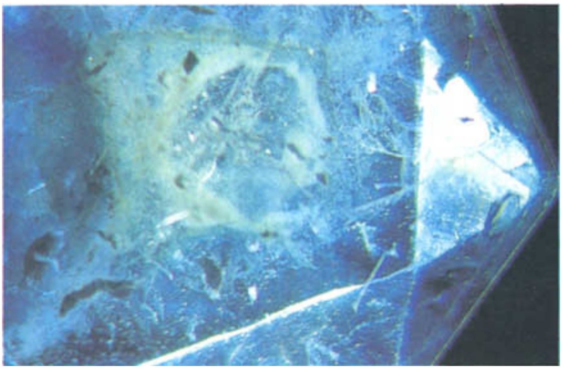

FIG. 1. Synthetic flux-grown sapphire by Chatham. Tabular crystal with large basal plane surrounded by triangular rhombohedra. Note greenish core. 8×

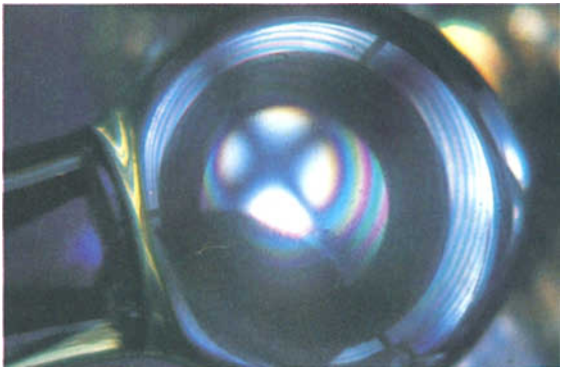

FIG. 2. Sapphire crystal in same position as in Fig. 1. The conoscopical image of the optical monoaxis passing vertically through the basal plane is made visible by a glass ball between crossed polars. 10×

FIG. 3. Parallel, structural zones flexed at an angle of 120°. 20×

The luminescence in ultraviolet light provided the only optical distinguishing factor in comparison with natural sapphires, as synthetic Chatham sapphires glowed with an intense pale green in long-wave ultraviolet light, and appeared dull green in short-wave ultraviolet light, especially the yellow areas. No phosphorescence was observed. Natural blue sapphires do not react to ultraviolet light, and synthetic Verneuil sapphires appear whitish- to milky-green in short-wave ultraviolet light. (However, two synthetic blue faceted sapphires by Chatham—obtained very recently—do not display any luminescence.)

Inclusions

Just as with the synthetic stones by Verneuil and the new synthetic rubies by Chatham, Kashan and Knischka, the best possibility of a successful and reliable identification lies in the inclusion scene.

Although this is not so variegated by far as in the new synthetic rubies, it is none the less confusing, for it is very similar to that of natural sapphire in many ways. With low magnification such as a pocket lens, irregular coloration and crazily intertwined or single unfurled banners are apparent, as well as coarse flux-inclusions and black daggers and platelets which glint silvery in reflecting incident light.

The impression of irregular coloration is caused by colourless, yellow and blue areas, and phantoms occurring either singly or in combination with each other. The latter are usually yellowish of varying intensity, and are situated in the centre of the crystal (Figure 1). In faceted stones these may or may not be present, depending upon the cut. These yellow patches are often more strongly populated and defiled with flux-formations than the colourless or blue areas. The variegated colour-zones are not curved like those in the synthetic Verneuil sapphires, but straight and often angular like those in natural sapphires: i.e. they represent the growth-stages of the hexagonal prisms or rhombohedra, and very often both forms are represented (Figures 3 & 4). Sometimes these zones are formed by lamellae as a result of polysynthetic twinning which, in contrast to the zonal structure, show no angles (Figure 5). Rough flux inclusions are much commoner than in the

FIG. 4. Characteristic inclusion scene in synthetic sapphire by Chatham, comprising angular zones, tiny flux grains and black platelets of platinum (one of them in the top right-hand corner with silvery reflection). 15 ×

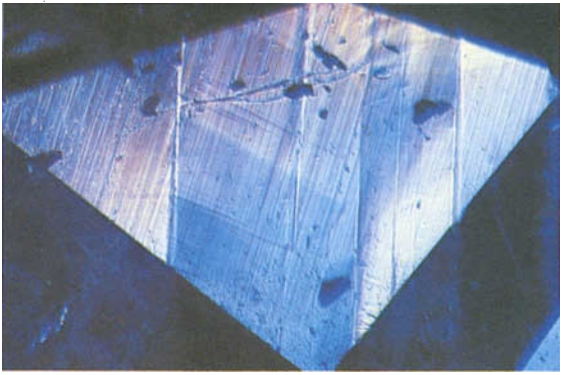

FIG. 5. Broad straight polysynthetic twin lamellae in parallel alignment. 25 × (*Photo by J. Koivula, G.I.A.*)

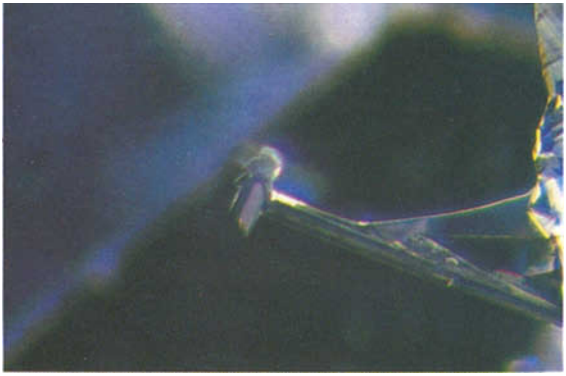

FIG. 6. Strange combination of prismatic platinum crystals with flux residue. 40 ×

FIG. 7. Coarse formation of flux inclusion. 40 ×

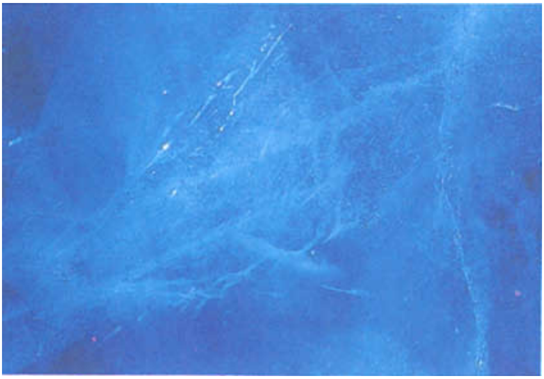

FIG. 8. Nebulous cloud formed by very fine wisps of flux inclusions. 20 ×
(Photo by J. Koivula, G.I.A.)

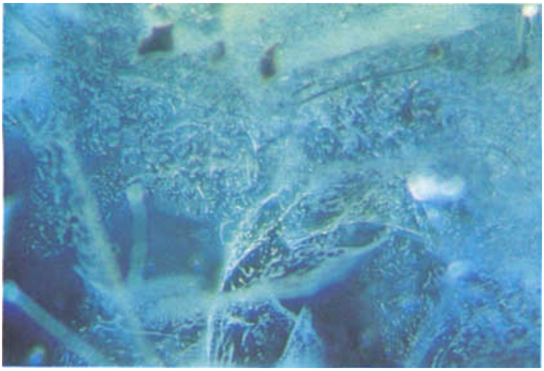

FIG. 9. Dense accumulation of 'feathers' representing various kinds of patterns as are often observed in synthetic sapphires by Chatham. 25 ×

synthetic Kashan-rubies, and do not appear white like those, but dirty grey, yellow, and brownish. Their shapes and sizes vary from small circular shapes through torn scraps to indescribably irregular forms (Figures 6 & 7).

The more subtle flux-inclusions form the well-known 'fingerprints' (healing fractures) of many varieties which are so easily confused with those in natural sapphires and will certainly be mistaken for such by many gemmologists who are unacquainted with this new phenomenon in synthetics. In those Chatham sapphires which contain numerous inclusions, these create an impression of wildly interwoven veils similar to the unmistakable inclusion-scenes—under low magnification—of the early synthetic emeralds (Figure 8), as well as of inclusion-rich synthetic Chatham and Kashan rubies. Under stronger magnification they disclose themselves as fantastically lacy, net-, mesh- or fingerprint-like, spotted, veined, striped or otherwise patterned banners, veils or cloudy smoke-like formations, having sometimes the detrimental effect of dulling the interior of the host stone (Figures 9-20). It is extremely difficult, if not in some cases almost impossible, to distinguish these inclusions from the natural ones, and since even the most elaborate descriptions could never do justice to the full quantity of their forms and patterns, an appropriately large number of microphotographs portray these in detail.

The black splinters and platelets which glint in reflected light like silver (Figures 21, 22; 24-27) occur either in close masses, scattered groups or singly, and some observers might consider them as a definite means of identification. Yet those who have examined Australian sapphires with ilmenite inclusions and sapphires from other sources housing hexagonal haematite flakes, will at least consider them as an unreliable criterion (Figure 23). However, a means of identification of the platinum inclusions in synthetics does exist in the silvery reflection of these (Figures 24 & 27), while haematite and ilmenite remain black under all conditions. Gemmologists are already familiar with the occurrence of platinum flakes in certain synthetic emeralds, synthetic alexandrites and synthetic Chatham and Knischka rubies. An x-ray analysis with the Gandolfi camera identified these splinters and platelets without doubt as platinum, thus indicating that platinum crucibles are being used in combination with this process of synthesis.

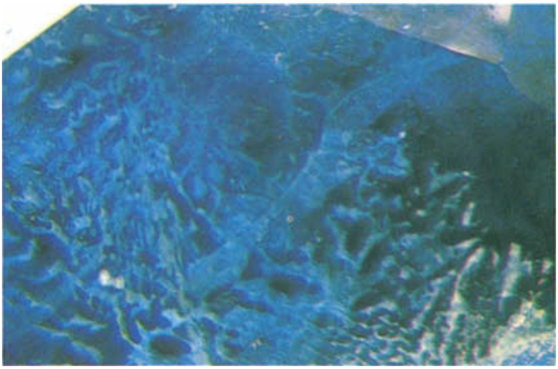

FIG. 10. Lace-like pattern of an extended plane of residual flux. 20 ×

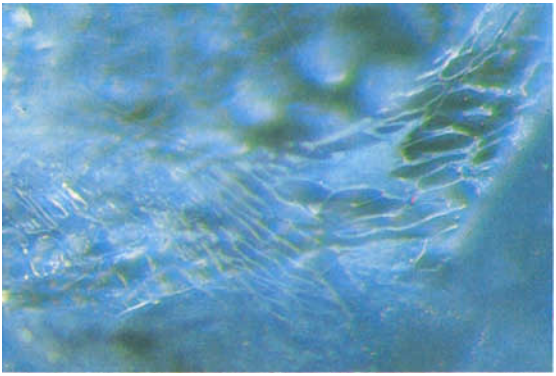

FIG. 11. Net-like distribution of film-like flux inclusions. 20 ×

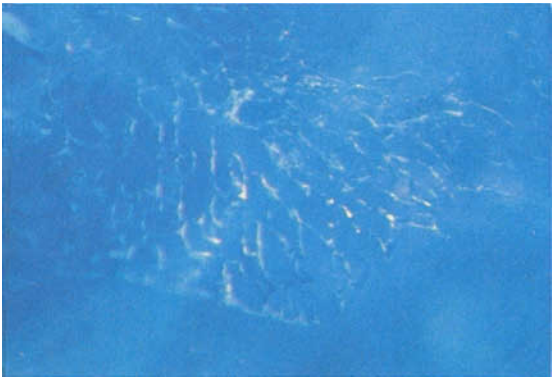

FIG. 12. Mesh-like arrangement of small discrete flux inclusions of bizarre shapes. 80 × (*Photo by J. Koivula, G.I.A.*)

FIG. 13. A loosely designed 'fingerprint' inclusion superposed by a 'feather' of dense lace-like flux-remnants. 20 ×

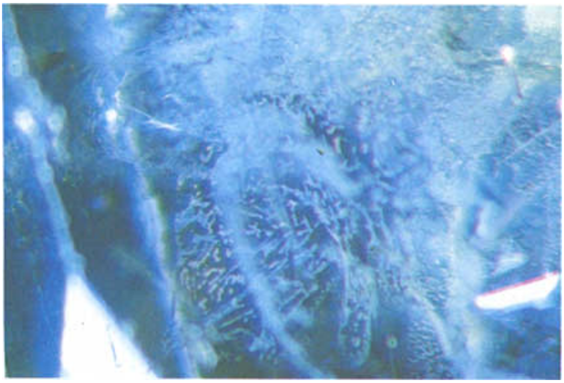

FIG. 14. Dense concentration of residual flux inclusions with shred-like forms. 25 ×

FIG. 15. 'Fingerprint' inclusion of white flux, highly confusing with similar inclusions in natural sapphire. 25 ×

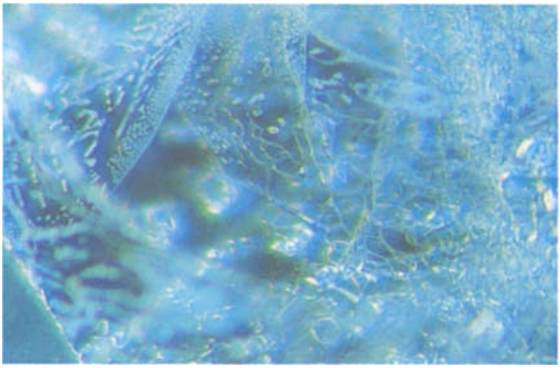

FIG. 16. Intertwined 'feathers', 'nets', and 'fingerprints' of white flux inclusions. 25×

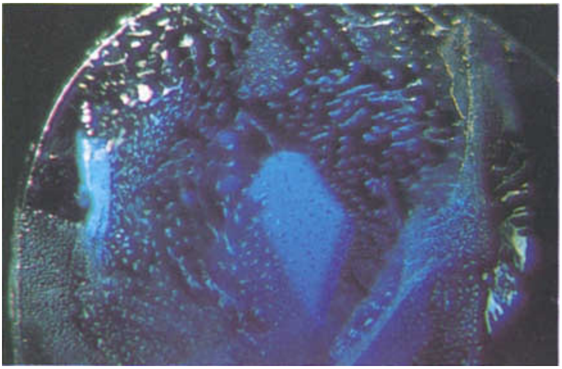

FIG. 17. Various irregular shapes of individual flux remnants massed to form a large flat inclusion. 20×

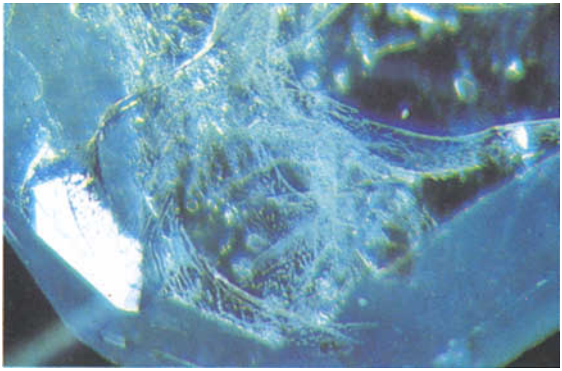

FIG. 18. Combination of various hammock-shaped flux inclusions, the appearance of which is quite typical for synthetic sapphires by Chatham. 16×

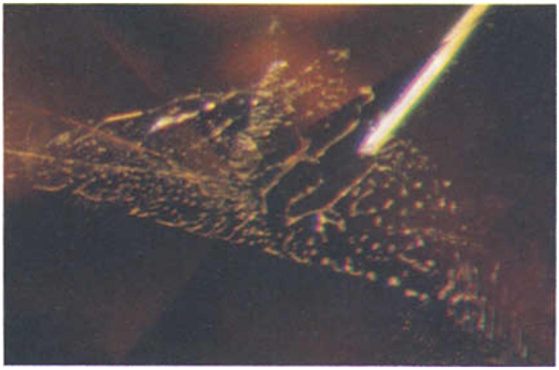

FIG. 19. Illusive 'fingerprint' inclusion of residual flux in a flux-grown synthetic orange sapphire (padparadschah) by Chatham, simulating 'fingerprint' inclusions in natural padparadschahs. White streak is a reflecting platinum needle. 40 ×

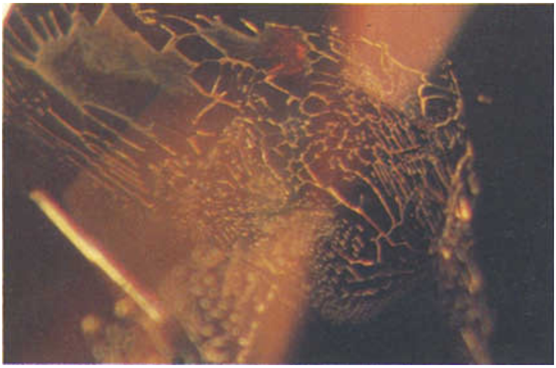

FIG. 20. Net-like pattern of stretched flux inclusions in a synthetic orange sapphire (padparadschah) by Chatham (easily mistaken for a partially healed fracture in a genuine padparadschah). White streak is a reflecting platinum needle. 32 ×

Inclusions depicted in Figs. 3, 5 and 7-20 may also be observed in natural sapphires, and are therefore highly misleading.

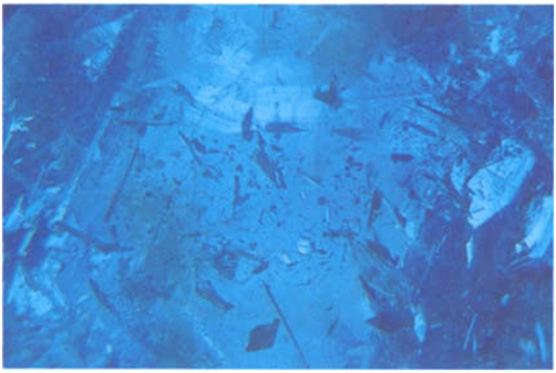

FIG. 21. Flux-grown sapphire by Chatham teeming with platinum inclusions of various shapes (hexagonal, triangular and rectangular platelets, rods, spikes, splinters, etc.) 8 ×

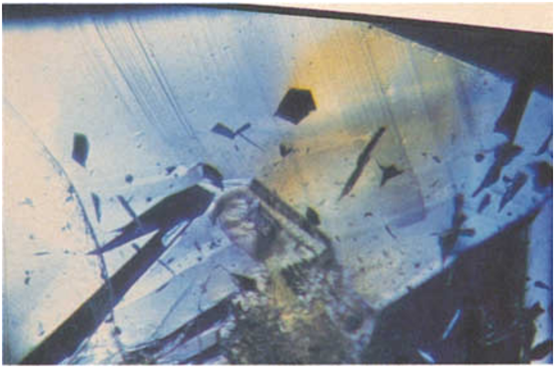

FIG. 22. Hexagonal and wedge-shaped platinum inclusions marking a flux-grown Chatham sapphire. 26×

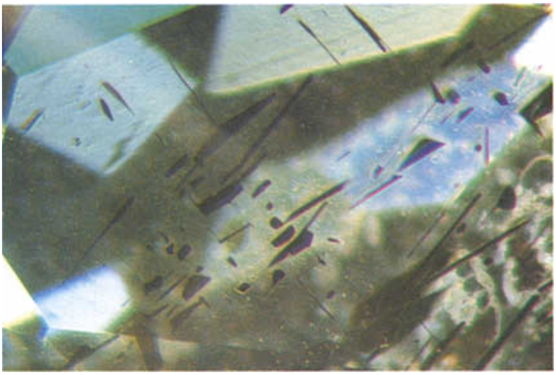

FIG. 23. For comparison: black ilmenite inclusions in a green-blue sapphire from Australia. 35×

FIG. 24. Large misleading 'fingerprint' inclusion superimposed by two tabular platinum crystals reflecting the impinging light with a silvery lustre. 26×

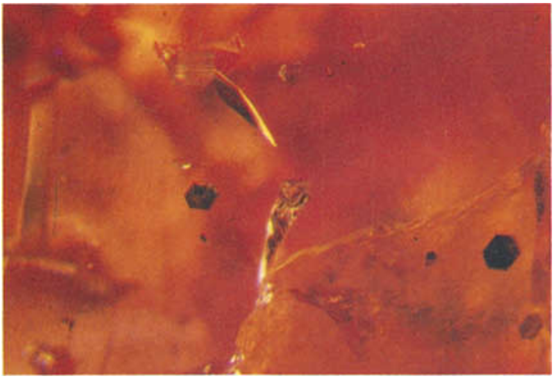

FIG. 25. Hexagonal platinum platelets and coarse flux inclusions in a synthetic orange sapphire (padparadschah) by Chatham. 22×

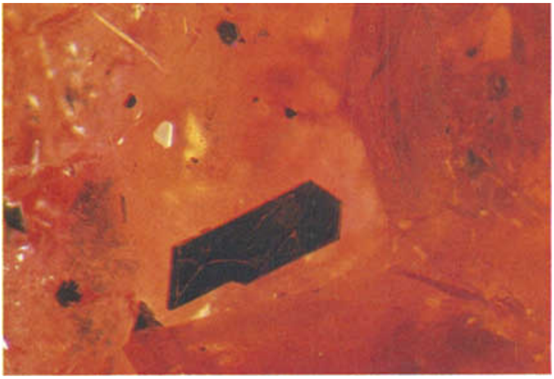

FIG. 26. Concentration of platinum platelets of various shapes within a small area betray the synthetic origin of the host padparadscah. 17×

FIG. 27. Hexagonal platinum platelet reflecting the impinging light with a metallic silvery lustre. 25×

SYNTHETIC ORANGE SAPPHIRES

Quite recently, after having reached satisfactory results with their blue synthetic sapphire, Messrs C. and Th. Chatham succeeded in realizing a more ambitious project by producing orange synthetic sapphire, yet simultaneously involving the gem trade and gemmologists in even more intriguing problems and dilemmas.

The colour range of these latest synthetic sapphires encompasses all the hues from brownish orange via pure orange to orange-red, excelling in the finest pinkish orange of the lotus flower called padparadschah, which is extremely difficult to discern from the natural counterpart—at least by the inexperienced. Brown and orange sapphires have been manufactured for decades by the Verneuil process, yet their colours were definitely less attractive, and they could be identified by their inclusions—gas bubbles and curved growth lines (in immersion)—and the absolutely pure ones by means of electron spin resonance (Figures 28 & 29). In congruity with the blue synthetic sapphires by Chatham, the physical properties of these orange synthetic corundums hardly differ from those of the natural gems, i.e. the *refractive indices* vary within the same limits (n_D = 1.60-1.70); the *birefringence* ($n_\Delta = -0.008$) and the *density* ($d = 4.00$ g/cm^3) are conspicuously constant; even the *dichroism* (pink for ε and brownish yellow for ω) and (to a certain extent only) the *luminescence* concur with those manifested by natural orange sapphires.

The latter characteristic, however, deserves some more detailed discussion, because a careful observer may perceive some slight differences. While in long-wave ultraviolet light the fluorescence is intense and of pure orange colour, in short-wave radiation the intensity of the dark orange hue is dimmed and some synthetic stones display a greenish cast; the synthetics tend to be rather patchy, whereas the fluorescence of the natural gems is quite homogeneous.

The *spectroscopic examination* discloses several interesting peculiarities, which, if permanent through many more future tests, might serve as a means of identification. In general the details of the absorption spectrum closely resemble those of ruby. The tell-tale absorption doublet at 692.8 and 694.2 nm in the red section converts into a bright emission line centred at 693.5 nm under oblique illumination. The absorption in the green at 550 nm and the

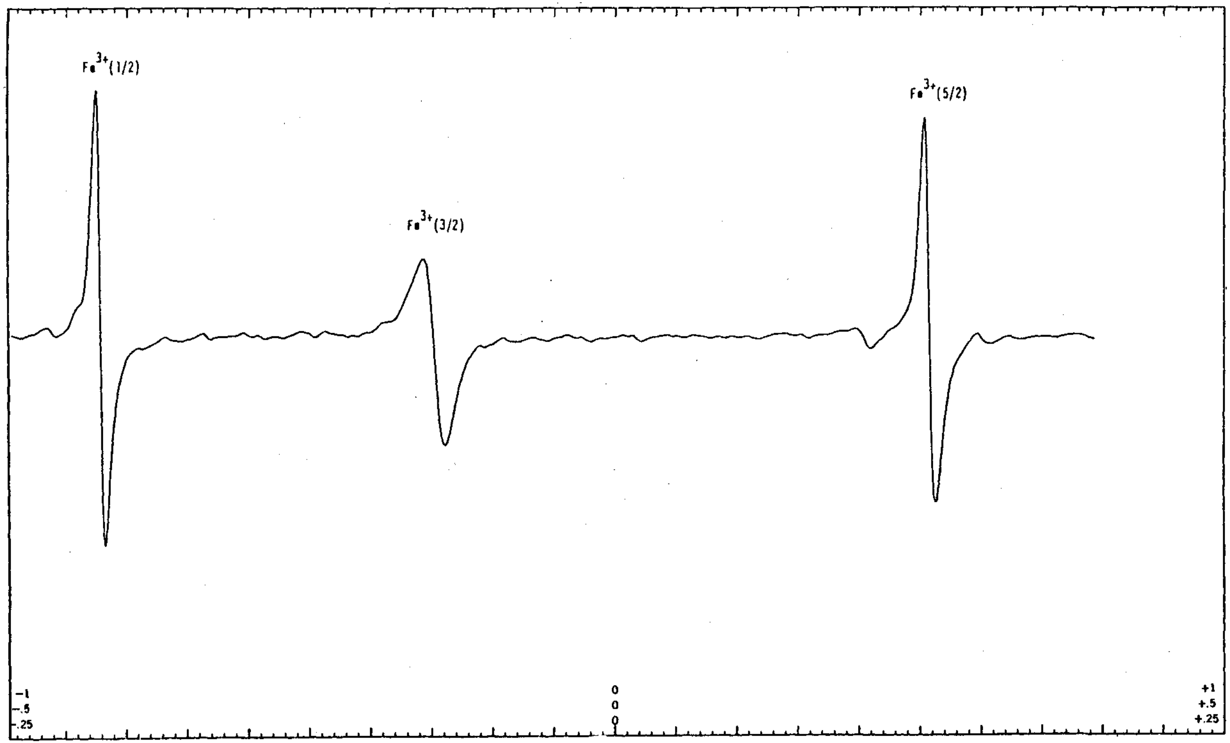

FIG. 28. Electron spin resonance spectrum of a natural golden brown sapphire from Bang Kah Cha (Thailand) || *c*-axis, recorded at a modulation frequency of 100 kHz and a microwave frequency of 9.48 GHz with a medium signal for Cr^{3+} and strong signals for Fe^{3+} (*recorded by Dr L. O. Andersson, Zug*).

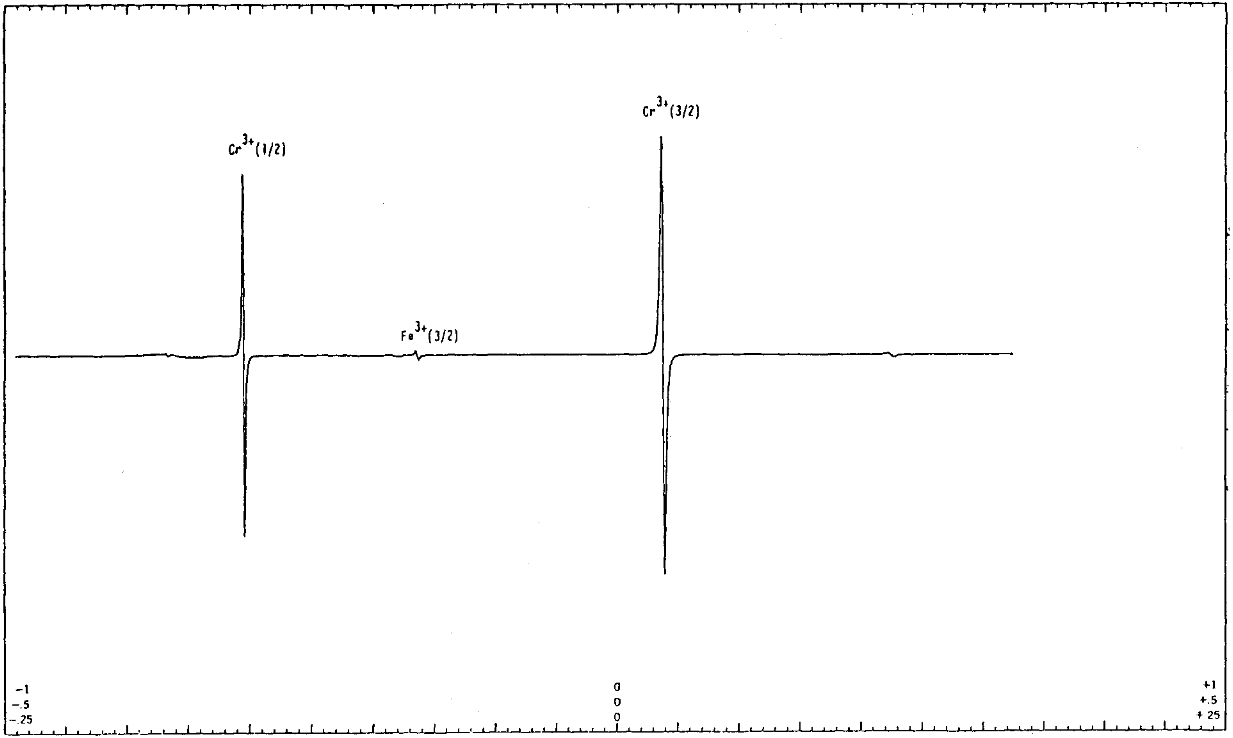

FIG. 29. Electron spin resonance spectrum of a synthetic brown yellow sapphire (Verneuil) c-axis, recorded at the same frequencies as Figure 28, gives very strong signals for Cr^{3+} and an extremely weak signal for Fe^{3+} (*recorded by Dr L. O. Andersson, Zug*).

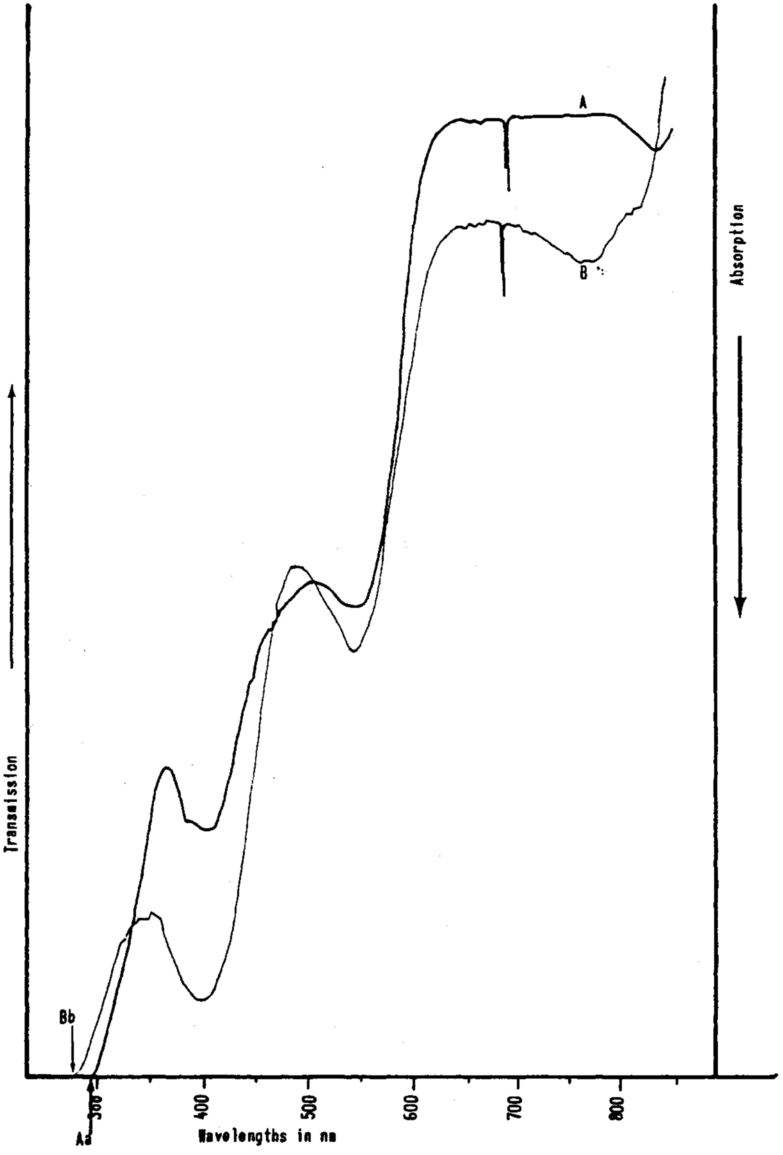

FIG. 30. Absorption curves of a natural padparadschah (bold curve A) and of a synthetic orange sapphire (Chatham) (fine line B). The former reaches complete absorption at 295 nm, the latter at about 270 nm (*recorded by C. A. Schiffmann, Lucerne*).

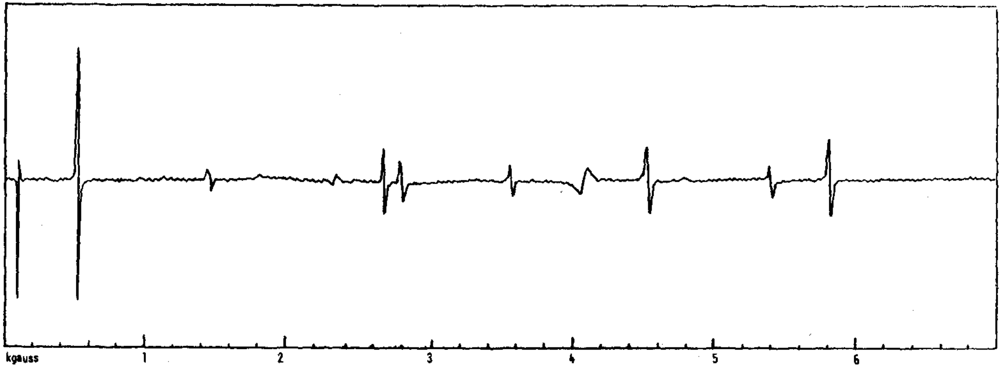

FIG. 31. Electron spin resonance spectrum of a natural padparadschah from Sri Lanka c-axis, recorded at a modulation amplitude of 10.0 G and a microwave frequency of 9.40 GHz depicting a medium number and medium intensity of signals within the magnetic field H[hOe] between 2.5 and 7 kgauss (*recorded by Dr D. Barberis, Zürich*).

FIG. 32. Electron spin resonance spectrum of a synthetic orange sapphire (Chatham c-axis, recorded at a modulation amplitude of 6.3 G and a microwave frequency of 9.506 GHz manifesting a medium number of very strong signals within the magnetic field H[hOe] from 2 to 7 kgauss (*recorded by Dr D. Barberis, Zürich*).

transmission in the blue-green region at 500 nm are somewhat more pronounced in the orange synthetic sapphire. Beyond a second gap of transmission at 368 nm for the natural and at 350 nm for the synthetic padparadschah, the absorption increases rapidly towards shorter wavelengths and reaches a *maximum at about 300 nm for the natural gem* and *at about 270 nm for the synthetic* (Figure 30). With regard to the trace elements, the comparison of the absorption features of a natural and a synthetic padparadschah of precisely the same hue reveals that both contain about the same percentage of chromium, while the synthetic stone has very little or no iron.

The inclusions in the new synthetic padparadschahs are very similar to and equally as confusing as those in Chatham's blue synthetic sapphires. They also consist of unmolten flux-remnants of almost indescribably varying patterns. They are either extremely fine—like wispy clouds or gossamer veils—or they present formations with lace-, mesh-, net-like and other fantastic intertwined patterns (comparable to Figures 19 & 20), which are almost impossible to distinguish from similarly shaped and designed healing fractures in natural padparadschahs. Sometimes, but rather rarely, the very coarse flux inclusions may be observed—like those in blue synthetic sapphires by Chatham as depicted in Figures 6 & 7. The other kind of inmate of synthetic orange sapphires is represented by platinum platelets of various shapes—hexagonal, triangular, rectangular, spiky and other more or less geometrical forms (Figures 25 & 26). Black inclusions of some ore such as haematite, pyrrhotite and ilmenite might occasionally, yet rarely, occur in genuine orange sapphire, but they would not reflect with the same silvery, highly metallic lustre as the platinum platelets (Figure 27). If orange sapphire happens to house an accumulation of various forms of black platelets throughout the entire body, or even within a relatively small area, it is a strong indication of the host stone's synthetic nature.

Not completely satisfied with the relatively small number of distinguishing features and reliable tests, the author pondered on other methods of distinction between natural and synthetic orange sapphires. Encouraged by the comparatively good results of the electron spin resonance employed 4 years ago (see Figures 28 & 29) to discriminate synthetic brown yellow sapphire from its genuine

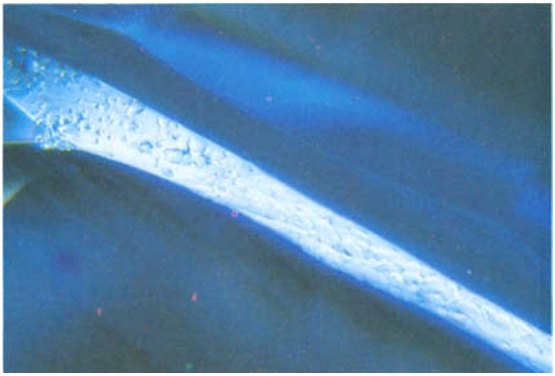

FIG. 33. Scabs on the surface of the reflecting half of a 'double girdle', indicating that this sapphire was heat treated. 25 ×

FIG. 34. Pockmarked upper half of a 'double' girdle on a heat treated sapphire. 40 ×

FIG. 35. Tell-tale inclusion scene consisting of several 'cooked' mineral inclusions surrounded by circular lace-fringed fractures. 32 ×

FIG. 36. Characteristic appearance of the interior of heat-treated sapphires: turbid zones encompassing white, dusty particles and typically atoll-like inclusions (the one near the upper right-hand corner shows high reflection). 25 ×

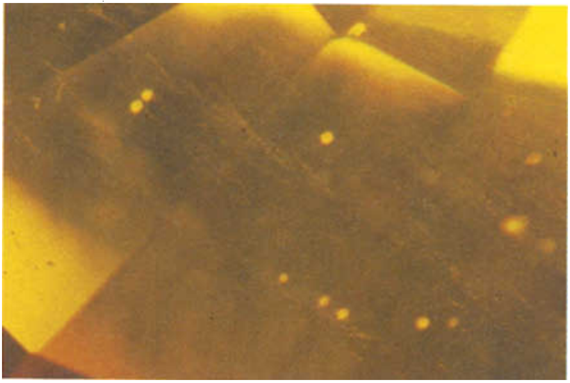

FIG. 37. Typically fringed perimeter of an inclusion modified by heat treatment. 64 ×

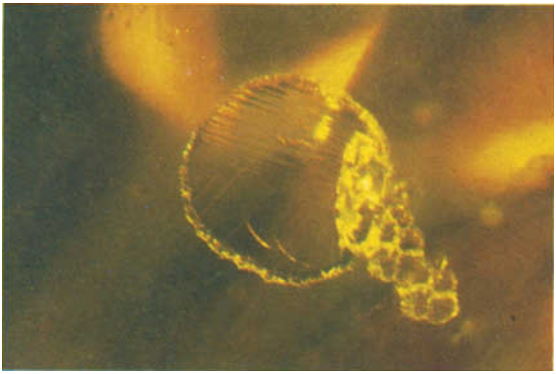

FIG. 38. Unusual cluster of molten mineral inclusions in contact with a circular tension fracture in front of zonal turbidity in a heat treated yellow sapphire. 40 ×

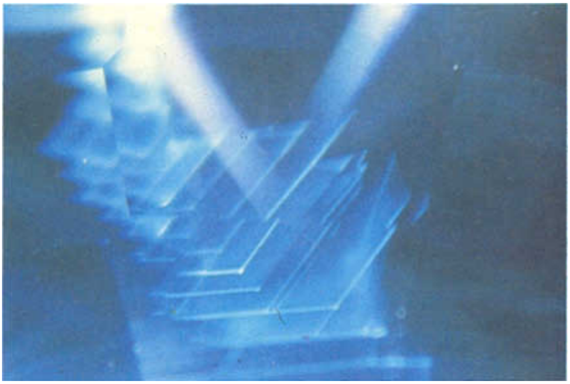

FIG. 39. Strongly emphasized textural pattern indicating thermal improvement of colour. 32×

FIG. 40. Phantom-like cloud enhanced by thermal heat treatment. 32×

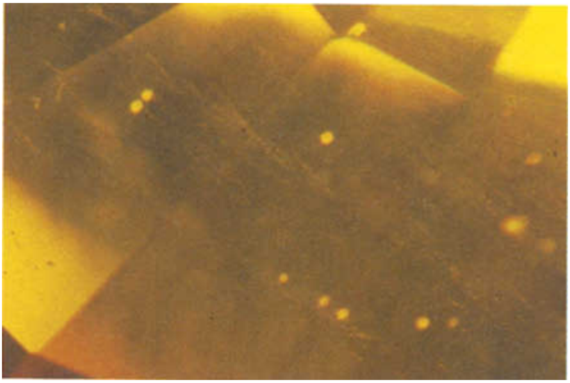

FIG. 41. Unambiguous appearance of the interior of a heat treated yellow sapphire: rounded 'cooked' mineral inclusions amidst striped 'fog' causing turbidity. 25×

FIG. 42. Molten mineral inclusions and dense cloud of some whitish exsolved matter of yet unknown nature. 25×

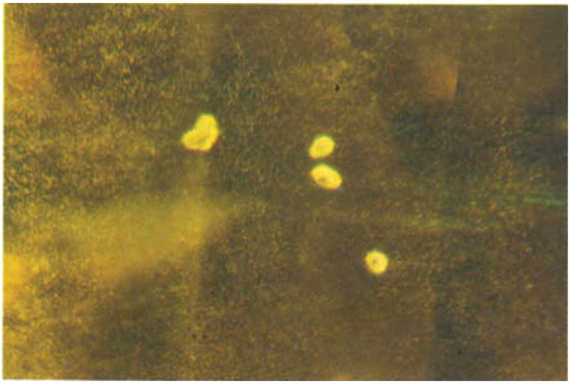

FIG. 43. Typically rounded molten mineral inclusions and fog-like turbidity characteristically associated with heat-induced colour alteration. 32×

FIG. 44. Fracture, open at the surface of a diffusion treated sapphire, dyed deep-blue by penetration of the dye. 16×

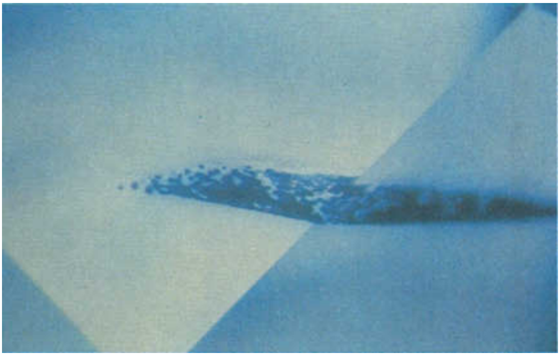

FIG. 45. Slender fissure touching the surface of a diffusion coloured sapphire. The dye entered the fissure by diffusion and double-dyed it by coating its walls. 30 × *(Photo by C. A. Schiffmann, Gem Laboratory Gübelin)*

FIG. 46. Enhanced coloration of an inclusion cut flush with the surface of a sapphire diffusion treated for colour alteration. 50 × *(Photo by C. A. Schiffmann, Gem Laboratory Gübelin)*

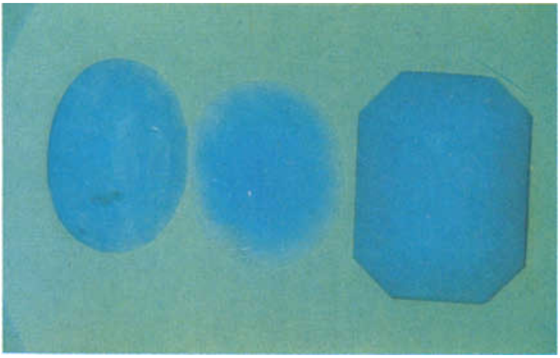

FIG. 47. Oval-cut gem in the centre is a Burma sapphire of natural colour, revealing neither facet edges nor girdle, flanked by two sapphires whose surface had been coated by the diffusion method to improve coloration. Note emphasis of blue colour along the facet junctions and the girdle of the two treated sapphires (immersed in methylene iodide). 7 ×

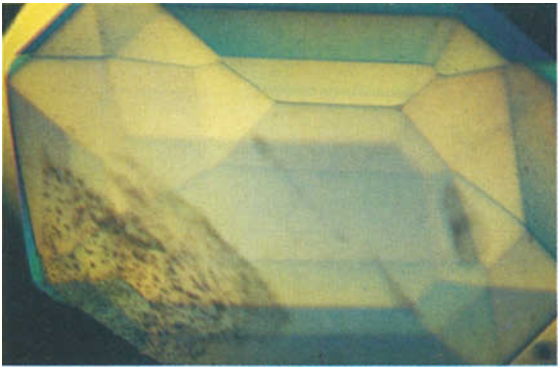

FIG. 48. Diffusion treated sapphire immersed in methylene iodide showing strong blue relief of facet edges and girdle. 16 ×

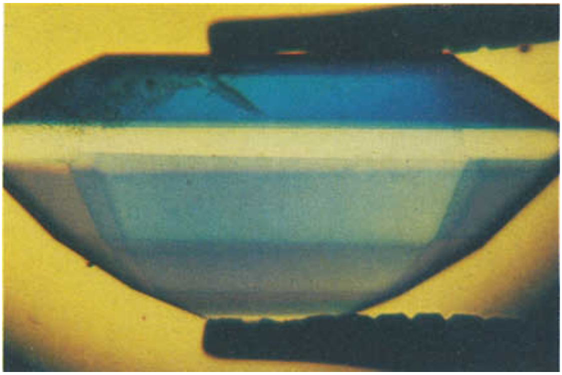

FIG. 49. Diffusion treated sapphire displaying irregular coloration and colour concentration on facet junctions and contour. The girdle has been repolished too much, so that it has become too broad and lost its diffused colour skin: hence it appears colourless. 16 ×

counterpart, he sought the co-operation of Prof. Dr F. Walder, of the Institute of Physics at the University of Zürich, who is a specialist in this field of investigation. His assistant, Dr D. Barberis kindly made several records of natural padparadschahs and synthetic orange sapphires, of which two representative spectra are portrayed in Figures 31 and 32. The visual difference of the signals in the magnetic field H [hO_e] between 2 and 7 kgauss* is quite

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* 10 kgauss ≈ 1 tesla.—Ed.

obvious. The accurate interpretation of the individual signals and their precise significance (whether they are quanta transitions or indicate various trace elements) call for many more experiments on many more samples. This task will be carried out in the near future. Nevertheless, for the time being it appears quite comforting to know that there are further methods—though rather elaborate and complicated ones—of separating synthetic orange sapphires from genuine padparadschahs. Even if they are rather limited with regard to their application (because only small specimens <10 ct may be examined) and may not easily be employed by the ordinary gemmologist, they definitely help to increase the number of testing methods and thus develop the degree of reliability.

In summarizing, it may be suggested that only the intense green fluorescence in long-wave ultraviolet light—if present—in blue sapphire, and total absorption below 270 nm of orange sapphire (padparadschah) as well as the tell-tale platinum platelets in their interior, may be considered as a warning indication of synthetic origin. However, should platinum platelets be absent in certain samples of the present and future synthetic Chatham sapphires, every feature—i.e. the macroscopic appearance, all the physical properties and the microscopic characteristics—will have to be checked very precisely and carefully compared to each other before formulating a definite verdict. Probably it would be wiser and more prudent to have the stone in question tested thoroughly by a gemmological laboratory in order to obtain a reliable opinion, particularly if the co-operation of a university is needed.

NATURAL SAPPHIRES TREATED FOR COLOUR ALTERATION

Quite apart from the difficulties of distinguishing natural from synthetic specimens, the artificially coloured natural sapphires which have been invading the market in quantities for some time now also present many additional problems, as they have caused a feeling of insecurity and confusion in our branch of the trade. It is therefore perhaps not out of place to add a full description of the distinguishing characteristics of artificially coloured blue, yellow, golden and brown sapphires to this paper, without going into the details of the methods of coloration (thermal colour-improvement and diffusion-coating) which have been fully described several times already (see bibliography). However, it is worth mentioning that in both processes high temperatures between 1200 °C and 1700 °C and more are applied. The resulting colour-change has no great influence on the diagnostically important physical properties of the sapphire in question—such as refraction, birefringence, dichroism, absorption of light and density—since these remain unchanged. However, some blue sapphires subjected to heat-treatment for colour improvement display a soft but distinct blue fluorescence under long-wave ultraviolet light. Further changes are in the appearance to the naked eye, i.e. colour and surface marks, and especially the internal scene visible under the microscope. On the polished facets, and especially on the girdles (often doubled) of these treated sapphires, tiny scabs form through the influence of great heat and these are frequently left untouched by the lapidaries (Figures 33 & 34).

It is only possible to carry out the thermal colour-change if a supersaturated solid solution of the colouring agents is present in the sapphire. This condition often occurs in combination with the existence of solid inclusions, e.g. calcite, feldspar (albite, orthoclase, plagioclase), mica (biotite, muscovite, phlogopite), niobite, pyrite, pyrrhotite, uraniumpyrochlore and others, which melt at high temperatures and at the same time, because of greater expansion, stress the body of the host crystal, i.e. develop an inner tension that releases itself by forming a fracture. The molten mineral inclusions have lost their crystal forms, have turned white, and merely display rounded melt-shapes. The tension haloes create an unmistakable picture, which in many ways is reminiscent of the 'lily-pads'' in peridots from San Carlos (Arizona). They are almost circular and have a smooth, conchoidal surface from which the incident light is strongly reflected (Figures 35-38). They iridesce with lively interference colours when light impinges vertically. On their inner surface they seldom bear any marks, but the rims on the other hand are characteristically fringed with lace-like patterns. If a comparison is permitted: in the blue treated sapphires, they might best be likened to circular coral reefs (atolls) washed by white breakers in the blue ocean, as seen from an aircraft (Figure 37). If the coefficient of thermal expansion of the guest minerals is less than that of the host corundum, the former simply melt and assume rounded melt-shapes, but do not produce a circular fracture (Figures 41-43).

Any dark or light coloured zones, cloudy structures or other ghost-like internal features which were already in existence before treatment, are emphasized and appear as defined foggy layers, patches or phantoms with sharp contours (Figures 39 & 40). As a result of exsolution, occurring during cooling, some minor solid solution of still unknown nature (perhaps boehmite, diaspore or gibbsite) is deposited as ultra-tiny grains in treated yellow, golden and brown sapphires, forming stripes and clouds, which themselves cause a more or less distinct turbidity (Figures 41-43). Whether partially healed fractures (feathers, fingerprints, wings and veils) are produced or altered during the annealing process is difficult to assert, if the treated gem was not examined before treatment.

For coloration by the diffusion method, clear sapphires, usually without inclusions and poor in TiO_2 are generally preferred, as they are unsuitable for colour improvement by the thermal method since they lack the necessary trace elements which become colour-active through annealing. Since the diffusion method also requires high temperatures, existing mineral inclusions are altered in exactly the same way as in the sapphires treated by the thermal process, and thus they can be recognized as being artificially coloured (Figures 33-43). Another characteristic which betrays the coloration by diffusion is the intense coloration of fissures which penetrate the interior of the sapphire from the outer surface, because the colouring matter diffused into these fissures during the treatment (Figures 44 & 45). Inclusions which extend as far as the surface of the host gem are also coloured an intense blue for the same reason (Figure 46).

Whereas both cut gemstones and rough crystals are suitable for thermal treatment, only cut stones can be used for the diffusion coloration. The facets become rough and matt during this process, and have to be repolished. Since this work is seldom accomplished with the necessary care, the relatively thin film of diffusion coloration not only becomes thinner, but is polished off unevenly so that an irregular coloration results—paler facets with uneven colour intensity and stronger-coloured edges—which fact can be considered as a reliable means of recognition (Figure 48).

These characteristics can be seen best if the stone is immersed in a highly refractive liquid such as monobromonaphthalene or, even better, methylene-iodide. In order to do this, the stone should be laid in a glass cuvette (circular glass dish with a flat bottom) and covered with highly-refractive liquid. Then the cuvette should be held over a diffused light-source such as a fluorescent tube or the daylight lamp of the 'Gemolite' tipped forward, and then viewed under low magnification such as a pocket lens or a reading glass. In the case of a naturally-coloured sapphire, all the facet edges, including the girdle, disappear, and only a blurred blue shimmer remains (Figure 47). Diffusion-coloured sapphires on the other hand, display a patchy coloration, and all the facet edges including the girdle appear sharply defined, just as if the sapphire had been designed with a blue pen on the bottom of the glass cuvette (Figure 48). In case of uncertainty it is advantageous to hold the sapphire girdle-up with a pair of tweezers, so that the table facet is vertically aligned to the eye, in order to view the girdle, which on the diffusion-coloured sapphires appears very sharply contoured (Figure 49).

May the above descriptions, together with the very eloquent illustrations, help the reader to distinguish natural and naturally coloured sapphires from synthetic and from artificially coloured sapphires.

ACKNOWLEDGEMENTS

The author wishes to extend his gratitude to Messrs C. and Th. Chatham for supplying him with samples of synthetic blue and orange sapphire, to Dr L. O. Andersson, Varian AG., Zug, Prof. Dr Waldner, University of Zürich, and Mr C. A. Schiffmann, Gemmological Laboratory of Gübelin, Lucerne, for their co-operation in recording Figures 28 to 32.

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FURTHER INVESTIGATIONS ON OPAL IMITATION MADE OF PLASTIC

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INTRODUCTION

Since the conclusion of the report in 1964 of the Commonwealth Scientific and Industrial Research Organization (CSIRO) on the cause of 'play of colour' in gem opal, the interest in producing opal-like substances attracted many a scientist. Pierre Gilson of France achieved the honour of being the first manufacturer of gem quality synthetic opal (Nassau, 1980). Even though John L. Slocum, of U.S.A., intended producing a synthetic gem opal, the result was an effective opal simulant referred to in the trade by the term 'Slocum stone' (Dunn, 1976; Farn, 1979).

Recently Dr Akira Kose, of the Japanese Institute for Applied Optics (JIAO), and Dr Sei Hachisu, of Kyoiku University in Tokyo, proved that by using spheres of plastic suspended in another mass of plastic, the effect of play of colour can be produced. The successful growth of such an opal-like imitation was initially reported in this *Journal* (O'Donoghue, 1980) and elsewhere (Horiuchi, 1978; Pough, 1982). Further investigations done by the author on these opal-like plastic imitations are detailed below.

PRODUCTION METHOD

Details given by Dr Kose and Dr Hachisu in their paper (in 1976) are insufficient for a commercial production in large quantities. However, the process described in the present paper is sufficient for the purposes of the discussion. The prime requirement, polystyrene spheres of 150 to 300 nm in diameter, are produced by introducing sodium polyacrylate into a polystyrene latex. At a polymerization degree* of 400 000 the polystyrene forms as hexagonal crystallites, which act like the silica crystallites (α-cristobalite) of gem opal. Suspended in water these plastic spheres have revealed a milkiness without play of colours.

The play of colour effect can be achieved by arranging the spheres in a regular order. This regularity will create the conditions

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*Polymerization degree = the number of basic molecules forming the larger molecule of the substance.

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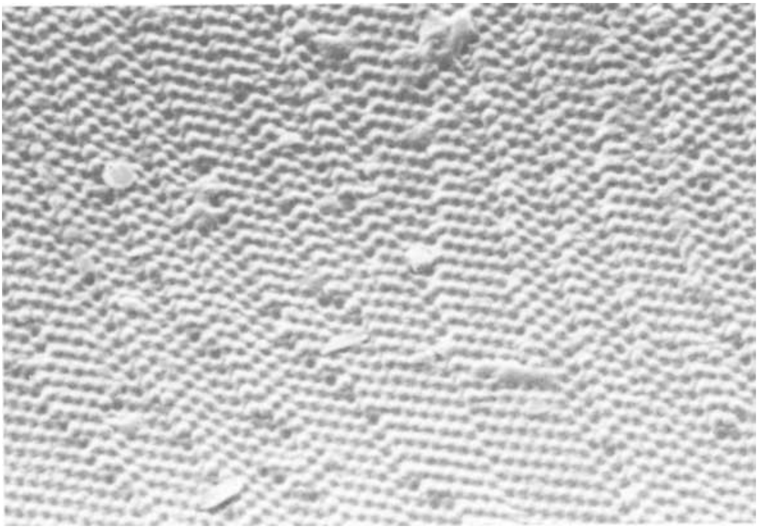

FIG. 1. Scanning electron microscope view of the cross-section examination of plastic opal imitation made in Japan. *(Photo: H.-G. Röpert, TÜV Rheinland)*

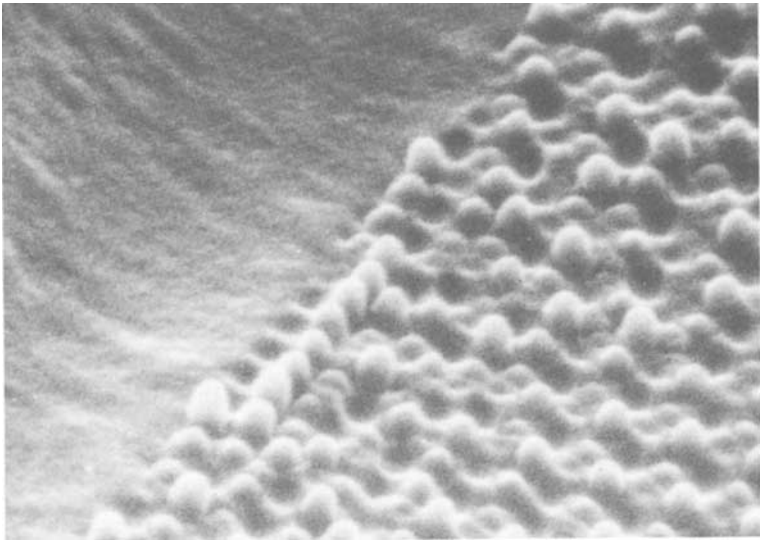

FIG. 2. Demarcation line of the polystyrene latex and the methacrylate coating. *(Photo: H.-G. Röpert, TÜV Rheinland)*

The play of colour effect can be achieved by arranging the spheres in a regular order. This regularity will create the conditions for the 'Bragg reflection' effect to occur. Rapid arrangement of the plastic particles can lead to lattice defects and dislocations which in turn would disturb the play of colour effect. These defects can be controlled by allowing the sedimentation at successive time intervals. This settling is similar to the natural α-cristobalite arrangement process occurring in nature. Reported speed of sedimentation under such conditions is about 3.5 mm per month and the optimum length of time required in forming quality material is about 3 to 6 months. Any disturbances caused during the sedimentation would disperse the spheres and a new start in such case is necessary.

Even though the actual transformation of the flocculated, monodisperse latex into opal-like plastic masses is kept as a secret, the interstices resulting after the evaporation of the liquid matter is filled by polymerization of polymethyl methacrylate which has a quite different refractive index from that of the latex. This forms as a coating to the sphered layer to strengthen the finished product.

As reported by the co-workers of CSIRO the varying sizes of cristobalite spheres in natural gem opals produce different colours in the visible spectrum. Similarly, varying sizes of plastic spheres, as in Figures 1 and 2, have shown varying colours according to Dr Kose's experiments (1976).

GEMMOLOGICAL CHARACTERISTICS

The stones observed by the author in this determination were divided into two types. One with *'compact colour domains'* and the other with *'scattered colour domains'*.

Visual and microscopic examinations

In *compact type* imitations the visual observations revealed a similar grain structural appearance to that of harlequin type Gilson opal, showing clear-cut boundaries between the colour domains. However, the typical honeycomb or lizard-skin effect of synthetic opal was not present in this *compact type.* Plate-like colour patches were seen somewhat similar to goldstone-type glass imitations. The grain structure of *scattered type* showed no distinct boundaries between the colour domains. The appearance of this type of imitation was very similar to that of natural opal. Therefore further investigations under magnification seemed necessary.

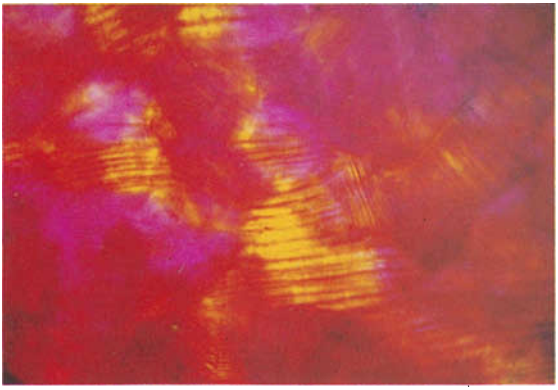

FIG. 3. The *compact colour domain type* showing the 'zebra-skin' pattern under reflected light method. *(Photo: M. Gunawardene. 20×)*

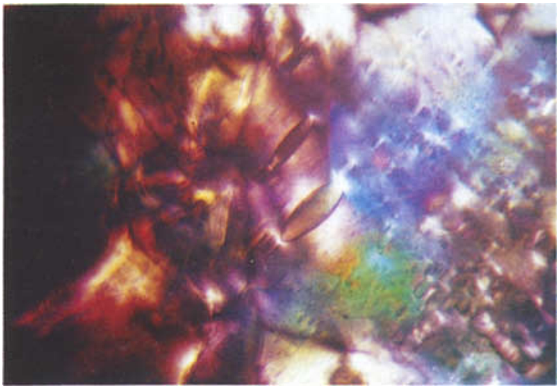

FIG. 4. The *scattered colour domain type,* between the crossed polarizers, showing the strain-knots with longitudinal gas bubbles. *(Photo: M. Gunawardene. 20×)*

FIG. 5. A side-view observation of both types of plastic imitations showing the acrylic resin coating and polystyrene inner structure. (Arrow indicates the division). *(Photo: M. Gunawardene. 20×)*

Careful observations under the gem microscope, using reflected light, without immersion liquids, revealed that the colour domains of the *compact type* displayed a 'zebra-skin' (also similar to an uneven paint brush movement) effect (Figure 3). The *scattered type* imitations displayed no such effect as in Figure 3. Employing crossed polarizers with magnification revealed another interesting feature in the transparent *scattered type.* This feature is very similar to an effect seen in certain synthetic spinels, namely strain-knots. These knots were seen attached to longitudinal gas bubbles as in Figure 4. Side-view examination of both types is shown in Figure 5 with the colourless acrylic coating. Gas bubbles were even seen on the acrylic coating.

Behaviour under transmitted light

Both tungsten and mercury vapour fluorescence lighting conditions were used. The *compact type* plastic imitations transmitted a mixture of red and orange wavelengths corresponding to 620-640 nm. The *scattered type* transmitted shorter wavelengths in the blue at about 430 nm. On comparison with natural and synthetic opals, the *scattered type* showed close resemblance, whilst the *compact type* displayed no such similarity.

Absorption spectrum

In spite of the fact that the main component of the plastic opal-like imitations is colourless polystyrene, an absorption region between 565-590 nm was detected in both types. The cause of this absorption is most probably due to the structure. A spectrophotometric absorption curve diagram recorded by the Leitz Unicam SP 800 is given in Figure 6.

Refractive index and optical polarization.

The recorded refractive index determination was 1.485 (± 0.005). The values obtained were higher than for natural and synthetic opals. These RI values correspond to the acrylic layer. The RI of polystyrene is known to be about 1.53-1.59 (Webster, 1975). This RI difference is clearly shown in Figure 5. Many *compact type* stones showed a doubly refractive aggregate-like reaction due to the close-packing of the polystyrene spheres. Some of them showed anomalous double refraction. The anomaly effect was very prominent with the *scattered type.*

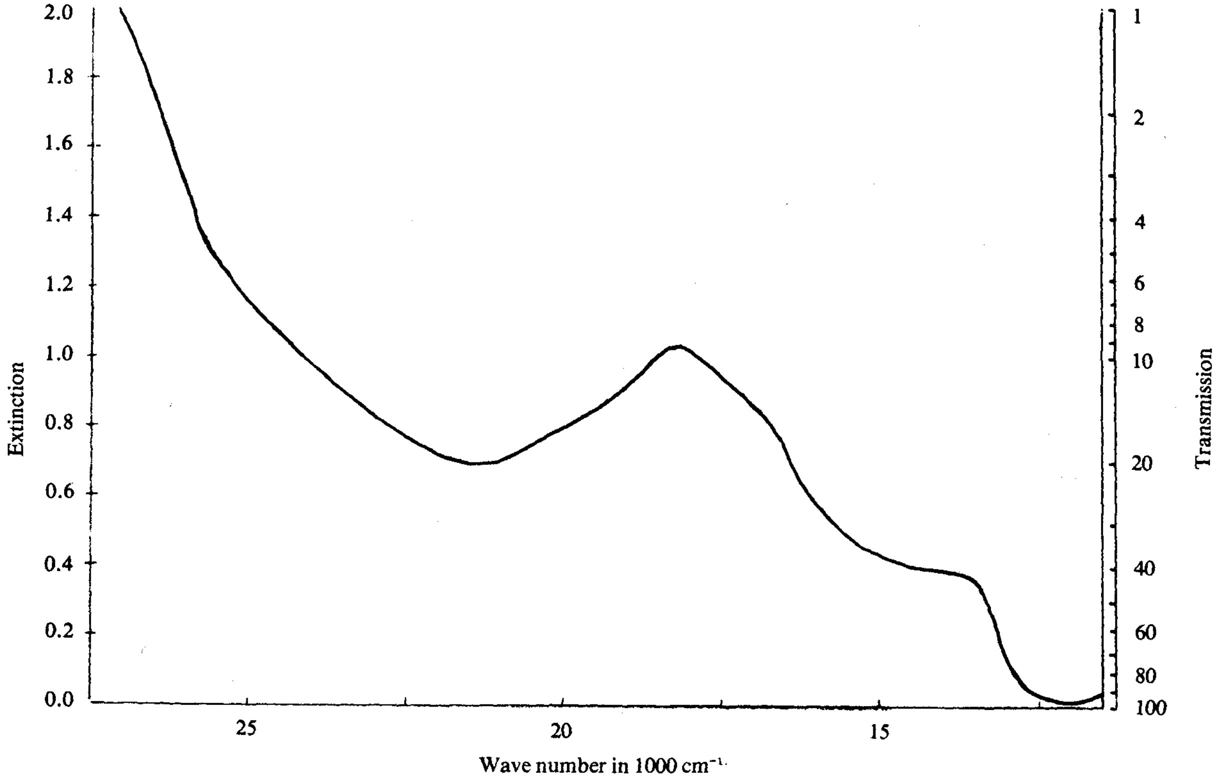

FIG. 6. Recorded transmission absorption curve of plastic opal-like imitation.

Specific gravity

Owing to the high surface tension of water it was difficult to immerse these plastics for accurate work. A few drops of liquid detergent were added to the water in obtaining the density values of 1.19 g/cm^3 (± 0.01).

Reaction under ultraviolet radiations

All the samples were subjected to both long- and short-wave ultraviolet radiations. A strong bluish-white glow was seen under the long-wave (365 nm) radiations and a weaker, but similar, glow under the short-wave ultraviolet (253 nm) radiations. There was no phosphorescence detected in these imitations.

Thermal conductivity and affinity for water

Plastic opal-like imitations are warm to the touch; therefore the thermal conductivity should be much lower than that of natural or synthetic opals. Tests with a thermal conductivity probe indicated no reactions. The exposed methacrylate layer was hydrophobic*, opposed to the hydrophilic† nature of natural and synthetic opals.

CHEMICAL COMPOSITION

The two types of plastic imitations mentioned consist of Styrene-divinyl benzene copolymer and polymethyl methacrylate. The physical and chemical properties may possibly correspond to those of these polymers. Analysis by electron microprobe showed no distinct elements to be present.

DISCUSSION

These plastic imitations are sold under such names as 'Pastoral Opal', 'neo-noble opal', etc. Fire opal has been made by giving an orange colour to the acrylic resin, and doublets are also available.

Although it may be easy for an experienced gemmologist to identify these imitations, possibly they may find their way into jewellery items. The above mentioned properties must be considered in future discriminations. The internal characteristics, refractive index, lack of reaction to thermal conductivity probes, and, lack of affinity for water are of prime importance to consider in distinguishing these 'cheap' imitations.

*hydrophobic - ὕδωϱ, water + φόβος, fear) = having a lack of affinity for water.

† hydrophilic = having a strong affinity for water.

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ON THE IDENTIFICATION OF PEARLS BY X-RAY DIFFRACTION

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PREAMBLE

A convenient way to distinguish between *natural* and *cultured* pearls is to examine them by x-ray radiography. In transmission, cultured pearls often show additional contrast close to their surface, which is due to the different x-ray absorption coefficients of the 'mother-of-pearl'* bead and the deposit of conchiolin. If such an inhomogeneity can be detected on the x-ray radiograph, the pearl is almost certainly cultured. The inverse, however, is not always true, i.e. the *absence* of a detectable inhomogeneity close to the pearl's surface does *not* prove that the pearl is natural. Such a situation may arise, for instance, with pearls of large size, whose correct identification is of particular interest because of their potentially high value. For such pearls, additional methods for testing are required. A safe, although elaborate method is to study their structural symmetry by x-ray diffraction methods, such as the *Laue technique.*

As can be seen in Figure 1, a natural (genuine) pearl is made up essentially of concentric layers of aragonite crystallites with their principal axes oriented radially, while a cultured pearl consists of a few concentric layers of aragonite crystallites arranged with their principal axes oriented radially which surround a mother-of-pearl bead nucleus made by more or less parallel layers of aragonite crystallites with their principal axes oriented perpendicularly to these layers. If these pearls are placed into a narrow beam of polychromatic x-rays, they will show different diffraction diagrams.(2,3) Those of natural pearls show sixfold symmetry, which is due to the fact that the aragonite crystallites growing away from the pearl's centre tend to form cyclic twins having pseudohexagonal symmetry. The over-all aspect of these patterns does not change much if the pearl is rotated about its centre, provided the x-ray beam always passes through its centre.

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*Mother-of-pearl' consists of thin plates of aragonite with conchiolin deposits which are deposited parallel to the surface of the shell.(1)

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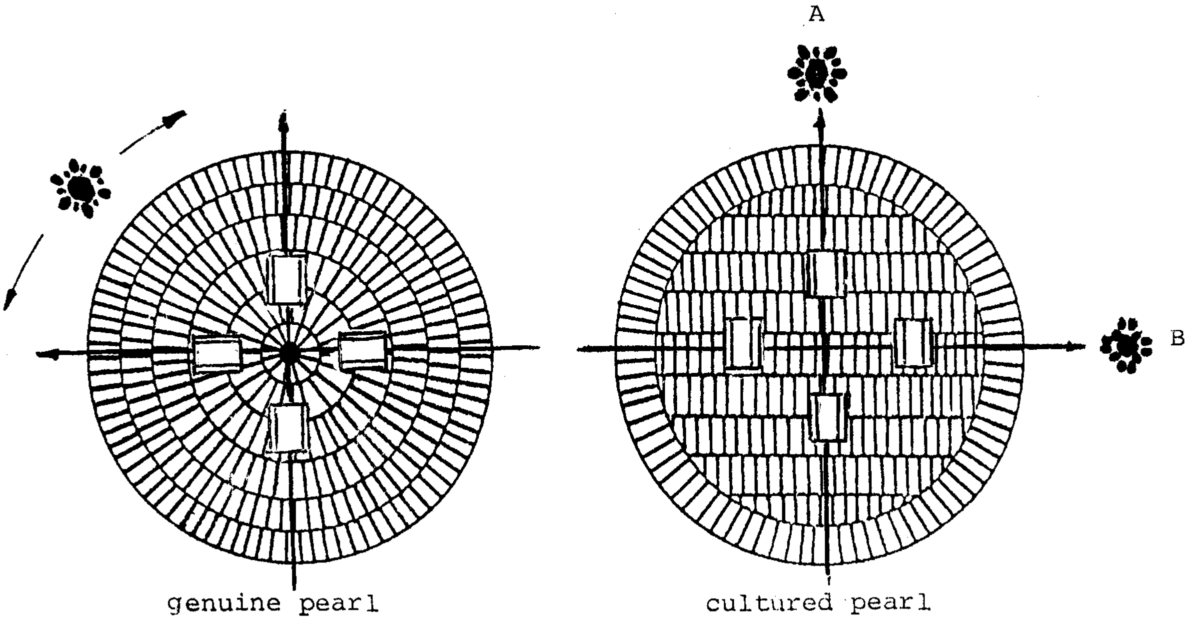

FIG. 1. Diagrammatic arrangement of aragonite crystals in pearls (after Refs 2, 3 & 8) and the symmetry of their x-ray diffraction patterns at different orientations.

The diffraction patterns of cultured pearls* show hexagonal symmetry only with respect to one particular orientation (position A in Figure 1). Usually they show lower than hexagonal symmetry (position B in Figure 1). In contrast to the patterns of natural pearls, their over-all aspect changes markedly if the pearls are rotated about their centre.

X-ray diffraction studies using this technique have so far only been described in handbooks(2, 3) without, however, specifying experimental conditions, nor stating the precautions necessary to avoid errors of identification. As will be shown in this communication the successful application of the Laue technique to natural pearls imposes rather stringent requirements on the experimental set-up such as, for instance, a careful alignment of the pearl's centre of nucleation with respect to the x-ray beam. If the pearls to be examined are of big size and/or irregular shape, their centre of nucleation cannot always be determined by visual inspection. Consequently, in preliminary experiments the x-ray beam may be travelling considerably off-centre, leading to diffraction patterns which can easily be confused with those of cultured pearls.

The pearls studied in this work (Figure 2) were bronze-coloured and pear-shaped, and they were of rather big size (maximum/minimum diameter : approx. 11.0/11.4, 12.0/11.6 mm). They were mounted on ear pendants, and their origin was unknown to the authors. Preliminary tests confirmed that they were pearls. The important point was to determine whether they were genuine or cultured, and whether their colour origin was natural or not.

COLOUR ORIGIN

A simple means of identification would have been to take a cotton swab with a very weak solution of nitric or hydrochloric acid, and, at an inconspicuous place, try to obtain a discoloration on the swab.(4) However, this method was not used, since it could have been destructive to the pearls beauty in case of surface artificial colour. Another non-destructive test determining the colour origin of black pearls consists of studying their UV fluorescence. White pearls which have been centre-treated to

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*We would like to stress that the test procedure described in this paper applies only to nucleated cultured pearls. Unnucleated cultured pearls would in all cases invariably show an hexagonal spot pattern.

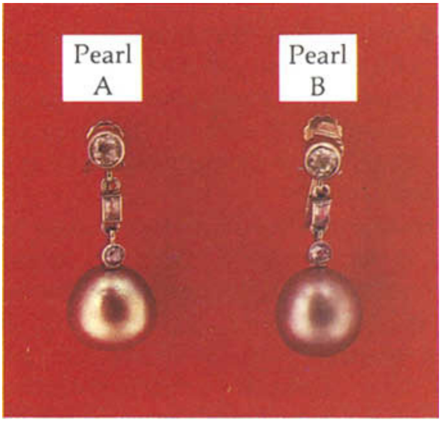

FIG. 2. Pearl A and pearl B in their setting (actual size).

impart a desirable dark body colour, and whose surface nacreous layers are not saturated with the dye, will usually fluoresce with a strong white or nearly white colour. Other white pearls treated by various coatings, dyes, or silver nitrate do not fluoresce. So far white fluorescence has never been encountered in naturally coloured black pearls tested to date (except in mottled low-quality specimens), while nearly all naturally coloured black pearls (about 99% of them) show a reddish fluorescence.(4, 5)

The two pear-shaped pearls studied in this work were exposed to UV radiation of 365 nm wavelength. They both showed a pinkish-yellow glow, suggesting that their colour origin was natural.

Unfortunately, a natural colour does not mean that the pearl is genuine. Cultured black pearls using black-lipped pearl oysters (pinctada margaritifera) have been produced since 1912,(6) and they show the same UV fluorescence as the genuine black pearls.

In order to establish whether the pearls were cultured or natural, they were examined by x-ray methods.

X-RADIOGRAPHS

The triangular pear-shaped pearl (label A in Figure 3) showed no contrast in any of the different radiographs taken. Thus one was left with a strong impression that this pearl could have been

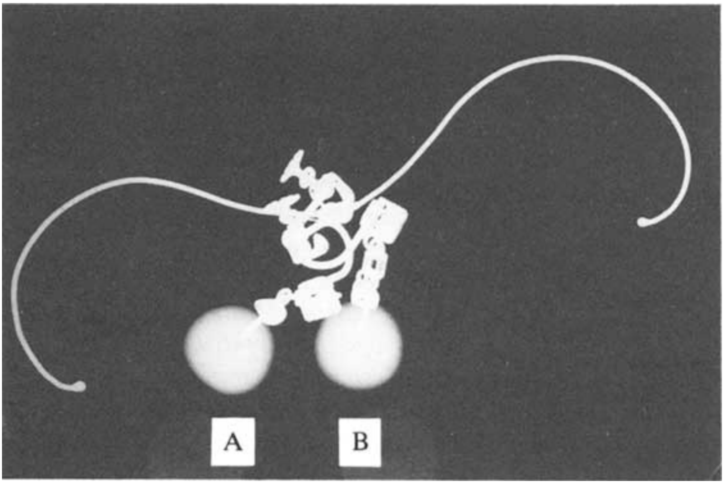

FIG. 3. X-radiographs of pearls A and B mounted on ear pendants (actual size).

cultured. For the roundish pear-shaped pearl (label B in Figure 3) the radiographs showed a regular circular line very near its edge. This pearl therefore also looked as if it had been cultured. At this point it was thought that a conclusive test would be to check for x-ray fluorescence. If hardly any genuine sea-water pearls fluoresce under x-rays (those which do, fluoresce in a particular manner), all cultured pearls which have a fresh water mother-of-pearl bead do fluoresce.(4, 7)

Surprisingly, no fluorescence could be detected with either one of the pearls, thus leaving the possibility open that they were of natural origin. In these circumstances, the only test which could have given a conclusive answer was to take x-ray diffraction patterns.

LAUE X-RAY PHOTOGRAPHS

The pearls were placed into a polychromatic collimated x-ray beam of 1 mm diameter, which was produced by a standard x-ray generator (Philips PW 1008; operating conditions, 45 kV, 20 mA). The distances between the centre of the pearl and the x-ray tube focus was 160 mm. A photographic film (Kodak, SB5) was placed at a distance of 60 mm behind the pearl, corresponding to the standard set-up for Laue transmission photography. Particular care was taken to align the pearls so that the x-ray beam was passing through their centres of gravity, supposing that the latter corresponds to a good approximation to the centre of nucleation. The axis of the pearl's support was oriented perpendicularly to the x-ray beam. Due to the large size of these pearls, exposure times of up to 10 days were necessary to obtain photographs of sufficient quality.

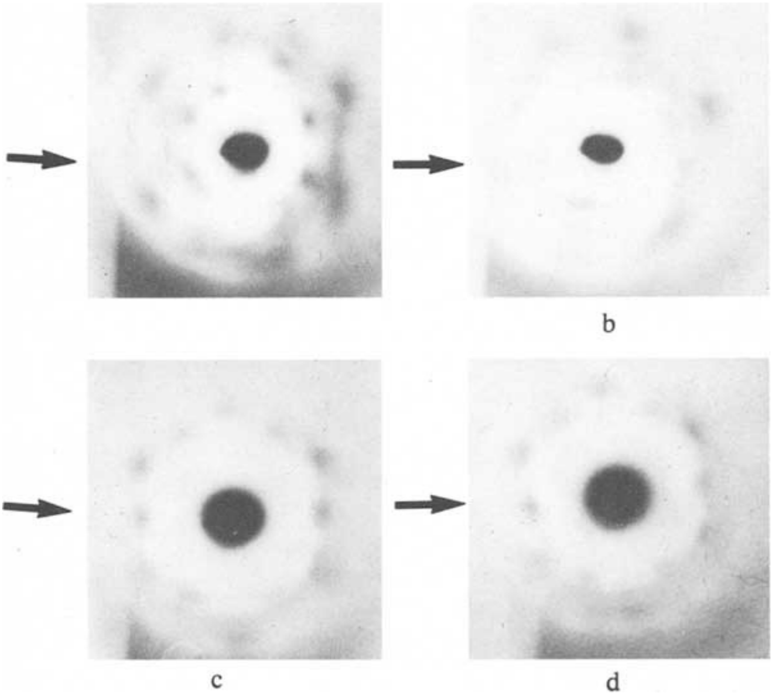

FIG. 4. X-ray Laue diffraction patterns of pearl A in positions 1 (a), 2 (b), and 3 (c), and after rotation by 90°(d). Positions 1-3 correspond to displacements of about 1 mm of the pearl in a plane perpendicular to the x-rays. The arrows indicate the axis of the pearl's mounting.

The first Lauegram (position 1) of the pearl A is represented in Figure 4a. It shows low symmetry (possibly of type m) and can be considered as being typical for a cultured rather than a natural pearl. Thus from this exposure one might have concluded that pearl A is cultured.

It was decided to perform additional x-ray Lauegrams by displacing the pearl *laterally* with respect to the x-ray beam, thus deliberately passing away from its presumed centre of gravity. An exposure (position 2) taken at about 1 mm away from position 1 is shown in Figure 4b. Its diffraction pattern is quite different from that obtained in position 1, and it shows a very vague possible pseudohexagonal symmetry. Finally, a third Lauegram was recorded in position 3 by displacing the pearl about 1 mm away from both position 1 and position 2. The pattern obtained (Figure 4c) showed almost perfect hexagonal symmetry, thus suggesting that pearl A was in fact of natural origin.

Unfortunately, the bead of cultured pearls, in one direction only, can also give the hexagonal spot pattern of genuine pearls. This is due to the fact that most beads consists of mother-of-pearl made up by more or less parallel layers of pseudohexagonal aragonite crystallites arranged with their principal axes oriented perpendicularly to these layers. Therefore a bam of x-rays passing through the pearl at right angles to the layers (position A in Figure 1) will be travelling along the vertical axes of the crystallites and will give a pseudo-sixfold symmetry figure similar to that in genuine pearls,(2) while in directions at right angles to this, the x-rays will be travelling across the prisms of the crystallites, and the diagram will have nearly twofold symmetry (position B in Figure 1).(3)

Another photograph was therefore taken with the pearl turned by 90°. This fourth photograph (Figure 4d), showed again a hexagonal pattern. This was the final proof that pearl A was genuine. The second pearl (B in Figures 2 & 3) which on all radiographs seemed to be cultured, was tested in the same manner, two photographs (not represented here) were taken in two different positions (after a rotation of 90°), and both showed the characteristic hexagonal spot pattern of genuine pearls. This second pearl was therefore also confirmed as natural.

CONCLUSION

This study shows that the identification of natural pearls by the x-ray diffraction (Laue) technique may be troublesome. The main problem arises from the fact that the pearl's centre of nucleation may not coincide with its centre of mass and thus cannot be aligned in the x-ray beam by visual inspection.(7) The need for an empirical centring procedure becomes apparent from inspection of the series of photographs reproduced in Figure 4, which show that small displacement of the pearl by about 1 mm may totally change the overall aspect of the x-ray diffraction patterns. This indicates that in some cases *several* photographs in *different* positions are necessary, in order to obtain diffraction patterns of hexagonal symmetry indicative for pearls of natural origin. On the other hand, the failure to observe a pattern of hexagonal symmetry on a visually well centred pearl does *not* always indicate that it is of cultured origin.

ACKNOWLEDGEMENTS

We would like to thank Dr Bernard Chabot for his help while taking the x-ray photographs, and express our gratitude to Phillips Fine Art Auctioneers, and in particular to Mr Ian Blowfield, Director of their Geneva office, for his interest and kind permission for publication.

Note added in proof

The authors would like to draw attention to a thorough independant study of the above subject which has been reported by Dr Hänni in a recent issue of the *Journal of Gemmology.*(9)

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THE SENSE(S) OF GEMMOLOGY

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Frinton-on-Sea

Nothing can be so tedious as an elderly person relating to someone much younger how it was done in his day. 'When I was your age', or, 'When I first started', are two phrases often used to start this form of diatribe. 'They never had it so good' is a now well worn cliché, almost as annoying to those to whom it is directed as the accusation of feather bedding was to the farmers! Having pointed out the annoyance caused by these practices, I am now going to preach a little upon matters gemmological of my day and age which stretch up to the present.

Some few years ago—just before the Second World War—the railings which surrounded Chelsea Polytechnic in Manresa Road bore framed placards describing the various evening classes conducted therein. One was 'Mineralogy for Jewellers', which is gemmology as we know it. The venue has now been changed due to an upgrading of the status of Chelsea Polytechnic. Classes are now conducted under the Inner London Education Authority and are not strictly trade orientated as was an earlier tendency. The examinations are organized by the Gemmological Association of Great Britain, which is an offspring of the National Association of Goldsmiths. The 'N.A.G.' as it is popularly known is primarily a body representing the retail jewellery trade and has long been a keen leader in trade education. A member at an annual conference of the N.A.G. in 1908 proposed that teaching should be provided and examinations in gemmology held—he was Samuel Barnett, of Peterborough. Thus the seed sown by Samuel Barnett was, according to B. W. Anderson, 'the beginning of organized Trade gemmology, not only in this country but in due course for the whole world' (*J.Gemm.*, 1981, XVII (8), 518).

Samuel Barnett provided a good example by sitting the gemmology examination in 1913 and passing to become holder Number 1 of a diploma in gemmology. All of those who passed in 1913 were from the provinces, none from London.

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The First World War interfered considerably with classes and exams; it was in 1922 that a fresh start was made. There are many famous names in those earlier days, many from trade houses, auctioneers, pearl merchants, factors, pearl stringers, etc., etc. It would be invidious to mention specific names, but the vast majority were in the jewellery trade. Without being racist it is equally true to state that the major portion were from Great Britain; the compliment of the invasion by overseas contingents had not yet started—and it *is* a compliment.

The Gemmological Association (which stemmed from the N.A.G.) and the Laboratory of the London Chamber of Commerce contributed considerably to the conducting of classes, the supply of specimens and the provision of instructors. In fact, most Chelsea and Northern Polytechnic students who were trade-employed became so used to the presence of Anderson and Webster at evening classes and subsequently seeing them again in their daytime role as gemmologists at the laboratory of the London Chamber of Commerce in Hatton Garden that they thought it was the N.A.G or G.A. laboratory.

Anderson and Webster between them inspired many of the earlier students to become practical gemmology instructors as classes expanded and the older instructors eased from their very heavy commitments of evening class teaching. In the earlier days of examinations at centres outside London it was not unusual for Robert Webster to travel to set up the practical examinations with apparatus laboriously carried from London to supplement the less well catered for centres. It is also true that on these occasions the laboratory was almost denuded of small glass cells, its best refractometers and, of course, the services of Robert Webster.

The accent most of this time was upon tradespeople and their requirements. The laboratory which played such an important part in the supply of teachers, specimens, instruments, as well as the checking of examination specimens, had the lengthy title of 'The Laboratory of the Diamond, Pearl and Precious Stone Trade Section of the London Chamber of Commerce'. Lengthy it was and certainly descriptive of its precise role and for whom it worked. Its importance was emphasized precisely by the content of the words, *diamond, pearl* and *precious stone trade* section and *commerce.* The accent was upon trade and commerce, the needs and requirements basically of jewellers being the identification of gemstones, pearls, their imitations and synthetic counterparts.

From the researches of B. W. Anderson, B.Sc., F.G.A., at the Laboratory came the gift to all gemmologists of his monumental work on the absorption spectra of gemstones. His findings and teachings put Great Britain in the forefront of gemmology for many years. The use of the hand spectroscope was an art reasonably easy for students to acquire. It was positive, speedy, non-destructive and could be used on large or microscopic specimens, cut or rough, mounted or unmounted. It was equally very manoeuvrable, portable and relatively inexpensive.

Without launching upon too long a peroration of the Laboratory's role I want to try to arrive at gemmology today and its participants. Since the war we have seen a tremendous expansion in the number and variety of people who have sat for and passed the examinations in gemmology, a great compliment to Great Britain and an acknowledgment of the status of our gemmological diploma. Together with an influx of overseas examinees, we have had an increase of people who are not trade based or trade orientated. This leavening must of course be to our advantage—and disadvantage in some respects.

The earlier volumes of the *Journal of Gemmology* and *The Gemmologist* seemed to me to be more readable and understandable than they are today. The reason for this may well be that because of the advancement of techniques in the manufacture of synthetics and artefacts of new types of gemstones greater expertise and more sophisticated equipment are required. Gone perhaps are the days when one could rely upon a good polarizing microscope, a hand spectroscope, a refractometer, hardness points, careful hydrostatic density tests, etc. to identify all and every gemstone successfully. Certainly with the very awkward Kashan synthetic rubies a good practical knowledge of inclusions is paramount. With an experienced trade gemmologist it might be possible to write a certificate positively for such stones. Certainly it seems that further sophisticated tests need to be carried out upon this particularly difficult synthetic ruby. The use of ultraviolet spectrophotometry is a modern method recently explained in the *Journal of Gemmology*. The use of an electron microprobe for chemical analysis is another of today's methods in gem testing or rather research. This kind of equipment requires expertise of a very high degree and funds to provide it. Usually these instruments are found in universities or museums. Certainly today's gemmology needs the back up of these advanced workers and their equipment. We cannot put the clock back, whether it be today's quartz oscillation design or the thirty hour spring wind alarm of yesteryear.

Equally certain is the fact that some of today's gemmologists are not just Fellows of the Gemmological Association of Great Britain, neither are they products of the retail jewellery trade. They have those very necessary extra qualifications in certain fields. The foundations of gemmology were based upon the needs and requirements of the jewellery trade; today's researches have stemmed from these needs. It is an unfortunate fact of life that the pre-war and immediate post-war shop assistant was extremely poorly paid and often worked long hours. This applied to the jewellery trade as well. The retail trade was not sufficiently attractive to interest lively minds, and so I believe we suffered from this handicap. The actuality that people of the calibré of Robert Webster *did* emerge from this employment is a compliment to tenacity and interest. Today one needs qualifications of sufficient quality to ensure the adequate understanding and appreciation of the techniques employed to detect synthesis, heat treatment, irradiation, etc., to name but a few.

Having discussed the contents of our *Journal of Gemmology* with one of our leading gemmologists who is also a scientist, I was somewhat pleased and relieved to find that he didn't understand all of the articles all of the time. Comforted by this I am encouraged to suggest the phrase 'Nil desperandum' to all ordinary gemmologists, who may well be from trade sources (as I was).

Despite the facts of today's requirements in the detection of modern artefacts and synthetics, there are many opportunities for the use of very ordinary gemmological tests based upon the sense (common) and senses. One cannot always afford ultra sophisticated equipment, neither (despite some very ingenious attempts at portability) can one easily carry a case equipped for tests under the 'while you wait' system. However, we are all equipped with eyesight, noses, teeth (some of us) and hands. If we have had some gemmological teaching and know some basic facts and can use a 10× lens, we are reasonably equipped to detect and/or reject quite a lot of gemstones which a practised scientist with a microprobe or spectrophotometer might even miss! The handling of gems and gem material conveys a sense of texture or finish as is exemplified by that well worn quote, 'the inner aspect of a well-educated thumb'. (Sir Arthur Church related how he successfully chose the true topazes from a bag of mixed yellow quartz and topaz by the superior silk-like finish obtained on the much harder surface of topaz compared to quartz.)* Certainly a light glancing touch across a quartz specimen feels a little tackier or more resistant to the finger than across a topaz. This handling of gems, whether touch or feel, is a use of one of the senses. Handling in another aspect can give a sense of heft, and it is possible, say, to decide between a very clever plastic imitation of carefully carved 'ivory' and the real thing by heft alone. A 10× lens would assist in determining the lines of Retzius in ivory or the Haversian canals in bone (a combination of heft and lens). Before the advent of polishing gems with diamond powder, which achieved a near perfect surface polish on jadeite-jade, it was possible to identify this material by its dimpled surface due to hardness (structural) differences which caused little variations in surface finish. To heft and feel I must add sound. A non-gemmologist friend of mine—a successful gem merchant—can distinguish between plastic imitation amber and true amber by the sound of amber or plastic beads rattled in the cupped hands. He can recognize the clack of plastic compared to the ringing/resonance of amber. Another merchant once relieved my worries over a very heavy 'silver' dish by holding it close to my ear, and on bending the metal it creaked, which to him spelled antimony (and it was too heavy for silver).

Those of us possessing our own teeth can distinguish between imitation pearls and both natural and cultured pearls. Imitation pearls slide smoothly if drawn lightly across the teeth. Both natural and cultured pearls have a gritty pull to them due to the surface structure of the thin sub-microscopic overlapping platelets of nacreous aragonite. Natural pearls will bounce rapidly with a resonant rhythm compared to the short-lived flat thud of cultured pearls. This is due to the regular radial and concentric structure of natural pearls compared to the banded one direction of mother-of-pearl bead in cultured pearls. Again, with drilled pearls a 10× lens

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*B. W. Anderson, *Gem Testing*, 9th edn, p.294: Butterworths, London, 1980.—Ed.

examination at the drill hole will reveal the discontinuity layer of nacreous pearl exterior and the cold grey of the mother-of-pearl bead. The 10× lens will show junction lines of garnet-topped glass-based doublets, particularly if examined under a table or bench lamp. The difference in polish is seen between the superior hardness of garnet and the softer glass; where the two media are jointly polished over the junction is easily seen. If tested by microprobe or spectrophotometer one wonders what the results would be.

The fascinating curved fine lines of asbestos seen in demantoid garnet are a positive hallmark, sometimes referred to as 'horse tail' inclusions. Another easily observed characteristic seen by 10× lens is the flame structure of pink pearl (conch pearl)—this is something like pink lines of Retzius or the banding seen in some red/pink corals. Just as decisive is the schiller seen in amazonite (microcline feldspar) due to reflections from myriad cleavages of the material. Asterism in both forms of epiasterism and diasterism can be seen by 10× lens. With diasterism the effect is the reflection of asterism as seen in rose quartz cabochons sealed with a blue mirrored *base;* this *reflects* the asterism of the rose quartz and reveals its diasteric effect by the reflection of the examining light bulb at the intersection of the rays at the surface. No natural star sapphire will show a light bulb at the intersection of its rays. For that matter, most synthetic star stones have a too perfect symmetry, a very suspect sharp intersection, a too good or strong body colour plus a flat ground finish base with no signs of natural structure. This is probably the easiest test with a 10× lens for the practised gemmologist. There are many other hints and tips which can be usefully employed with a 10× lens and a background of gemmology.

Apart from the sense of light, sound and touch, there is the very important olfactory sense which is commonly called our sense of smell. It is mostly the organic products which produce a characteristic smell. Celluloid, which can be a convincing imitation of ivory, often has a distinct smell of camphor when rubbed on cloth, and, of course, it burns very readily! The latter test is *not* recommended, although one of my gemmologist trade friends had the pleasure of his doubted word being vindicated when the somewhat overbearing know-it-all non-gemmologist shopkeeper pooh-poohed the suggestion that his buffalo carving was celluloid. With just the aid of a match he proved it in a flash. Celluloid is sectile—it peels easily with a sharp knife—but ivory is much tougher. The smell of burning hair is obtained if a hot needle is applied to tortoiseshell whereas its plastic similar-looking imitation smells of burnt milk. One of the earliest, if not the earliest, of materials we now label 'plastic' is bakelite, which is produced from a condensation of creosol or phenol with formaldehyde. When vigorously rubbed or lightly heated it will smell of carbolic or coal tar soap. Bakelite incidentally is named after L. J. Baekeland (1863-1944).

The smell of sulphuretted hydrogen (rotten eggs) is readily attained if a piece of reconstructed Gilson lapis lazuli is crushed; the same material, because it contains calcite in finely divided (scattered) content, gives an immediate furious effervescent effect when touched by a small drop of dilute hydrochloric acid. The *entire* surface of the drop bubbles. In natural lapis lazuli the calcite is not regularly distributed and the acid test, whilst not recommended on potentially fine pieces, does not have a fast immediate or all-over reaction; it is in fact hard to find and is a slow bubbling reaction.

Whilst I have dwelled on only a few simple unsophisticated tests (there are many more), I hope I have made a point that the experience of a trade gemmologist can be followed or emulated by commonsense application. There is ample room for all of us, whether trade orientated or sophisticated academics. Gemmology, the science and study of gemstones, is a broader subject today than when suggested as a course of instruction and examination by Samuel Barnett in 1908. Whilst we need the special skills of the trained scientist, there is a lot we can still do and enjoy for ourselves by dint of application and observation, particularly with that portable simple microscope the 10× lens.

Commonsense demands, of course, that non-destructive tests are a requirement when dealing with expensive precious stones. If the acid drop test is conducted, obviously it should be on the back of a piece of lapis lazuli or in some place hidden by the mounting in jewellery. The acid reaction will leave a flat matt stain. Care is needed. One of my colleagues once tested a very fine bonamite (zinc carbonate) by this acid test. It took him a long time to carefully and painstakingly polish out the attacked material, even though it was in the back of a ring. Heat tests on beads should, if possible, be at or just inside the drill hole and one should avoid testing the largest centre bead. If they all appear to be similar, test the smallest at the clasp end. The same advice applies to sectility tests. Many of these tests, whether by acid or peeling (sectile), can be observed with the aid of a microscope. For those who wish to go further there are the intriguing chemical tests described by Robert Webster in his great book 'Gems, their sources, description and identification'. It is not very difficult for a gemmologist to obtain specimens of most gem material, plastics, etc., which need not be of jewellery quality. With these comparison specimens he can practise, a sort of aide-memoire.

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RUDDIGORE

By the Revd S. B. NIKON COOPER, B.D., F.G.A.

'. . . who would have thought the old (bird?) to have had so much blood in him?'(1) Maybe not the exact words of Lady Macbeth—but she might have said it, had she been a student of gemmology; had she been considering, that is, the ruby—of which we all know one fact: that its colour is that of 'pigeon's blood'.

It is fascinating to see how a vivid and lively description—one presumably, originally, easily identifiable—has so captured the imaginations of generations of gem-writers, even when its original significance has long since (thankfully) passed into oblivion. (How many pigeons have *you* killed today?) Or has it become so much a part of the folk-history of gems that the various authorities dare not but reiterate it?

At any rate all seemingly pay lip-service to the term. Max Bauer(2) *Precious Stones* (1904) (*Edelsteinkunde*—1896):- 'this colour has been compared by the Burmese to that of the blood of a freshly-killed pigeon, hence the reference to such stones as being of "pigeon's-blood" red.' Or Kunz(3) (1892):- 'the finest pigeon's-blood-colored rubies are found in Mandalay in Burmah.' Herbert Smith,(4) *Gemstones* (1912), has the decency to add a qualifying 'so-called' ('The most highly-prized shade of red is the so-called pigeon's blood . . .'). L. J. Spencer(5) (1936) gave the perfect—and unwittingly prophetic—comment:- 'The colour of the best rubies is said to be "pigeon's blood red", *a statement slavishly copied parrot-like from book to book.'* (our italics.)

And so true! We meet the same description again in Anderson's(6) *Gem Testing* (1942):- 'Only in one locality, the Mogok stone tract in Upper Burma, are stones found which have the coveted "pigeon's blood" red . . .' Robert Webster, too(7) —but with a qualification:- 'the so-called and one may say indefinable "pigeon's blood" . . . is the prized colour of the best

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Burmese rubies.' And Gübelin(8) as well, with his poetic '. . . the crown of all beauty, the noblest and most precious nuance is pigeon blood red . . .'

And so on . . . Sinkankas(9) (1968), Desautels(10) (1969), Hurlbut(11) (1969), Bancroft(12) (1973), et cetera. . . Was there ever a description that has so captivated the minds of gem-lovers, or—as evidenced by their unquestioning 'homeworks'—succeeding generations of students even today? But some of us are heartily tired of it and wish only that the unfortunate Burmese Bird could at long last be laid to rest.

It might be said, does not this description keep alive the original etymology? We trace the pedigree of our modern ruby back via its medieval ancestors (rubie, rubis, rubith) to the Latin 'ruber' = 'red', itself coming from the Greek 'erythros' (ἐρυθρός), but originally from Sanskrit 'rudhira'—which meant, not just 'red', but 'blood', 'blood red' (it is unspecified whether of pigeon derivation or not).

What are the alternatives? Colour (as Robert Webster(7) said) is so indefinable. Once we have seen a fine specimen of ruby we *know* the colour—but try to describe it! The authors we have mentioned above, referring to the same gem, vary from 'a deep red'(11), 'a deep rich red'(10), 'a saturated shade of carmine red'(8), 'a carmine red with a slight bluish tinge'(2) to 'a red which is slightly inclined to purple'. (9, 4, 7) It is fortunate that we recognize a perfection colour at sight—once seen, never forgotten.

The less poetic would seek to tie us down to mathematical exactitudes, for instance a Munsell Notation of 9.5RP 3.3/8.9 . . . How easily this falls from the tongue is a moot point, but even with defined parameters of Hue, Value and Chroma the doubt remains—*is* this the colour? It is notoriously difficult to compare the shade of a transparent gem with that of a given colour sample.

We would suggest a practical solution lies with the 'eye of experience'. A perfection colour is recognized at sight by those who handle them daily—to those with less facility a synthetic control stone could be reasonably available. Forget about 'pigeon's blood' and the not necessarily geographically exact 'Burma' label—let it be named 'ruby red', with a qualifying term for those that fall from that standard. It is our trade, it is our experience; we believe that we should have the right to define our own terms—but, please, let the meaningless 'pigeon's blood' be consigned back where it belongs—to the realms of ornithology.

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STABILIZED CERULEITE

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ABSTRACT

Plastic-impregnated (stabilized) ceruleite is described. The plastic impregnation procedure of ceruleite is comparable with the stabilization treatment of turquoise; the distinction of treated and untreated ceruleite material is possible by infrared spectroscopy.

The Cu-Al-arsenate-hydrate ceruleite was first described by Dufet (1900). At that time, the type material originated from the Emma Luisa gold mine near Huanaco, Taltal Province, Chile. For a long time this mineral was cited in mineralogical tables and textbooks only as an inadequately defined mineral. Recently, the existence of ceruleite as a natural phase was confirmed by the investigation of samples which were described to come from Bolivia (Schmetzer *et al.,* 1976a, b; 1978). Meanwhile, it came to our knowledge, that the new material, which also appeared on the gemstone market, probably originated from the Emma Luisa mine or at least from a locality close to this place in northern Chile, too.

Only part of the material described by Schmetzer *et al.,* (1976b) was of compact quality, which could be cut to intensively blue coloured gem material resembling turquoise without further treatment (cf. Schmetzer *et al.,* 1976a, 1978). A great part of the samples, however, were of high porosity with a light bluish or even white coloration. In an untreated state this material was not suitable for the gemstone industry without improving its properties by a treatment procedure.

Similar problems have been known for a long time with the gem mineral turquoise. A great part of the rough material of this mineral species is not suitable for gem purposes without treatment of the samples. At present, the best treatment procedure for turquoise is thought to be a stabilization treatment by plastic impregnation techniques. A great part of turquoise rough material of all qualities is treated in this manner. For a recognition of treated and untreated turquoise material a combination of x-ray diffraction methods and infrared spectroscopy is suggested (Lind *et al.,* 1983a, b).

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Meanwhile, it is not astonishing, that those qualities of ceruleite, which were not suitable for gem purposes due to their high porosity, are stabilized by a plastic impregnation procedure. The material available to us for investigation has an intensive blue colour, which is comparable to the colour of the more compact material in untreated state. The density of the plastic-impregnated ceruleite is found to be 2.58 g/cm^3, which is distinctly lower than the density of the untreated material, which can be given as 2.70 g/cm^3. The investigation by x-ray powder diffraction methods showed the plastic-impregnated ceruleite to have the powder diffraction pattern of the untreated material without further additional diffraction lines. By infrared spectroscopy, however, an additional absorption band is found in the spectrum of the treated material at 1725 cm^{-1} besides the characteristic absorption bands of the untreated material (cf. Schmetzer *et al.,* 1976b). This additional infrared absorption band is also found in plastic-impregnated turquoise.

For an investigation of unknown blue material, i.e., for the determination of the crystalline phases in an unknown sample, an investigation of the x-ray powder pattern is necessary. Infrared spectroscopy is suggested for the recognition of plastic impregnation of a sample, which is found to consist of ceruleite by x-ray diffraction techniques. According to the nomenclature of turquoise, in our opinion every treatment of ceruleite is also necessary to be mentioned in the trade. Therefore, the samples described in this paper should be named stabilized ceruleite or plastic-impregnated ceruleite.

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ORANGE SYNTHETIC CORUNDUM

By *MICHAEL O'DONOGHUE, M.A., F.G.S., F.G.A.*
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The writer recently received through the courtesy of Mr Tom Chatham, a group of orange corundum crystals manufactured by his well-known firm. A similar group has recently been reported by Kane (1982). My group, weighing just over 13 ct, consists of a number of crystals which are less bladed in habit than those of blue sapphire produced by the same firm some years ago. The orange crystals in my specimen range up to about 1 cm in height and show basic rhombohedral form. The colour is a fine reddish-orange with some zoning, though again this feature is less marked than with the blue sapphire crystals. The crystals could be faceted since they are sufficiently thick but there are numerous inclusions, particularly of angular flakes recorded as platinum by Kane. These are large enough to be seen with the unaided eye. On the back of the group is a substance containing numerous gas bubbles and Kane states this to be a liquid silica-based ceramic glaze which is applied to the groups and fired at 1000°C in a kiln (information from the manufacturer). It is also stated that a similar practice is routine for all orange and blue Chatham crystal groups.

The most interesting features of these groups were their behaviour between crossed filters and the absorption spectra recorded. My specimen was examined by the light of a high-intensity lamp passed through a flask of copper sulphate, the ray being picked up through a red gelatine filter. The specimen glowed a very bright reddish-orange, which was also seen to a lesser extent under long-wave ultraviolet radiation. Examined with a hand spectroscope, a sharp emission line was noted in the deep red: this was so prominent that even students who had never used the instrument before could see it with ease. There was no change of colour after exposure to daylight for several days nor after ultraviolet irradiation. This was not in action for very long (one hour on two separate occasions) but such a change, though

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recorded for some Chatham blue sapphires after exposure to x-rays, would not be expected in a Cr-bearing material. Kane records the SG of his specimen as 4.00± 0.003 and the refractive index as 1.762-1.770 with a birefringence of 0.008. I was not able to measure these constants on my specimen, but have no reason to suspect that they would be materially different. The pleochroism recorded by Kane (strong pink-orange and brownish-yellow) is substantially the same in my specimen, allowing for slight differences in the meaning of the words.

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CANADIAN VESUVIANITE GEMS

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INTRODUCTION

Vesuvianite occurs in many colours and at many localities in a variety of geological environments. It has a very complicated chemical formula and crystal structure. Indeed, mineralogists are still studying this mineral and presenting us with differing views on its crystal chemistry. Even its name is in dispute—vesuvianite (from the Italian locality at Mount Vesuvius) tends to be used by mineralogists, while idocrase (from the Greek *idos* = appearance and *krasis* = a mixture, because its crystal forms resemble those of other minerals) is more likely to be used by gemmologists and jewellers. For the sake of consistency, the use of 'vesuvianite' is encouraged.

Vesuvianite gems are usually seen in yellow to brown and green shades (Arem, 1977; Webster, 1975). Facetable vesuvianite comes from Italy, Québec (Canada), Pakistan, Kenya, and New York (U.S.A.). It crystallizes in the tetragonal crystal system, the most common crystal forms being a square prism terminated by pyramids and a basal pinacoid. With a hardness of 6½, it is suitable for some types of jewellery, and the golden-brown stones are definitely attractive. A fairly common massive green vesuvianite, often intergrown with grossular garnet, is found in California ('Californite') and has been used as a jade imitation.

Golden-brown transparent vesuvianite was collected from Laurel in Argenteuil County, Québec, Canada, early in this century, and faceted gems were marketed with limited success as 'Laurelite'. Unfortunately the crystals (up to 2″ in diameter and 3-4″ long) were badly shattered and there were very few stones over 2 carats in weight (Sinkankas, 1959). Most gem material from the now-flooded pits of this occurrence has been removed. Several fine golden-brown gems (2.95, 2.28, 2.08 ct) are in the National Museum's collection, as well as a 3.15 ct, greenish-brown stone (Boyd and Wight, 1981).

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Our interest in Canadian vesuvianite gems was stimulated by the recent appearance of olive-green gems from the Jeffrey mine at Asbestos, Richmond County, Québec (Wight and Grice, 1981). Comparison of the green vesuvianite from the Jeffrey mine with the golden-brown vesuvianite previously known from Laurel showed differences in their optical properties.

The Jeffrey mine has produced vesuvianite in several colours—greens, brown, mauve (reddish-violet), and light red, although only green has been available as faceting material. This wide range of colours offered an opportunity to correlate colour with chemical composition, and the results were presented by Grice and Wight (1982).

GEOLOGY

The Jeffrey mine is located about 160 km east of Montréal in the second largest asbestos deposit in the world. It is notable for an extensive suite of Ca-silicates (vesuvianite, grossular, diopside, prehnite, pectolite and wollastonite) which are associated with rodingites—dykes that have undergone extensive calcium metasomatism (Grice and Williams, 1979).

There is little information available on the geology of the Laurel deposit, which is about 75 km north-west of Montréal. Sinkankas (1959) describes the Laurel deposit as a small pit in forested land within the marble of the Grenville series with additional mineralization provided by intrusion of a feldspar pegmatite. The mining of the pegmatite for mica first brought to light the gemmy yellow vesuvianite.

OPTICAL PROPERTIES

Table 1 gives the chemical analyses and refractive index for the various colours of vesuvianite from the Jeffrey mine and from Laurel. Our analysis of Laurel material agrees very well with that of Manning (1975). Optical properties of the faceted gems are listed in Table 2.

In general, vesuvianite has a low birefringence due to the pseudo-cubic nature of its crystal structure. All the Jeffrey mine samples were uniaxial negative with very low birefringence. The refractive index of the green gems (6 specimens) is 1.716. Double refraction was easily observed with the polariscope but not on the refractometer. In contrast, the Laurel vesuvianite gems generally

TABLE 1. Vesuvianite Chemical Analyses*
and Refractive Indices

	Jeffrey Mine, Asbestos, Québec					Laurel, Québec
Colour	Green	Emerald green	Brown	Mauve	Pale Red	Brownish yellow
NMNS #	32839	42913	36884	42936	47774	42853
SiO_2	37.0	36.4	36.0	37.1	36.6	36.2
TiO_2	0.28	0.00	0.48	0.00	0.00	2.1
Al_2O_3	17.8	15.0	17.4	18.6	17.9	16.2
Cr_2O_3	0.19	0.18	0.08	0.18	0.12	0.17
Mn_2O_3	0.11	0.00	0.00	0.27	0.59	0.00
Fe_2O_3†	1.93	5.24	2.47	0.73	0.34	0.54
FeO	0.19	0.28	0.90	—	—	0.44
MgO	2.48	2.90	1.71	2.28	3.03	3.1
CaO	37.3	37.0	36.9	37.6	37.3	36.4
H_2O‡	2.72	3.00	4.06	3.24	4.12	4.85
Total	100	100	100	100	100	100
ε	1.704	1.717	1.711	1.703	—	1.705
ω	1.708	1.721	1.714	1.704	—	1.710

* Electron microprobe analyses by Dr D. Smith, University of Alberta.

† Total iron unless FeO determined separately by titration.

‡ By difference.

have a higher birefringence of 0.005 to 0.007, which is easily measured on the refractometer. We have found one exception, however—a greenish-brown gem (NMNS #20515, 3.15 ct) with only a single measurable refractive index of 1.725.

Dark orange-brown gems had a higher RI than the golden-brown stones, presumably because of higher iron and/or titanium content. The Jeffrey mine gems had a higher RI than all except one of the Laurel gems. Our chemical analyses show that the Laurel gems contain significantly less iron (0.98% iron oxide v. 2.12 to 5.52%) and more titanium (2.1% titanium oxide v. 0 to 0.48%).

TABLE 2. Optical Properties of Vesuvianite Gems

Locality	Jeffrey Mine, Asbestos, Québec		Laurel, Québec		
Colour	olive green	light green	yellowish brown	dark orange brown	greenish brown
RI	1.715 to 1.718	1.712 to 1.717	ε 1.702 ω 1.709	ε 1.706 ω 1.711	1.725
Birefringence	not visible	not visible	0.007	0.005	not visible
Dichroism	strong green/orange	distinct green/greenish yellow	strong olive green/dark orange	strong olive green/orange brown	strong dark olive green/orange

CAUSE OF COLOUR IN VESUVIANITE

Details of experimental work on the colour of Jeffrey mine vesuvianite and grossular are given by Grice and Wight (1982). Readers are referred to this paper as only a brief overview is given here.

The chemical composition of vesuvianite may be stated as $Ca_{19}Al_4Fe(Al,Mg,Fe)_8(SiO_4)_{10}(Si_2O_7)_4(O,OH)_{10}$, with the possible substitution of transition metal ions (titanium, chromium, manganese and iron) in the Ca, Fe, and Al/Mg/Fe crystal structure sites. These substitutions impart colour to vesuvianite, and a higher content of transition metal ions corresponds to an increase in colour intensity and refractive index.

Transition metal ions have *d* orbital electrons. These electron orbitals, when placed in a crystal structure, have discrete energy levels which are capable of absorbing radiation energy within the visible spectrum (400 to 700 nm). Two electronic processes need to be considered: the energy required to absorb light caused by internal electron transitions between *d* orbital energy levels within a single co-ordination site, and by electron transitions between elements in adjacent atomic sites. The wavelengths that are not absorbed are then transmitted to our eyes as colour.

The valency state and co-ordination polyhedra for each of the transition metal elements are also important in colour theory. The combination of these factors makes the optical absorption spectra of vesuvianite very complicated. Much has been written on the subject of colour in vesuvianite, and readers are referred to Burns (1970) and Manning (1975, 1976, 1977) for further discussions.

In the vesuvianite from these two localities, we have five cations with different numbers of d^n electrons: Ti^{4+} with d^0; Cr^{3+} with d^3; Mn^{3+} with d^4; Fe^{3+} with d^5 and Fe^{2+} with d^6. For the substitution of these transition metal ions in vesuvianite, there are three possible co-ordination symmetries: square antiprism (8-fold co-ordination), octahedral (6-fold co-ordination) and square pyramidal (5-fold co-ordination). In general, the 8-fold co-ordination site is occupied by calcium; the 6-fold co-ordination site has either aluminium, magnesium or iron; and the 5-fold co-ordination site is occupied by iron (Figure 1).

For the Jeffrey mine vesuvianite, the green colour can be attributed almost entirely to ferric iron in the octahedrally co-ordinated Al/Mg/Fe site. The intensity of the green depends on the

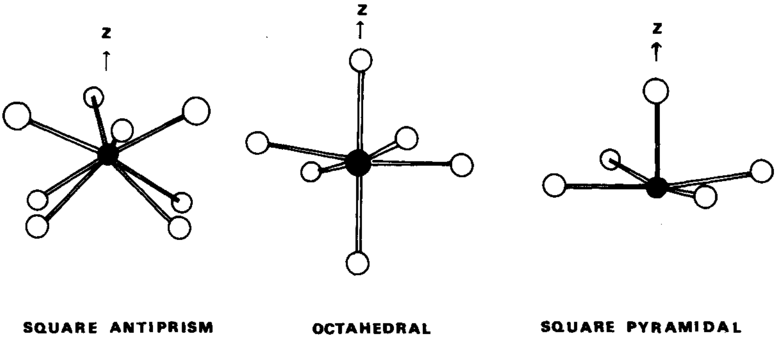

FIG. 1. Co-ordination Polyhedra of Vesuvianite
o oxygen ion • cation

Fe^{3+} content. Mauve or light red vesuvianite is often an overgrowth on light green, and this combination illustrates how sensitive colour change is to chemical composition. The green contains $\sim$2% Fe_2O_3 and 0.1% Mn_2O_3, while the mauve contains $\sim$0.5% Fe_2O_3 and $\sim$0.5% Mn_2O_3. The optical absorption spectrum for mauve vesuvianite shows a broad absorption band in the green part of the spectrum while red and blue are transmitted. Iron is present as Fe^{3+} in the square pyramidal site, and Mn^{3+} is probably in the octahedral Al/Mg/Fe site.

The final colours to be discussed, brown and yellow, have the most complicated OAS since three cations (Fe^{2+}, Fe^{3+}, Ti^{4+}) are present in all three co-ordination sites. It appears that as the Fe^{2+}/Fe^{3+} ratio increases, the colour becomes brown rather than green, as observed in the Jeffrey mine specimens. This decrease in the charge of iron is no doubt coupled in response to the charge balance required by increasing amounts of Ti^{4+}. In general Ti^{4+} is in the octahedral Al/Mg/Fe site and Fe^{2+} is in the square pyramidal Fe site, but minor amounts of each occupy the 8-fold antiprismatic sites. The Fe^{3+} is divided between the octahedral and square pyramidal sites perhaps with some in the antiprismatic site (Manning, 1976). The Ti^{4+} ion does not have any *d* electrons and thus cannot have any internal crystal field transitions, but there is an $Fe^{2+} \rightarrow Ti_{4+}$ charge transfer process involved in the colouring of brown vesuvianite. The 'golden' yellowish brown or brownish yellow of the Laurel vesuvianite is an extension of this argument. As the titanium content and the ferrous/ferric ratio increase, the resulting colour is more yellow.

PLEOCHROISM

In large grains and faceted gems, vesuvianite from both the Jeffrey mine and Laurel exhibits strong dichroism, in contrast to vesuvianite from many other localities that displays only weak dichroism (Deer, Howie and Zussman, 1962; Webster, 1975). The dichroic colours of the gems are given in Table 2. Brown grains of Jeffrey material showed greenish brown/brown, while mauve grains showed magenta/greyish pink.

Pleochroism in the visible spectrum is the phenomenon of differential selective absorption of light as it passes through a coloured, doubly-refractive mineral. The ordinary and extraordinary rays in uniaxial crystals such as vesuvianite (or the three rays corresponding to the three principal vibration directions in biaxial crystals) take different paths through the crystal, and differential absorption can occur. Two causes of this are the presence of asymmetric co-ordination sites, and electron charge transfers along a specific crystallographic direction. These conditions can exist in vesuvianite since the square pyramidal site is asymmetric, and the $Fe^{2+} \rightarrow Ti^{4+}$ charge transfer occurs along the z-direction. At present the authors have no explanation for the varying degrees of pleochroism in vesuvianite.

ACKNOWLEDGEMENTS

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OBSIDIANS AND GEMMOLOGY

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'Among the various types of glass also belongs obsidian, that is like the stone found by Obsidius in Ethiopia. This type of glass is completely black, dense, sometimes transparent and, when used in wall mirrors, reflects silhouettes instead of a picture. It has frequently been used for gems, and I have personally seen obsidian busts of Emperor Augustus, who loved the substance for its density and also, for its remarkableness, had four obsidian elephants made and set up in the Temple of Concord.' (Pliny, *Natural History,* Book 36.)*

As the natural physical conditions obtaining when minerals and igneous rocks, the inorganic matter in nature, are formed clearly favour crystallization, most rocks and minerals are crystalline. Glass is the rare exception. It is thermodynamically unstable and devitrifies in (geologically speaking) a short period of time during which it decomposes completely.

Of the variety of natural glasses accessible to us in the surface of the earth (Table 1), *obsidian* is the most wide-spread. It is a separation product of magma containing large quantities of silicic

*C. Plinius Secundus, *Historia naturalis.*

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TABLE 1

Types of Natural Rock Glasses in the Earth's Surface

Obsidians	Magmatic melts with acid character, that consolidate on or near the earth's surface as glass
Basalt Glasses	Mostly basaltic melts that consolidate under water as glass
Tektites *Impact Glasses*	Mainly melts that consolidate as glass and originate in connexion with the impact of large meteorites on the earth's surface, whether they become liquid just before impact or while travelling through either the earth's atmosphere or outer space (moldavites, billitonites, australites, etc.)
Fulgurites	Glasses formed when lightning strikes and locally melts sands or the surface of quartziferous rocks
Libyan Desert Glass	Genesis uncertain
Pseudo-Tachylites	Partially vitreous consolidations of rocks that are melted by the heat from friction caused by the sliding during great landslips

acid, which, due to its high viscosity upon rapid cooling, solidifies as glass. This differentiation (the process of splitting a magma into a variety of partial products) explains why obsidians are found in so many places even if they are unevenly distributed. Large numbers of obsidians are found in volcanic areas above subduction zones of tectonic layers (e.g., the Mediterranean, Asia Minor, the Caucasus). Others are found in rift zones (like the East African Valley, Iceland), and still a few others over hot spots of continental or oceanic segments of the earth's crust (see Table 2). They should all, however, be classified as rocks rather than as minerals.

Due to its hardness and the sharp edges it can form under pressure or impact, obsidian was the material preferred by many early cultures for tools and weapons. Moreover, archaeological findings also give proof of export trading in obsidian from source areas in central and eastern Asia Minor to Mesopotamia as early as

TABLE 2

SELECTED OBSIDIAN SOURCE LOCALITIES

Europe	Hungary (Tokaj)	
	Slovakia	
	Iceland	
Mediterranean	Sardinia (Monte Arci)	
	Pontine Islands	
	Pantellaria	
	Lipari	
	Melos	
	Antiparos	
	Yali (Giali)	
Asia	Cappadocia	
	(Acigöl, Çiftlik)	
	Van Lake District	
	(Bingöl, Nemrut Dağ)	
	Kars District	
	Armenia	
	Caucasus, Georgia, Iran	
	SW. Arabia	
	Japan	
Oceania	Indonesia	
	New Zealand	
Africa	Tibesti (Libya, Chad)	
	Abyssinia	
	Kenya	
America	California, U.S.A.	Widespread Occurrence
	Nevada, U.S.A.	
	Oregon, U.S.A.	
	Mexico	
	Guatemala	
	El Salvador	
	Peru	

TABLE 3

VARIETIES OF OBSIDIAN PARTIALLY USED AS GEMSTONES (BY NAME)

'Snowflake' or *'Flowering' Obsidian*	black with numerous grey-white spots due to gas cavities (California, Yali)
'Mountain Mahogany'	brown-grey stripes
'Chatoyant' Obsidian	iridescent in various colours due to inclusions
Marekanite	transparent, partially coloured obsidian, globes of perlite (see below), named from the Marekanka River near Ochotsk in East Siberia
'Tokaj Deluxe Sapphire'	brown-black (Tokaj, Hungary)
Also:	
Perlite	rock glass that, due to internal tension, decomposes into little globes
Pitchstone	obsidian dissolved as a result of water absorption, partially re-crystallized

the seventh to the fifth millenia B.C. Indeed, aside from rock salt, obsidian was probably the first article of trade, at least in that geographical area. In the Mediterranean and the Near East obsidian was in wide use until well into the chalcolithic period. In other parts of the world it remained in use almost until today. Throughout the pre-Columbian cultures of Central America and in the Indian cultures of California, for example, obsidian was an important raw material.

As mentioned above, these early cultures used obsidian to make weapons (chiefly arrow heads) and various kinds of tools (blades, sickles, saws, scrapers, drills, etc., but due to the brittleness of the material, however, it was not used for hammering or impact tools.) In addition, articles for everyday use, such as ornaments and religious objects, were fashioned from obsidian quite early. Grinding and polishing obsidian could transform it into—needless to say, rather dark—mirrors, and such mirrors were already to be found in the Late Stone Age in the ceramics of Çatal Hüyük in Asia Minor. Razors made of obsidian were still in use in the Aegean area during the Bronze Age.

Owing to the colour and brilliance of this natural glass, obsidian also came into use as a gemstone (see Table 3): and what considerable knowledge and skill in handling this hard and brittle material that required! Yet pre-Columbian Mexico, in particular, achieved extreme technical perfection, as is evidenced by a large number of sculptured and relief figures and personal ornaments.

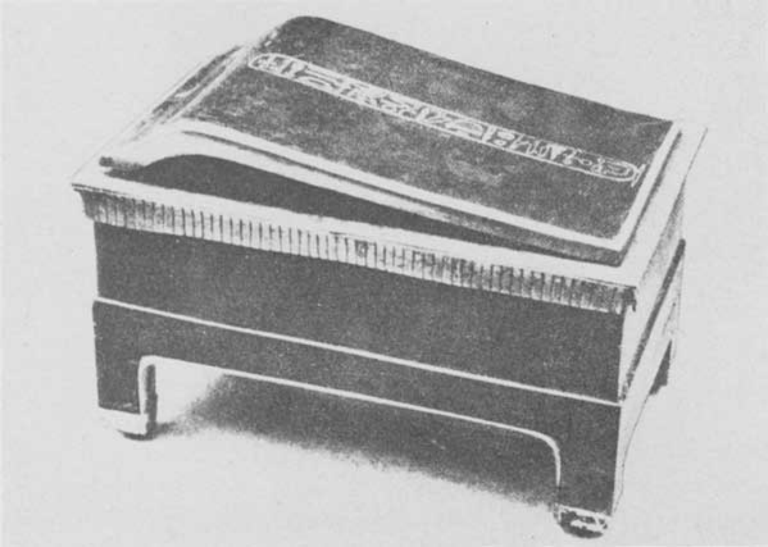


FIG. 1. Egyptian jewellery box made of obsidian with hieroglyphic inscription and golden appliqué. (*Byblos/National Museum, Beirut.*)

Obsidian artefacts were by no means lacking in the early cultures of the Near East either, but they appear to have been less common. A high point in obsidian handicraft was reached in Egypt, however, during the second millenium B.C., when obsidian pieces of absolute perfection were made, especially vessels and sculptures (see Figure 1). We know of obsidian vessels from Crete as well (Figure 2), and through Pliny we know of obsidian sculptures in ancient Rome. Not only have fragments of such works been actually found in Rome, but also diggings in the ancient Italian town of Stabiae have uncovered obsidian vessels which provide impressive proof of artisans' skill in working with the material during the Roman Empire (Figure 3).

FIG. 2. Minoan chalice of 'snowflake' obsidian. (*Palace of Kato Zakro, Heraklion/National Museum, Crete.*)

FIG. 3. Richly decorated cup made of obsidian, from Imperial Rome. (*Stabiae/National Museum, Naples.*)

For a rather long time it was customary in ancient Greece to employ obsidian as pupils for the eyes of statues and portrait-busts that were made of other materials. During the archaeological investigation of Phidias' workshop obsidian scraps were found, which suggest that Phidias probably also used obsidian for his great statue of Zeus with its lustrous surface of gold and ivory. Stonecutters in antiquity sometimes used obsidian for making seals and gems—infrequently, and probably first in Assyria, but we have proof also of their perfection in manipulating this and other extremely brittle materials.

Yet this highly developed technique of tooling obsidian was somehow lost in the late periods of antiquity. Obsidian thus disappeared from the palette of minerals and rocks used for decorative purposes, not to reappear until its use as jewellery for mourning in quite recent times. The current use of synthetic black glasses for such jewellery today, however, has once more pushed obsidian back into oblivion. As a result the gemmologist's interest in obsidian will, in general, remain restricted to historical objects for which he may receive enquiries as to origin and genuineness.

The assignment of an obsidian artefact to a particular culture must first be made on the basis of stylistic considerations. But in the case of tools such classification may well present problems, especially as the purpose of the tool and the properties of the material largely determined the form of the tool without regard to the peculiarities of the individual culture.

For exact determination of origin the chemical compostion or typical physical characteristics of the artefact (Table 4) must be compared with those of the other possible source-localities. The prerequisites for such comparisons are:

1. that the composition and characteristics of obsidians from the localities in question are known;
2. that the obsidians from such sources differ so greatly from group to group (as to composition and properties) that they are recognizable as being of specific types; and
3. that the various sample pieces from each place of origin are so homogeneous that variation in composition and properties for the one source-locality is small in comparison with variations found in pieces of different origins.

Until the present, determination of the origin of obsidian artefacts has been made almost exclusively on the basis of the traces of the other chemical elements they contain. Incidentally, this has shed light on a large number of prehistoric trade routes, particularly in the Mediterranean area and in the Near East. The methods used for determination (optical spectroscopy and neutron activation analysis), however, still remain the preserve of special laboratories and are largely or completely non-destructive.

As yet there have been practically no investigations of homogeneity in the distribution of trace elements for the various source localities. Indeed, hardly any locality has been subjected to thorough geochemical exploration to date, although it might well reduce the value of many existing expertises on origin.

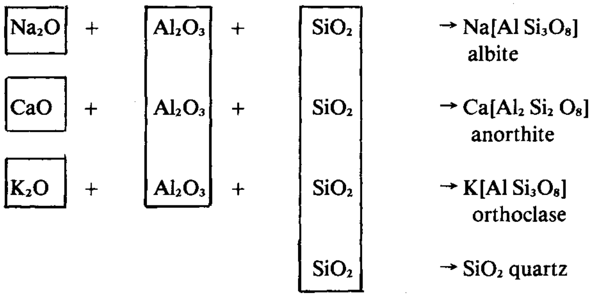
More recent studies have revealed that the relative contents of the major components (SiO_2, Al_2O_3, CaO, K_2O, Na_2O) may be put to very good use in establishing the chemical peculiarities of the various localities of occurrence. Genetically, these substances, together with a few secondary elements (Fe, Ti, Mn, Mg, P), are closely connected with the magmatic development of the respective

TABLE 4

DETERMINATION OF ORIGIN OF OBSIDIAN PIECES

Possible by

1. *The Chemical Composition*
1.1 Major Components
(Si, Al, Na, K, Ca)
Calculation of the normative minerals content



☐ means total amount of respective oxide in the analysis

Concentration Diagrams: 1. orthoclase-anorthite-albite,
2. quartz-albite-anorthite.

1.2 Secondary and Trace Elements (Geochemical Fingerprinting)
For example: Fe, Ti, Mn, P
Ba, Zr, Y, Nb . . . .

Correlation Diagrams Showing Elements in Characteristic Pairs

2. *Physical Properties*
depending upon the chemical composition and characteristic for distinct Obsidian source localities (Colour, Fluorescence, crystalline and non crystalline inclusions).

3. *Geological Age and/or Age of Manufacture of the artefact.*

TABLE 5

Chemical Composition of Obsidians

Rhyolitic Obsidians
correspond, in their composition, to the effusive rocks Quartz porphyries/rhyolites and the deep-seated aplitic granite.

		Wt %
SiO_2		70-76
Al_2O_3		10-17
K_2O		1-7
Na_2O		3-7
Fe_2O_3	Less than	2.5
FeO	”	1.5
CaO	”	1.5
MgO	”	0.5
TiO_2	”	0.5

Rarer Obsidians

Dacitic Obsidians
correspond to the partially crystalline effusive rock dacite and the plutonic Quartzdiorite.

	Wt %
SiO_2	55-70

Trachytic Obsidians
correspond to the partially crystalline effusive rock trachyte and the plutonic Syenite.

	Wt %
SiO_2	50-65

volcanic areas so that it is also possible to distinguish between localities even if they lie close together either in time or space (Table 5).*

Studies not only of the chemical but also the physical peculiarities—colour, light-absorption, perhaps also fluorescence, Mössbauer spectrum, devitrification tendencies (crystallites), gas and liquid constituents—can give indications of the individual source localities. As yet, however, there have been no systematic studies made in this direction either.

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*cf. H. G. Büchholz and E. Althaüs, *Archäologische Obsidian-forschüngen*, vol. 1, Nisyros-Giali-Kos, pp. 66-77, Verlag Philipp von Zabern, Mainz, 1982. [Also cf. R. E. M. Hedges, (1980), Archaeological Evidence from Chemical Analysis, *Science & Industry*, **15**, 12-15.—Ed.]

Megascopic observations of colour and surface properties (Table 6), though quite typical for individual localities (for example, for the locality of Nychia on the Isle of Melos), in general do not suffice for exact determination of origin.

TABLE 6

OBSIDIAN: MEGASCOPIC PECULIARITIES

Colour	black, grey, brown, reddish, greenish, white, colourless (seldom) Colour Distribution: even, cloudy, doughy, spotted, striped, opaque, visible at edges, transparent (seldom)
Lustre	glassy, mother-of-pearl
Tenacity, Fracture	brittle, conchoidal, splintery, upon mechanical stress (impact, pressure) forms extremely sharp edges
Hardness	6 on Mohs's scale, may be compared with Cr Ni-steel
Density	2.3-2.5 g cm^{-3}, depending upon composition, gas bubbles and included crystalline bodies
Refractive Index	1.45-1.55

In addition, the geological age of an obsidian, meaning the length of time that has passed since its magmatic solidification, can also aid in determining its origin (Table 7). Methods for establishing the age of an obsidian are the dating of

1. fission tracks,
2. thermoluminescence.

They are based on changes in the glass base (1) and crystalline inclusions (2) under the influence (in ppm) of ever-present radioactive elements, particularly of uranium, and they presuppose similar findings in age tests of the localities in question. Yet, due to the relatively large test quantity required (approximately 1 cm^3), these methods may hardly ever be applied in the case of very valuable artefacts.

TABLE 7

DETERMINATION OF AGE OF OBSIDIAN

Geological Age (Time of Genesis)

1. Fission Track Dating

    Exposure of radiation damage (by etching)

    Comparison of the spontaneously formed fission track density with that which has been induced (by defined neutron radiation in the reactor)

    Absolute method in range 10^2 to 10^7 years, depending upon uranium content.

2. Thermoluminescence Dating

    Release, through heating away, of energy stored in the radiation damage (glow curve), comparison of spontaneously formed thermoluminescence with that which is induced (by defined neutron radiation)

    Method for absolute age of minerals, ceramics, slags; applicable for obsidian as well as under certain conditions.

Note:

Both methods reveal the last time of use of an artefact which—for example, during a catastrophic fire—has been heated above 500 °C. In this case the fission tracks and the thermoluminescence (acquired as a result of irradiation during geological times) are removed.

Age of Genesis or Manufacture

3. Dating Hydration Layer Thickness

    Measurement of thickness (which is dependent upon the time, climate and soil) of hydration layers.

    Geological age since formation of unchanged surfaces.

    Age of artefacts and scraps (from time in which they originated).

Note:

Relative method, especially for distinguishing archaeological objects from recent copies.

The investigating methods discussed so far make it possible—at least in principle—to determine the origin of an obsidian artefact, and, as already described, origin, in turn, is especially important in answering questions concerning cultural history through geographic location of places in which obsidian was won and tooled in antiquity and in earlier prehistoric times and of where trade was undertaken with this highly cherished material.

The period in which obsidian artefacts were made is also interesting from the historical viewpoint, and such knowledge becomes essential when historic obsidian objects are to be distinguished from later copies.

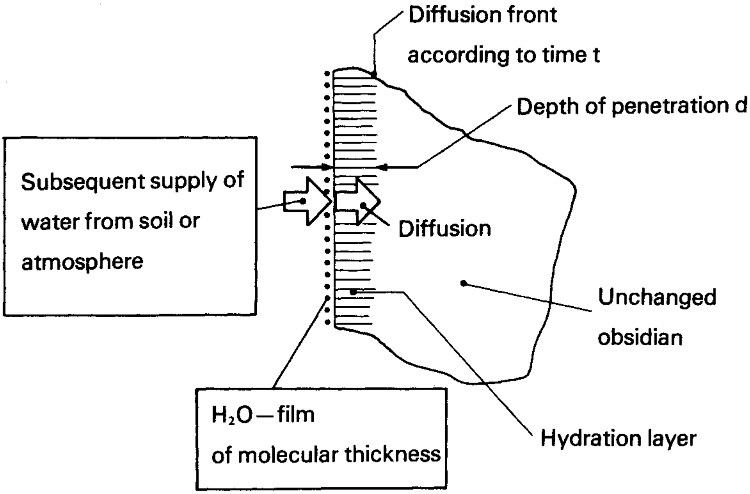

FIG. 4. Schematic Representation of the Formation of a Hydration Layer in Obsidian by Way of Diffusion of the Solid.

One possibility of dating artefacts made of obsidian is based on the observation that all obsidians absorb water from their surroundings and change—from the surface inward—in a characteristic way. That is to say that on the surface a hydration layer is formed, which grows in thickness according to a simple time law (Figure 4).* Hydration begins—*in situ*—with the cooling of the surface of the lava flow. When artefacts are made, it begins

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*The thickness of hydration layers grows according to a simple formula:

$$d = \sqrt{\ } k.t$$

with thickness d (in µm)
time t (in years) and
diffusion coefficient k

$$k = A.e^{-E/RT}$$

with the hydration temperature T (in K), the general gas constant R, the energy of activation of the diffusion E (in k cal/mol), the coefficient A.
A and E depend upon the physico-chemical properties of the obsidians.
The two coefficients may be experimentally determined for each kind of obsidian by diffusion.
[Calorie (cal) is not a S.I. unit but equals 4.184 J.—Ed.]

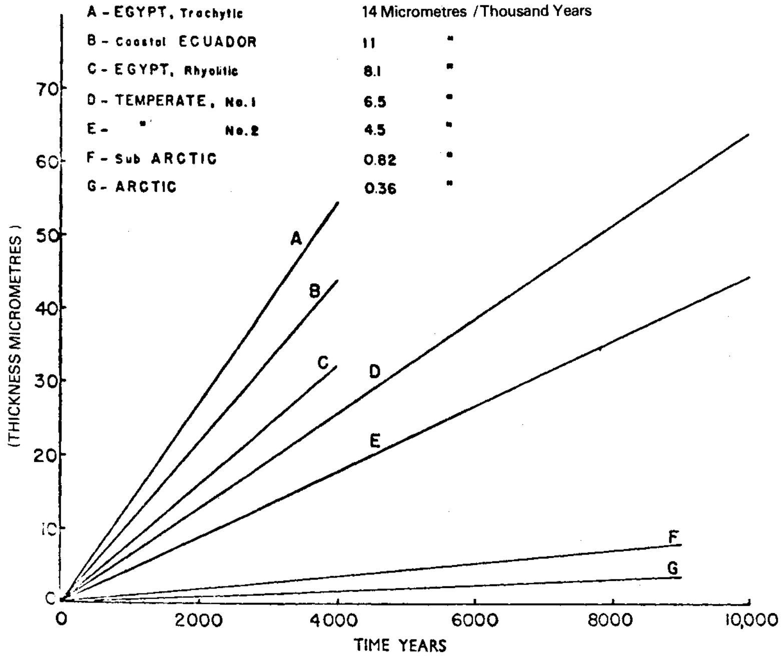


FIG. 5. Influence of climatic conditions on the hydration speed of obsidians (according to I. Friedman and R. L. Smith, 1960, *Am. Antiquity*, 25, 476-522.)

at the moment at which a fresh surface is formed—either on the artefact or on the residual scrap—as a result of the work procedure. Once the artefact is buried in the earth, hydration continues until the piece is recovered by the archaeologist.

Depending upon the temperature and the chemical composition of the soil, the thickness of the hydration layer may amount to 0.2 to 4μm in 1000 years. Once a petrological thin section has been obtained by cutting vertically into the surface, the thickness of the hydration layer may be measured directly under the polarizing microscope. When such a layer is totally missing, it is an indication of fresh surfaces, in other words, of recent origin.

Obsidian dating by determining the thickness of hydration layers is a comparatively recent method of establishing age (Figures 5 and 6). It was developed around 1960 and is applied routinely in several laboratories in the United States, primarily in connexion with archaeological problems encountered in North and Central

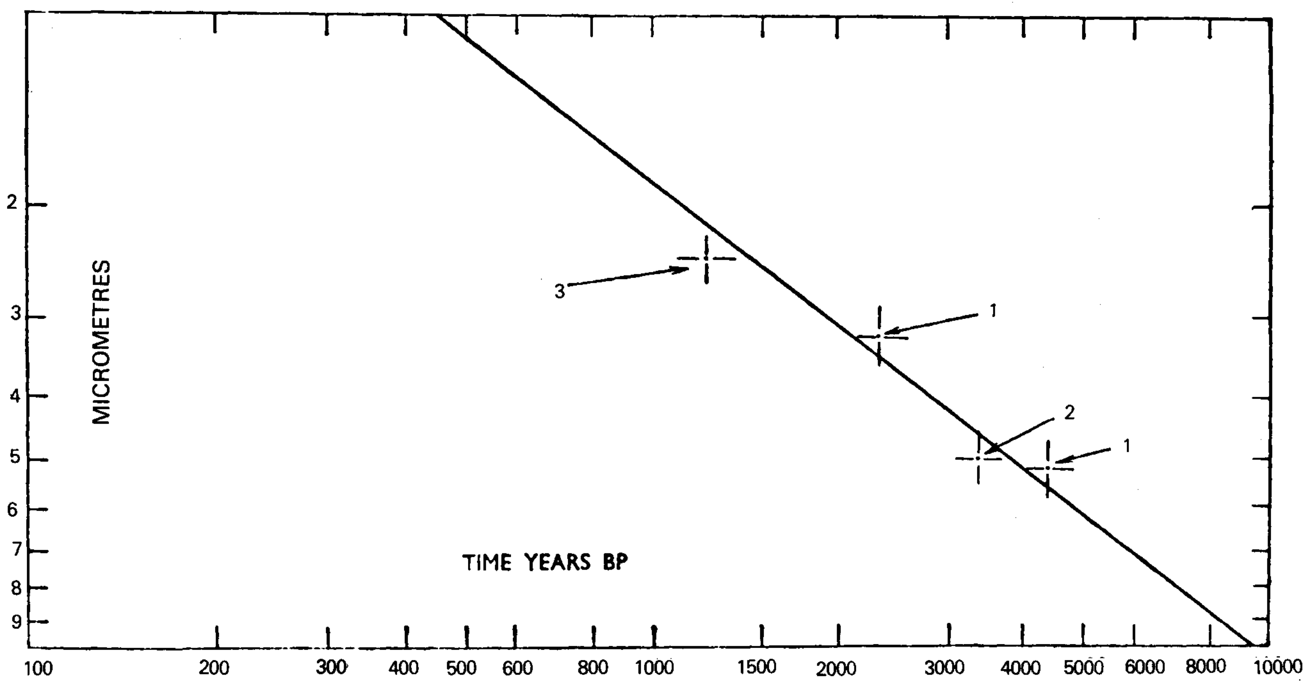


FIG. 6. Thickness of hydration layers on obsidian artefacts from California and absolute age of the respective strata, determined by the ^{14}C-Method (found in D. L. Clark, 'Arch. Chronology of California and the Obsidian Hydration Method' in *Ann. Report of the Arch. Survey*, Dept. of Anthropology, University of California, 1964.)

America. Due to the complex effect of soil temperature and chemical composition on the growth in thickness of the hydration layer, this method is not yet completely satisfactory for determining the absolute time of manufacture of an obsidian artefact. Yet coupled with radiocarbon dating, for instance, it nonetheless supplies valuable indications of the age sequence of strata between the various fixed points on the absolute time scale. Moreover, this method requires only modest test costs and equipment (tools for preparing the petrological thin section, and a polarizing microscope). Even more important: only very small test quantities (approximately 1 mm^3) are needed, so that even rather valuable artefacts can usually be tested.

Obsidian, a subject for gemmological research? Certainly not, when the obsidian is viewed from the standpoint of its value as a 'rough stone'. Yet, if we consider the properties of many obsidians, we might perhaps answer this question with 'Yes'. If we take the beauty of artefacts made of natural obsidian and their value to cultural history into account, we might well come to the conclusion that investigation of this volcanic glass would be a rewarding task—even for the gemmologist.

BIBLIOGRAPHY

Literature on obsidian as a material used in antiquity and in prehistoric time is extensive and widely scattered. A good summary may be found in:

R. E. Taylor, ed., *Advances in Obsidian Glass Studies.* Noyes Press, Park Ridge, N.J., U.S.A. 1976. See especially the article by J. E. Dixon, 'Obsidian Characterisation Studies in the Mediterranean and Near East', pp. 288-333.

On obsidian dating by the thickness of the hydration rings, see

J. W. Michels and C. A. Berbrich, 'Obsidian Hydration Dating' in *Dating Techniques for the Archaeologist,* M.I.T. Press, Cambridge, Mass, U.S.A., 1971.

[*Manuscript received 9th November, 1981.*]

GEMMOLOGICAL ABSTRACTS

ANDERSON (J. E.). *Green fire from the Antarctic.* Lapidary J., **37**, 1, 84-6, 4 figs (3 in colour), 1983.

Peridot from the Antarctic is described: the location is Ross Island. M.O'D.

ANDRYCHUK (D.). *Measuring parameters characterizing gemstone performance.* Lapidary J., **37**, 3, 468-74, 8 figs, 1983.

Brightness, brilliance, dispersion, sparkle, life and fire are the areas for which parameters are determined for diamond, YAG and quartz. M.O'D.

ATKINSON (D.), KOTHAVALA (R. Z.). *Kashmir sapphire.* Gems & Gemology, **XIX**, 2, 64-76, 13 figs in colour, 1983.

An account of the history, geology and locality of the sapphire mines in Paddar in the Zanskar [Zaskar?] Range. The writers succeeded in visiting these in 1981. Sapphires have been found in weathered feldspar, or china clay, and in unweathered pegmatites. Mine areas are in high, very difficult terrain, just below the snow line and some 110 km from any proper road. The journey in took eight days in this expedition. Sapphires are not now being produced due to the difficult terrain and to the political situation in that part of the sub-continent. Mines are small and have been worked by hand in the past, although much blasting has been used more recently. Associate gems are beryl and tourmaline, but these appear to be rarer than the sapphires. Writers consider that the region still has undiscovered sources of fine sapphires. R.K.M.

BANK (H.). *Durchsichtiger Lazulith oder Scorzalith aus Brasilien.* (Transparent lazulite or scorzalite from Brazil.) Z.Dt.Gemmol.Ges., **32**, 1, 6-9, tables, bibl., 1983.

Transparent to translucent light and dark blue, even green, members of the isomorphous series lazulite-scorzalite are described and physical properties including x-ray powder data given. They can be distinguished from each other easily by optical and chemical investigation (due to their isomorphous replacement of Fe and Mg) but only with great difficulty by means of x-ray data. E.S.

BANK (H.). *Grüner, durchsichtiger, geschliffener Ludlamit.* (Green, transparent, cut ludlamite.) Z.Dt.Gemmol.Ges., **32**, 1, 75, bibl., 1983.

This is a short description under the 'gemmological short note' series. The stone was named in honour of Ludlam of London by Maskelyne and Field in 1877. It is a Fe-phosphate, monoclinic, H 3-4, SG 3.1, RI 1.653-1.693, double refraction 0.040. E.S.

Bracewell (H.). *Harts Range and beyond.* Wahroongai News, **17**, 2, 13-14, 1983.

A further instalment of the 'Round Australia' trip by the Bracewells. Zircon, beryl, garnets, epidote, sphene, kyanite, iolite, fluorite and others were found. R.K.M.

Bracewell (H.) *Kings Canyon—Henbury—Ayers Rock.* Wahroongai News, **17**, 2, 15, 1983.

Visits to geologically interesting tourist spots, but not gemmologically productive R.K.M.

Bracewell (H.). *The opal fields of Mintabie and Coober Pedy.* Wahroongai News, **17**, 3, 11-12, 1983.

240 km apart, these areas are the two biggest producers of opal in Australia, Coober Pedy being the larger of the two. Mining at Mintabie is mainly by bull-dozer after opal has been found by drilling. Mechanization leaves much opal in the huge mullock heaps, where 'noodlers' do well. Mintabie is owned by an aboriginal tribe. Information on Coober Pedy is sparse and the place seems to have been far from friendly. R.K.M.

Bracewell (H.). *The next epistle in the around Australia trip.* Wahroongai News, **17**, 6, 9-11, 1983.

Takes us from Mt Gunson to Adelaide and thence via Koppio to Port Lincoln and Elliston, to Ceduna and then West across the Nullarbor Plain to Eucla and eventually to Norseman. A further contribution to a long saga, a vastly entertaining account of an ambitious journey, visiting gem localities, museums and gemmologists on the way. R.K.M.

B[rown?] (G.). *The structure of synthetic non-silicate garnets.* Wahroongai News, **17**, 3, 15-16, 1 fig, 1983.

An attempt to explain how YAG and GGG and other synthetic 'garnets' conform to the structure of natural garnet. R.K.M.

Brown (G.). *Data on the Biron synthetic emerald.* Wahroongai News, **17**, 6, 23, 1983.

Information on a single example of a new high quality synthetic emerald from Australia. SG 2.68, RI 1.570-1.577, DR 0.007. Inert to UV, eye clean. This material would appear to be exceptional—better-looking than most natural emeralds.R.K.M.

Brown (G.). *Notes on the heat treatment of corundum.* Wahroongai News, **17**, 6, 15-18, 1983.

Summarizes available information on the heating of rubies and sapphires to improve colour, diaphaneity or asterism. R.K.M.

Brown (G.). *Supplement to Wahroongai News.* **17**, 5, 36pp, May 1983.

A compilation of available facts on rarer gem species—apophyllite, charoite, chlorastrolite, gypsum, hemimorphite, idocrase, lazulite, meerschaum, odontolite, pyrite and marcasite, smithsonite, sogdianite, steatite, stichtite, sugilite, thomsonite, tugtupite, violane and wardite. Some of these are 'way out' gems but the concentrated information is very valuable. R.K.M.

BROWN (G.). *Rhinoceros horn: some observations of use to the gemmologist.* Aust. Gemmol., **15**, 2, 38-43, 7 figs, 1983.

The rhinoceros is an endangered species in east Asia and Africa and is likely to become extinct because of demand in China and SE. Asian countries for its horn, which is valued, not as an aphrodisiac, but for anti-pyretic medical properties. Gemmological use is principally in carvings. H. 2, SG 1.30, RI (vague) 1.54; fluorescence, greenish-blue in long UV; microscope, oriented filaments incompletely fused together, probably related to hair. R.K.M.

BROWN (G.), BRACEWELL (H.). *Mt Isa iolite.—a preliminary note.* Aust. Gemmol., **15**, 2, 53-6, 7 figs in colour, 1983.

A report on samples from this region, mainly concerned with inclusions. Red haematite flake-like crystals appear to be common. [Abstracter reported these as a rare inclusion in Ceylon iolite in June 1955 (*Gemmologist*, XXIV, 110).] R.K.M.

BROWN (G.), MOULE (A. J.). *Gutta-percha—a rare organic gem material.* Aust. Gemmol., **15**, 2, 50-2, 3 figs, 1983.

A Victorian moulded cameo of this material is examined and discussed in detail. Moulded in two parts—surface painted black. H.2, SG 1.89, RI 1.58. R.K.M.

BROWN (G.), SNOW (J.). *The Regency synthetic emerald.* Aust. Gemmol., **15**, 2, 57-60, 8 figs, 1983.

This is the Linde synthetic now manufactured under licence by Vacuum Ventures Inc. Crystals and growth characteristics and four pictures of inclusions are given. Material is identical with the Linde product. H. 7-8, SG 2.68, RI 1.568-1.573, dagger-like and phenakite inclusions, strong red fluorescence. R.K.M.

CASSEDANNE (J.). *La mine de 'topaze' de la Fazenda Serra do Salto (Bahia-Bresil).* (The 'topaz' mine of Fazenda Serra do Salto, Bahia, Brazil.) Revue de Gemmologie, 75, 3-6, 8 figs, 1983.

Despite the name, the mineral produced at this mine in an area north-north-east of Brasilia, in the municipality of Licinio de Almeida, is not topaz but amethyst. Details of the occurrence and of the properties of the amethyst are given. M.O'D.

CLARE (S.). *What to facet—2.* Gems, **15**, 1, 13-14, 1983.

Deals with the selection of rough with particular reference to cleavage. M.O'D.

COLLINS (A. T.), THOMAS (M. F.), JORGE (M. I. B.). *Luminescence decay time of the 1.945eV centre in Type Ib diamond.* Journal of Physics C:solid state physics, **16**, 2177-81, 2 figs, 1983.

The luminescence decay time of the 1.945eV centre is determined as 13±0.5ns for natural Type Ib diamonds. The value for synthetic diamonds is slightly lower.

M.O'D.

CROWLEY (J. A.). *Axinite—old and new.* Lapidary J., **37**, 3, 444-8, 15 figs in colour, 1983.

Axinite has been found in California, the occurrence being discovered during the construction of the New Melones dam in Calaveras County. Some crystals are up to four inches in length, glassy in appearance and very clear. The colour is moderate to dark brown with purple as one of the dichroic colours. They occur in albite-axinite-quartz veins traversing dark metamorphic rock. Crystals from one part of the area have been found to be magnesium-rich ferroaxinite (dark violet-brown), while crystals from another part are lighter brown and manganese-rich ferroaxinite.
M.O'D.

CROWNINGSHIELD (R.). *Padparadschah: what's in a name?* Gems & Gemology, **XIX**, 1, 30-6, 7 figs in colour, 1983.

A rationalization of the use of this name derived from the Sinhalese word *padmaragaya* (lotus colour), concluding that an effort should be made to standardize the acceptable colour as pinkish-orange or orange-pink. Dark brownish-orange stones from East Africa would not qualify. Nomenclature is confused by the introduction of synthetics under this name. [And possibly by the fact that the lotus itself varies in shade?] R.K.M.

DAVIES (G.). *Diamond, strength in symmetry.* New Scientist, 1348, 638-41, 12 figs, 1983.

An interesting account of how diamond obtains its remarkable properties and of the uses to which they can be put. M.O'D.

DURAND (P.). *Amethyst, the royal gem.* Lapidary J., **36**, 11, 1824-6, 1983.

Reminiscences of a lapidary and notes on the availability of amethyst today.
M.O'D.

EBERT (J. M.). *Art Deco: the period, the jewelry.* Gems & Gemology, **XIX**, 1, 3-11, 9 figs (8 in colour), 1983.

Summarizes this rather indeterminate period in terms of the more unconventional jewellery designs it produced. R.K.M.

FRYER (C.), ed., CROWNINGSHIELD (R.), HURWIT (K. N.), KANE (R. E.). *Gem Trade Lab Notes.* Gems & Gemology, **XIX**, 1, 43-9, 21 figs (20 in colour), 1983.

A fine alexandrite cat's-eye, a carved diamond fish, a painted 'pink' diamond, and a natural one which became redder when heated, are described and a warning given on irradiation of diamonds of this colour. An emerald and diamond necklace, earrings and ring/pendant had as its largest stone a painted beryl which lost colour when steam-cleaned. Spicules seen in a low RI synthetic emerald were compared with rather similar tubules in a high RI natural emerald. A pale green fluorite, rose quartz and pearl necklace is described, as are 'buff-topped' garnet and green glass doublets. 'Buff-topped' means cabochon crown on a faceted base. A 1.5 carat orange-brown opal cat's-eye with a very strong eye is illustrated; a calcareous fossil trilobite suitable for jewellery use is also depicted. Flat button pearls on a brooch were mixed natural and tissue-nucleated and were compared with a large parcel of similar, flat-based, regular, fresh-water, tissue-nucleated cultured pearls of various colours; method of cultivating such regular shapes is not known. A hank of multi-coloured baroque seed pearls of a new type is causing identification problems. More button pearls of fresh-water origin were unmounted to find that they were tissue-nucleated, again by an unknown cultivation process, information is asked for. An unusually fine large quartz cat's-eye, and a ruby and synthetic ruby doublet were described; a blue spinel with a colour change to purple-blue in incandescent light was identified as natural spinel coloured by cobalt. An organic concretion found in a tin of tuna fish was not identifiable. R.K.M.

FRYER (C.), ed., CROWNINGSHIELD (R.), HURWIT (K. N.), KANE (R. E.). *Gem Trade Lab Notes.* Gems & Gemology, **XIX**, 2, 112-17, 22 figs (19 in colour).

Odd inclusions in diamond, 'seagull in flight', 'Thomas Jefferson's Head'; a painted (nail varnished) pink diamond which was switched for a genuine pink stone in a Sotheby Parke Burnet presale viewing, described and illustrated. A very thin rose diamond of 20 mm diameter was set with 'faceted' foil backing; cubic zirconias were submitted for diamond grading and an intense yellow diamond had a GIA certificate as a naturally coloured light yellow stone while spectrum showed 5920A line which proved that stone had been treated after the certificate had been issued.

New synthetic emeralds from Russia had whitish seed plates and appeared to be hydrothermal stones, but no UV fluorescence and little red through colour filter. RI 1.572-1.580 gives exceptionally high DR of 0.008. SG 2.67.

A dyed turquoise-blue jadeite, a black opal naturally embedded in a yellow brown white opal with little play of colour, from Lightning Ridge; a black non-nacreous pearl with 'fur-like' markings and a bald patch, all described and illustrated. Early mabe pearls on a choker necklace had unusual structure and could be from around 1890: they did not fluoresce under x-rays. A large green quartz of good colour was thought to be naturally coloured; a faded natural yellow sapphire (over-heated) was restored by exposure to x-rays, and colour is (hopefully) permanent; two taaffeites are illustrated. Two different imitations of turquoise are discussed, one with RI 1.58 or 1.59, SG 2.35, was dyed gibbsite, the other, RI 1.57, SG 2.27, was a mixture of materials, mainly quartz and zinc oxide; neither exhibited any absorption spectrum. R.K.M.

GREENBERG (E.), KATZ (G.), REISFELD (R.). *Radiative transition probabilities of Er^{3+} in yttria stabilized cubic zirconia crystals.* J. Chemical Physics, 77, 10, 4797-803, 1982.

The method of growing ZrO_2:Er by the skull-melting technique is described. Eigenvectors for Er in the range 330-1700 nm were calculated together with the transition matrix between each pair of electronic levels. Possible laser levels are indicated. M.O'D.

GÜBELIN (E.). *Genetische Aspekte der Mineraleinschlüsse in Farbsteinen.* (Genetic aspects of mineral inclusions in coloured stones.) Z.Dt.Gemmol.Ges., **32,** 1, 10-27, 33 figs (30 in colour), bibl., 1983.

In addition to giving character to the interior of gemstones their inclusions are essential witnesses to genetic conditions and processes in the silica zone of the earth. The guest minerals are primary phases of information because they have been effectively armoured against alien external influences, retaining their original condition. Investigations have been made into inclusions typical of definite phases of formation or shedding light on the complex correlationship during crystal growth under varying conditions. Local conditions could be observed and influence of syngenetic inclusions on form and habit and alien coloration of host gem could be examined and described. Notes on localities of finds are included. E.S.

GUNAWARDENE (M.), MERTENS (R.). *Japanische Opalimitationen aus Plastik.* (Japanese opal imitations made of plastic.) Z.Dt.Gemmol.Ges., **32,** 1, 59-68, 12 figs (6 in colour), bibl., 1983.

The plastic opals are made of styrene-divinyl-benzene-copolymer and polymethyl methacrylate. The effect of play of colour and manufacturing methods are described, as are physical constants. There is no sharp dividing line between the various colours. There are some tension knots together with stretched gas bubbles. SG 1.19 ± 0.01, RI 1.485 ± 0.005. The opals are offered under the names of 'pastoral opal' and 'neo-noble opal'. Fire opal is made by the addition of orange colour to the resin. There are also doublets of these materials on the market. E.S.

HANNEMAN (W. W.). *A new classification for red-to-violet garnets.* Gems & Gemology, **XIX,** 1, 37-40, 4 figs, 1983.

A slightly contentious paper which argues rather against the classification of pyrope/almandine garnets proposed by Manson/Stockton. R.K.M.

HÄNNI (H. A.), KEREZ (C. J.). *Neues vom Smaragd-Vorkommen von Sta. Terezinha de Goiás, Goiás, Brasilien.* (News from the emerald find of St. Terezinha de Goiás, Goiás, Brazil.) Z.Dt.Gemmol.Ges., **32,** 1, 50-8, 12 figs in colour, 2 tables, bibl., 1983.

Emerald crystals and rock samples from the new mining area of St Terezinha have been investigated by optical methods and by microprobe. The emeralds are characterized by inclusions of dolomite and picotite. The first discovered southern part is not worked any more, as 500 m north better material is found. The area is subdivided into many small claims (40-50 m^2). The rock is loosened by explosion, winched up and taken by lorry to the washes in the Rio Peixe. No production during the rainy season. RI 1.585-1.587, 1.592-1.595, double refraction 0.006-0.008, SG 2.752-2.764. Many crystals show internal fractures, but there are no liquid films or feathers. E.S.

HÄNNI (H. A.), KLEIN (H. H.). *Un gisement d'émeraudes à Madagascar.* (A madagascan emerald location.) Revue de Gemmologie, 74, 3-5, 4 figs, 1983.

French translation of a paper first appearing in *Z.Dt.Gemmol.Ges.,* **31,** 1/2, 71-7, 1982, and abstracted in *J.Gemm.,* **XVIII,** 6, 568, 1983. M.O'D.

HARDER (H.). *Qualitäten und Schönheitskriterien bei Edelopalen.* (Quality and beauty criteria for precious opal.) Aufschluss, **34**, 3, 121-33, 4 figs (3 in colour), 1983.

The main types of precious opal coloration are reviewed and their commercial significance assessed. M.O'D.

HEYLMUN (E. B.). *Map of the Queretaro opal mines, Mexico.* Lapidary J., **37**, 2, 344-5, 1 fig, 1983.

A useful map of the area with each mine marked. M.O'D.

HOOVER (D. B.). *The Gem Diamondmaster and the thermal properties of gems.* Gems & Gemology, **XIX**, 2, 77-86, 4 figs (2 in colour), 1983.

Describes the Australian made instrument which, like others, measures thermal inertia, and discusses the possibility of extending the use to discriminate between gems of different species and similar colour. Instrument is intended only to identify diamond and reject other species. Care is needed if its use is to be extended in this way and points to watch are given. R.K.M.

JAYAKODY (D. F.). *Taaffeite—a rare gemstone of Sri Lanka.* Lapidary J., **37**, 1, 74-8, 3 figs, 1983.

The discovery of taaffeite and its properties are described. M.O'D.

KELLER (P. C.). *The Capao topaz deposit, Ouro Preto, Minas Gerais, Brazil.* Gems & Gemology, **XIX**, 1, 12-20, 11 figs in colour, 1983.

An account of the history, geology and mining methods in one of the principal 'Imperial' Topaz mines of this small area. R.K.M.

KELLER (P. C.). *The newly expanded Deutches Edelsteinmuseum of Idar-Oberstein, Germany.* Gems & Gemology, **XIX**, 2, 97-102, 7 figs in colur, 1983.

An account of the new and greatly improved museum display at this important gem-cutting centre. Claimed to be one of the best of its kind in the World. R.K.M.

KOIVULA (J. I.), FRYER (C.), KELLER (P. C.). *Opal from Querétaro, Mexico: Occurrence and inclusions.* Gems & Gemology, **XIX**, 2, 87-96, 16 figs in colour, 1983.

Describes this important source of Mexican opal with fine colour play and illustrates in some detail a wide variety of volcanic inclusions found in these stones. R.K.M.

KRASHES (L. S.). *Harry Winston: a story told in diamonds.* Gems & Gemology, **XIX**, 1, 21-9, 6 figs in colour, 1983.

A brief account of the late Harry Winston and of some of the exceptional diamonds bought and sold by him. R.K.M.

LAURENCE (C.). *£5m bids invited for diamond heart.* Daily Telegraph, No. 39,871. pp.1, 32, 1 photo, 25th August, 1983.

Bids of at least £5m are invited by Graff's, Knightsbridge, for a 70.03 ct heart-shaped diamond, presently called Le Grand Coeur d'Afrique. The rough from which it was cut weighed 278 ct and was found in Kankan, [Guinea,] West Africa. Cut in New York, it yielded also a 14.25 ct gem (sold in New York) and a second heart-shape of 25.22 ct, called Le Petit Coeur. J.R.H.C.

LEAMING (S.). *A jade update from British Columbia.* Lapidary J., **37**, 2, 384-6, 1983.

The author states that there are jade fields in British Columbia other than the well-known Fraser river areas. Much nephrite now comes from the Cassiar jade field in the far north of the Province and another field is being worked in the Yukon Territory. M.O'D.

LIND (Th.), SCHMETZER (K.), BANK (H.). *Zur Bestimmung natürlicher, behandelter und synthetischer Türkise sowie von Türkisimitationen.* (On the determination of natural, treated and synthetic turquoise and turquoise imitations.) Z.Dt.Gemmol. Ges., **32**, 1, 69-74, 2 tables, bibl., 1983.

For the investigation of natural, treated, synthetic and imitation turquoise a combination of infrared spectroscopy and x-ray powder diffraction methods is suggested. Both these investigations can be done with a small quantity (3 mg) of the specimen. Some colours and lacquers are dissolvable in water or fat, paraffin can be got rid of by heating and turquoises are sometimes hardened, i.e. stabilized, with colourless or dyed synthetic resins or inorganic substances. In all these instances, light stones tend to darken. E.S.

McLAREN (A. C.), COOK (R. F.), HYDE (S. T.), TOBIN (R. C.). *The mechanisms of the formation and growth of water bubbles and associated dislocation loops in synthetic quartz.* Physics and Chemistry of Minerals, **9**, 2, 79-94, 21 figs, 1983.

TEM has been used to monitor the development of water bubbles in synthetic quartz by studying the intensity of the light scattered and the increase in volume of the crystal, both as a function of temperature and time. M.O'D.

MANSON (D. V.), STOCKTON (C. M.). *A response to 'A new classification for red to violet garnets'.* Gems & Gemology, **XIX**, 1, 41-2, 1983.

Denies some of Dr Hanneman's contentions and underlines the fact that the investigation of garnets by these authors is not yet complete. R.K.M.

MEEK (J. H.). *Gems, minerals and artifacts in the panhandle of Texas.* Lapidary J., **37**, 2, 316-27, 13 figs in colour, 1983.

The principal ornamental materials found in the area are Alibates flint/agate and quartz; examples of their use are given. M.O'D.

MITCHELL (J. R.). *An extensive agate deposit near Carter, Wyoming.* Lapidary J., **36**, 12, 1964-6, 11 figs (5 in colour), 1983.

Multi-coloured agate and some cornelian are found on a number of sites near Carter, Wyoming, U.S.A. Some of the material is of fashioning quality. M.O'D.

MITCHELL (R. K.). *The visual detection of Gilson 'lapis'.* Wahroongai News, **17**, 6, 7, 1983.

A brief exposition of the subtle visual differences between this artificial material and natural lapis which are quite sufficient to distinguish between them.

(Author's abstract) R.K.M.

NELSON (R. S.), HUDSON (J. A.), MAZEY (D. J.), PILLER (R. C.). *Diamond synthesis: internal growth during C ion implantation.* Proc. Roy. Soc. London, A386, 211-22, 9 figs, 1983.

A new technique for the synthesis of diamond relies on the creation of extra diamond lattice planes within the bulk crystal. High energy carbon ions are implanted into the crystal which needs to be heated for the process to succeed. Carbon ions of this energy (e.g. 20 keV) finish up many atomic layers below the surface and if they take up positions in conformity with the surrounding lattice will give diamonds synthesis. One disadvantage of the process is that irradiation with ions of this type of energy may lead to sputtering and to radiation damage which could limit the growth of crystalline material. M.O'D.

O'DONOGHUE (M.). *Industrial review:gemstones.* Encyclopedia Britannica Book of the Year, p.439, 1983.

Prices fell generally, diamonds of lower grades suffering most. In general, coloured stones have kept their price in the higher qualities. Treatment of diamond is still giving trouble. (Author's abstract) M.O'D.

O'DONOGHUE (M.). *The carbonate group of minerals—5.* Gems, **15**, 1, 33-4, 1 fig., 1983.

Some of the rarer carbonate minerals are discussed, including gaylussite, northupite and parisite. (Author's abstract) M.O'D.

O'DONOGHUE (M.). *The dealer looks at gemstones—9.* Gems, **15**, 1, 30, 1983.

Discusses a report from the Bourse at Idar-Oberstein in which the prices and availability of ruby, emerald, tsavolite and tourmaline are mentioned.

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

O'DONOGHUE (M.). *Franklin, the Mecca of fluorescent minerals.* Gems, **15**, 1, 21, 1983.

A history of the activities of the New Jersey Zinc Company who worked the mines at Franklin, New Jersey, until 1954, with some notes on the minerals found.

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

O'DONOGHUE (M.). *The carbonate group of minerals—6.* Gems, **15**, 2, 29, 1983.

The minerals stichtite and siderite are among those discussed. Constants and occurrences are given. (Author's abstract) M.O'D.

O'DONOGHUE (M.). *The dealer looks at gemstones—10.* Gems, **15**, 2, 35-6, 1983.

Details of the operation of the gem trade are given, with some notes on current prices and trends. (Author's abstract) M.O'D.

PEARSON (G.). *X-irradiation of spodumene.* Aust. Gemmol., **15**, 2, 45, 1983.

A colourless crystal irradiated with white x-rays for two hours became light green to a depth of about 4 mm on the side exposed and an odour of ozone was detected, possibly due to generation of short ultraviolet. Yellow and orange phosphorescence was observed to last for about three minutes. Induced colour faded completely after one day's exposure to sun. R.K.M.

PFAFFL (F. A.). *Topaz aus dem Fichtelgebirge.* (Topaz from the Fichtelgebirge.) Mineralien Magazin, **7**, 4, 183-5, 3 figs (2 in colour), 1983.

Light blue crystals of topaz showing good crystal form have been found in the Fuchsbau quarry near Leopoldsdorf in the Fichtelgebirge, West Germany. Yellow crystals are also known from the area. M.O'D.

READ (P.). *The Finsch diamond mine.* Australian Gem & Treasure Hunter, 78, 29-31, 2 figs, 1983.

Account of a visit to the Finsch mine 100 miles north-west of Kimberley, South Africa. M.O'D.

READ (P.). *The Kimberley Mine revisited.* Gems, **15**, 1, 22-4, 8 figs, 1983.

The Open Mine Museum constructed round the 'Big Hole' at Kimberley, South Africa, contains many relics of the original diamond workings and commercial activities of the 1870s. M.O'D.

ROBERTSON (A. D.). *Gem azurite from the Eclipse Mine, Muldiva-Chillagoe area, Queensland.* Aust. Gemmol., **15**, 2, 46-9, 3 figs in colour, 1983.

Fine azurite crystals found in abandoned silver mine. Divided into three crystal (habit) groups, none of which seem to conform with mineralogies consulted. This is chessylite and the expected replacement by malachite was found in some crystals. [Some crystal descriptions are puzzling, e.g. 'The dominant termination . . . . . is the prism (110)'.] R.K.M.

SATO (K.), SUNAGAWA (I.). *Quantitive evaluation of colour of diamonds by spectrophotometric method.* J. Gemm. Soc. Japan, **9**, 4, 8-16, 13 figs, 1982.

A spectrophotometer is used to evaluate the colour of a diamond in place of the eye. Absorption coefficients of colour-graded stones are measured and placed on a chromaticity diagram, enabling a correlation between the positions thereon and a conventional grading scale to be plotted. M.O'D.

SCHMETZER (K.). *Taaffeit oder Taprobanit—ein mineralogisches Nomenklaturproblem.* (Taaffeite or taprobanite—a mineralogical nomenclature problem.) Z.Dt.Gemmol.Ges., **32**, 1, 39-49, 8 figs (6 in colour), 3 tables, bibl., 1983.

An English version of this article was published in *J.Gemm.*, 1983, **XVIII**, 7, 623-34. E.S.

SCHMETZER (K.), BANK (H.). *Investigation of a cat's-eye scapolite from Sri Lanka.* Gems & Gemology, **XIX**, 2, 108-10, 2 figs in colour, 1983.

Describes a scapolite with fairly coarse included needles of pyrrhotite which was cut to give a 1.68 carat cat's-eye with a rather broad, intense eye. RI 1.583-1.553, negative. SG not quoted. R.K.M.

SCHNEIDER (W. L.), DRÖSCHEL (R.). *Beobachtungen an polysynthetisch verzwillingten Quarzen—ein Beitrag zur Unterscheidung natürlicher und synthetischer Amethyste.* (Observations of polysynthetic twinned quartz—a help in distinguishing natural and synthetic amethysts.) Z.Dt.Gemmol.Ges., **32**, 1, 28-38, 13 figs (8 in colour), bibl., 1983.

Gem quality synthetic amethyst—unlike natural amethyst—does not show polysynthetic twinning. Simpler than by spectroscopic analyses of the infrared part of the spectrum, synthetic amethyst can be recognized by the different interference figure in convergent polarised light. By slight repolishing with a fine grit on a soft wheel at low speed it is possible to produce visibly twin lamellae of cut natural stone. Then lamellae can be seen in natural stone with the naked eye, while synthetic material offered in the trade shows no lamellae. A second polishing of the stone reproduced the perfect cut without noticeable loss of weight. E.S.

SIMON (R. E.). *Creativity in jade sequel.* Lapidary J., **37**, 1, 18-22, 20 figs (16 in colour), 1983.

An illustrated account of jade carving, principally in Burmese jadeite. M.O'D.

SPALL (K.). *Reflections of a Harts hound.* Wahroongai News, **17**, 2, 11-12, 1983.

An account of gem possibilities in the Harts Range. R.K.M.

STOCKTON (C. M.), MANSON (D. V.). *Peridot from Tanzania.* Gems & Gemology, **XIX**, 2, 103-7, 6 figs (4 in colour), 1983.

A new source of gem peridot, which was at first marketed as rough enstatite. Material is compared with peridot from other sources. It is less iron-rich than all but the Norwegian material. It is shown that percentage of iron does not relate to the depth of colour. R.K.M.

SUNAGAWA (I.). *Gem materials, natural and artificial.* Current Topics in Materials Science, **10**, 351-506, illus. in black-and-white, 1982.

A comprehensive survey of minerals with gem application and of similar man-made substances. M.O'D.

SWERSKY (A.). *The High Priest's breastplate.* Ariel, 54, 107-20, 4 figs (2 in colour), 1983.

The breastplate is described and illustrated and an attempt made to identify the stones in present-day nomenclature. M.O'D.

VAVILOV (V. S.), GIPPIUS (A. A.), DRAVIN (V. A.), ZAITSEV (A. M.), ZHAKUPBETOV (B. S.). *Cathodoluminescence of natural diamond associated with implanted impurities.* Soviet Physics: semi-conductors, **16**, 11, 1288-90, 3 figs, 1983.

Cathodoluminescence spectra of diamonds doped by ion implantation showed lines associated with luminescence centres containing Cr, Ni, Zn, Ag and Tl.

M.O'D.

WIGHT (W.). *Faceted wollastonite from the Jeffrey Mine, Asbestos, Quebec.* Can. Gemmol, **4**, 1, 13-15, 2 figs, 1983.

A white transparent wollastonite, H 4½-5, SG 2.8-3.09, RI 1.610-1.634, is found at the Jeffrey mine, Asbestos, Quebec, Canada. It occurs with vesuvianite and contains some liquid healing-feather inclusions and signs of incipient cleavage. A stone of 4.05ct cut from this material forms part of the collections of the National Museum of Natural Sciences, Ottawa. M.O'D.

YU (R. M.). *An ineffective optic-fiber reflectivity meter.* Lapidary J., **36**, 12, 2038, 1983.

A reflectivity meter employing fibre optic light transmission mechanism was tested and found to be inadequate because of poor physical condition (many of the fibres were broken in transit) and because it was found impossible to calibrate even for plane surfaces. M.O'D.

ZEITNER (J. C.). *Some magnificent beryls from the Proctor collection.* Lapidary J., **36**, 11, 1836-43, 5 figs in colour, 1983.

Brief and personal survey of the beryl gems with particular reference to those in the celebrated mineral collection formed by Keith Proctor. M.O'D.

ZIRLIN (S. H.,). *Hexagonite, New York State's purple tremolite.* Lapidary J., **36**, 11, 1864-7, 6 figs, 1983.

The purple transparent variety of tremolite is found in New York State and has occasionally been faceted. M.O'D.

Émeraude synthétique fabrication Lennix. (Synthetic emerald made by Lennix.) Revue de Gemmologie, 75, 2, 2 figs, 1983.

Details are given of a synthetic emerald with SG 2.652 ± 0.002, RI 1.563-1.565 and showing a bright red under the Chelsea filter. Characteristic inclusions from the flux-melt growth process can be seen. M.O'D.

World's Industrial Diamond Center. Lapidary Reporter, 283, 21-2, 1 June 1983. (Reprinted in Lapidary Journal, September 1983).

Antwerp is the centre of industrial diamond business. Three out of four diamonds mined go to industrial use, estimated 30-35 million carats a year, while synthetic products amount to about 50 million carats. Uses of industrial diamonds for different industries and the role of the Antwerp merchant are described.

J.R.H.C.

BOOK REVIEWS

ANDERSON (B. W.). See WEBSTER (R.)

BENDER (F.). *Geology of Burma,* vol. 16 of *Beitrage zur regionale Geologie der Erde.* (Contributions on the regional geology of the Earth) Gebrüder Borntrager, Stuttgart, 1983. pp.viii, 293. Price on application.

Though there are numerous references to the various gem materials found in the country, the whole book is a detailed exposition of its geology. A number of chapters have been farmed out to different authors. After a general introduction and a description of regional geology, stratigraphy, tectonics and magmatism are described. The book then examines economic geology with chapters on energy, metallic and non-metallic raw materials, water and soil. There is a very extensive bibliography with a locality index and subject index. A geological map is provided in a pocket at the back of the book and there are numerous black-and-white illustrations throughout the text. M.O'D.

BELYAEV (L. M.), ed. *Ruby and Sapphire.* Amerind Publishing Co., New Delhi, 1980. pp.xix, 443. Illus. in black-and-white. Price on application.

This is a long-awaited translation of *Rubin i sapfir,* first published in Moscow in 1974. This edition has been revised and enlarged and now contains almost all the information necessary for a complete study of the growth of corundum. The greater part of the book is devoted to a discussion of the characterization of corundum crystals and the associated techniques. Details of the various methods used to grow the crystals are given in the first part of the book. There is an extensive bibliography, with a preponderance of Russian items. M.O'D.

CHERNOV (A. A.), MÜLLER-KRUMBHAAR (H.), eds. *Modern theory of crystal growth I.* Springer-Verlag, Berlin, 1983. pp.146. DM88.

Forming No 9 of the series *Crystals:growth, properties and applications,* this book covers the melting and solidification of epitaxial structures and intergrowth compounds, with further chapters on the microscopic theory of the growth of two-component crystals and on the statistics of surfaces, steps and two-dimensional nuclei. The final chapter deals with surface and volume diffusion controlling step movement. These are quite hard concepts and an attempt is made to enhance our admittedly incomplete knowledge of how defects and dislocations are formed. Transport between growing crystal and liquid is still not fully understood, and the authors make it clear that impurities in a crystal may result either from the time scales of convection patterns or interplay between kinetic incorporation, diffusion and convection.

Each paper has its own bibliography, and the volume also contains a general index to vols 1-9 of the series. M.O'D.

McLintock (W. F. P.). *Gemstones in the Geological Museum.* Fourth edition, revised by P. M. Statham. H.M.S.O., London, 1983. pp.v, 81. Illus. in colour. £1.95.

Worthy if a little unadventurous update of an old classic of the enhanced handlist variety, this booklet is quite well produced, quite well written and quite well illustrated with the all-too-familiar photographs once beloved by all but whose power to charm is fast fading. The style is lumpy, capitalization capricious and not enough has been done to eliminate discredited and dated names. There should also be a much better bibliography. M.O'D.

Meyer (W.). *Geologische Wanderführer: Eifel.* (Geological guide to the Eifel.) Kosmos Franckh, Stuttgart, 1983. pp.111. Illus. in colour. DM29.50.

The Eifel region of West Germany is important to mineralogists for in it is the celebrated Laacher See district in which fine sanidine and some peridot with many rarer minerals can be found. Mining in the area dates from the earliest times and this beautifully-produced book includes not only geological features but a good deal of history, botany, palaeontology and architecture. M.O'D.

Ogden (J.). *Jewellery of the ancient world.* Trefoil Books, London, 1983. pp.185. Illus. in black-and-white and in colour. £30.00.

The aim of this book is to relate the jewellery of early periods to the materials available at the time and to the tools which could be employed. In this task the author succeeds, and though he claims that the work is inspired to a large extent by the work of others he is, I feel, a little modest since, though a good deal of information has been published on the use of metals in history (to take one example), it is notoriously difficult to track it down since almost all is contained in a very wide range of papers. However the author has tracked down what appears to be the bulk of important data and for this alone readers owe him a great debt. He has done more: the book is very well produced and there is a first-class bibliography, a feature notably lacking from a number of large books in the field. Introductory chapters introduce the metals from which artefacts are made and some attention is paid to relating refining methods to the ultimate appearance of the metal (particularly in the case of gold). Further chapters deal with gemstones and ornamental materials and the way in which they are fashioned, including engraving techniques. Throughout the book there are constant references to ancient authorities and, where necessary, their statements are translated into modern and understandable terms.

This book, not at all highly priced for the value of the information it contains, should become a standard reference work. M.O'D.

Sauer (J. R.). *Brazil, paradise of gemstones.* Sauer, Rio de Janeiro, 1982. pp.136. Illus. in colour. Price on application.

This is the best-illustrated book on gemstones that I have yet seen. Most of the photographs have been taken by the celebrated Los Angeles partnership of Erica and Harold Van Pelt, well-known to readers of *Gems & Gemology* and the *Mineralogical Record.* The details of current Brazilian mining are given and one or two of the mines are depicted; it is most useful to know the names and whereabouts of individual locations in the State of Minas Gerais, for example. There is a small glossary and a map at the end of the book, but it is to the superb photographs that the reader will return. M.O'D.

WEBSTER (R.). *Gems, their Sources, Descriptions and Identifications.* 4th edn, revised by B. W. ANDERSON. Butterworths, London, 1983. pp.XXII,1006. Illus. in black-and-white with 17 coloured plates. £40.

This new edition of Webster's *Gems* brought up to date by B. W. Anderson will be reviewed in the next issue of this *Journal.*

ASSOCIATION NOTICES

OBITUARY

Mr Wilbur E. Dyer, F.G.A. (D.1971), Joliet, Ill., U.S.A., died on 4th February, 1983.

Mrs Lorraine A. Jamieson (née Fish), F.G.A. (D.1974), London, died on 17th June, 1983.

Mrs Doreen Read, wife of Mr Peter G. Read, C.Eng., F.G.A., died on 23rd July, 1983, after a short illness: although her main contribution to gemmology was by way of typing and proof-reading her husband's many articles and books, and acting as his projectionist at Branch lectures, she was also an enthusiastic collector of thematic stamps covering gems, minerals and mining.

GIFTS TO THE ASSOCIATION

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

Mr R. Acker-Holt, F.G.A., London, for several star quartz cabochons for study purposes.

Mrs Lilian L. Jackson, F.G.A., Clarendon, South Australia, for two specimens of nephrite jade from Covell, Eyre Peninsula, South Australia.

NEWS OF FELLOWS

On 15th June, 1983, Mr David J. Callaghan, F.G.A., the Association's Chairman, was elected to the Livery of the Worshipful Company of Goldsmiths.

Mr David Crouchley, F.G.A., and Mr Douglas Wheeler, F.G.A., the Association's Assistant Secretary, were admitted to the Freedom of the Worshipful Company of Goldsmiths, on 18th May and 20th July, 1983, respectively.

On 28th May, 1983, Mr Alan Hodgkinson, F.G.A., gave two lectures entitled 'Diamond Close-up, including its uses in technology, in medicine and in space' and 'Sapphires and rubies—testing for origin and treatment' at the Professional Centre, Colombo, Sri Lanka, under the auspices of the Gemmologists' Association of Sri Lanka, with its Vice-Chairman, Mr Hilal Abdulla, in the Chair. Mr Hodgkinson was introduced by Mr S. Nalliah, F.G.A., and received a vote of thanks proposed by Mr Hazim Narook, F.G.A. (Reported by Mrs Ameena Kaleel, F.G.A., Hon. Treasurer, Gemmologists' Association of Sri Lanka).

On the 10th May, 1983, Mr Alan Hodgkinson, F.G.A., gave a talk entitled 'Keep your moths in your diamonds' to the Ulster Jewellers Association Gem Group, at the Ulster Museum, Belfast.

Mr Richard T. Liddicoat, Jr, Hon.F.G.A., President of the Gemological Institute of America since 1952, has been elected Chairman of G.I.A.'s Board of Governors.

Mr M. J. O'Donoghue, M.A., F.G.S., F.G.A., gave a talk entitled 'The literature of mineralogy' to the Amateur Geological Society on 21st June, 1983.

Mr P. G. Read, C.Eng., F.G.A., and Mr M. J. O'Donoghue, M.A., F.G.S., F.G.A., were lecturers in two further two-day courses on 21-22 and 24-25 May, 1983. The first included topics in the syllabus for the Diploma Examination, with emphasis on the use of instruments, and the second was concerned with the beryl family of gemstones.

MEMBERS' MEETINGS

North-West Branch

On 15th September, 1983, at Church House, Hanover Street, Liverpool 1, Dr J. W. Franks, F.G.A., gave a talk on 'Gemstones in Jewellery'.

South Yorkshire & District Branch

On 4th September, 1983,members joined the Sheffield Amateur Geological and Lapidary Society for a field trip to Pindale and Dirtlow Rake, where specimens of barytes, calcite, galena and fluorite can be found.

On 11th September, 1983, a trip was arranged to Treak Cliff Cavern, Castleton.

BANGKOK DIAMOND SEMINAR IN NOVEMBER

A two-day seminar on 'Diamond (Natural and Synthetic) and Diamonds Simulants' will be given in Bangkok on 9-10 November, 1983, by Mr Roy V. Huddlestone and Mr Peter G. Read, C.Eng., F.G.A., hosted by the Asian Institute of Gemological Sciences (of which Mr John D. Rouse, M.A., G.G., has recently been appointed Managing Director). The seminar will include both formal lectures and practical sessions, and it will cover the history, mining, cutting and grading of diamonds, together with the evolution of diamond simulants from glass to CZ, with particular emphasis on the identification of diamonds (natural and synthetic) and its simulants.

The cost of the two-day seminar is US$88.00. For further particulars, apply to the Seminar Secretary, Asian Institute of Gemological Sciences, 987 Silom Road, Rama Jewelry Building, 4th Floor, Bangkok 10500, Thailand. [Telephone 233-8389; Telex 87971 AIMTHAI TH; Cable GEMSEARCH.]

EXAMINATIONS 1984

The examination dates for 1984 are as follows:

Gem Diamond Examination:
    Theory, Monday, 4th June
    Practical, Monday, 4th or Tuesday, 5th or Monday, 11th June.
Examinations in Gemmology:
    Preliminary (Theory): Tuesday, 26th June.
    Diploma: Theory, Wednesday, 27th June.
        Practical, Thursday, 28th June (but in London the Practical Examination may be held on other days in that week).

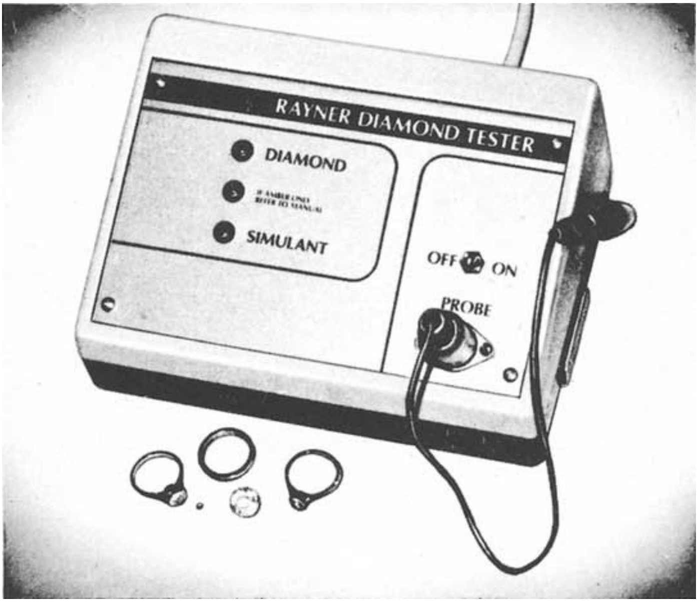
The *last* date for receiving examination entry forms is 31st March, 1984.

INDEX FOR VOLUME XVIII

The Index for Volume XVIII (1982-83) will be issued with Part 1 of Volume XIX in January 1984.

CORRIGENDA

On p.375 above, the curved lines mentioned in the caption of Fig. 19 were clearly visible in the original but were lost in the reproduction, and on p.629 above, Figs 4 and 6 were reproduced quite wrongly coloured blue: for which regrettable errors the Editor tenders his apologies to the respective authors and photographers.


RAYNER DIAMOND TESTER
DIAMOND
SIMULANT
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PROBE

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 a minimum of 25 prints of individual articles may be supplied to authors provided application is made on or before approval of proofs. Applications for prints should be made to the Secretary of the Association—not to the Editor—and current rates of payment for articles and terms for the supply of prints may be obtained also from the Secretary.

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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