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# IMMERSION CONTACT PHOTOGRAPHY

## A Simple New Technique

*by B. W. Anderson, B.Sc., F.G.A.*

"PHOTOGRAPHY without a camera" would perhaps have been a more attractive title for this article, but the phrase would not have described so exactly the nature of the process involved, and even the simplest process must have a descriptive name attached—if it is to be spoken of at all.

The first immersion contact photograph was made last autumn, at my suggestion, by my colleague, Robert Webster, to act as an illustration in a short article on curved colour bands in synthetic spinel.* On that occasion the stone was immersed in monobromonaphthalene in a shallow plastic dish, a piece of printing paper placed underneath the dish, and the whole exposed to light from an overhead electric lamp. The resultant image, though on printing paper, was, of course, a negative picture of the stone, showing the curved bands of colour as pale instead of dark, and a narrow bright rim round the specimen which really represented a black border due to internal total reflection at the edges of the stone, as the spinel had a higher refractive index than that of the surrounding liquid.

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* B. W. Anderson and Robert Webster. "Curved bands in synthetic spinel." "Journal of Gemmology," Vol. 3, No. 4, October, 1951.

The result of that preliminary experiment was sufficiently attractive and promising (though it did not reproduce well) to make me determine to carry out further experiments with other stones and other liquids when the opportunity arose. Some further trials have now been carried out, though very spasmodically, as the urgent demands of routine testing have afforded no chances lately for continuous and careful work. Nevertheless, the results have been even more interesting and fruitful than expected. Not only is a very clear indication of the refractive index provided, even when only a single liquid is used, but the pictures are also æsthetically pleasing. Moreover, since an exact record is given of the outline of the stone, of the disposition of the facets, and even of any notable internal features such as feathers, flaws, zoning or large inclusions, these contact photographs would serve very well as a means of identification of individual important stones, for which expensive and time-consuming photomicrographical methods have hitherto been employed.

All that is needed in the way of equipment (one could hardly call it apparatus) is a glass or plastic cell, a few selected immersion liquids of known refractive index, and " gaslight " printing paper, bromide paper, or slow, fine-grained flat film, according to the taste and needs of the experimenter. My first results were with printing paper, giving an exposure time of 20 or 30 seconds, but the photographs reproduced here were taken on Ilford " Line " film, and enlarged prints made from these negatives in order to show the effects " in their true colours," so to speak, i.e. as positives. The following liquids would form a useful range for most purposes: Toluene (1.50), ethylene dibromide (1.54), bromobenzene (1.56), bromoform (1.59), iodobenzene (1.62), bromonaphthalene (1.66) and methylene iodide (1.745). Several of these will already be in the hands of most gemmologists.

For most of the tests described here the same group of five stones was used. These were initially rather hastily picked out as being sizeable, transparent stones, colourless or pale in tint, roughly comparable in size, and of different refractive indices. Had all the specimens been brilliant cut this would in some ways have been better, as the inclination of the facets would have been more nearly the same in each case ; but, on the other hand, the different shapes of the five stones chosen make it more easy to recognize them in the several pictures. Here is a list of the stones:—

| STONE | CARATS | REF. INDICES |
|---|---|---|
| Oval mixed-cut quartz ... ... | 7.60 | 1.544—1.553 |
| Long oval topaz ... ... ... | 7.72 | 1.630—1.638 |
| Step-cut spodumene ... ... | 6.30 | 1.664—1.679 |
| Mixed-cut chrysoberyl ... ... | 10.33 | 1.748—1.757 |
| Round white zircon ... ... | 16.16 | 1.926—1.985 |

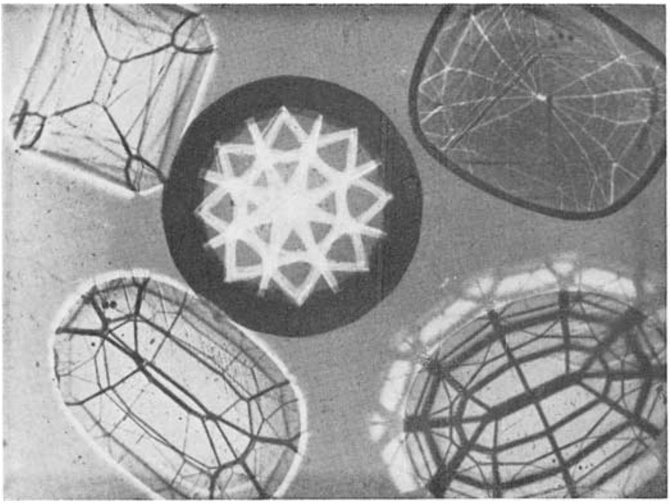

*Fig. 1 — Immersion contact photograph of quartz, topaz, spodumene, chrysoberyl and zircon in monobromonaphthalene. Enlarged about 2½ ×.*

Fig. 1 is a slightly enlarged immersion contact positive of these five stones in monobromonaphthalene. The quartz is in the bottom right hand corner followed in a clockwise order by the topaz, spodumene and chrysoberyl, with the round zircon in the middle. An attempt was made to arrange the stones in some semblance of order and symmetry, which would greatly have enhanced the appearance of the picture. But in the dim light of the dark-room lamp the stones were virtually invisible, and the slight movement of the cell as the film was inserted below was enough to disarrange them. Another defect is overcrowding of the specimens owing to the small size of the cell. The stones should ideally be well separated from one another and from the containing sides, where the meniscus caused noticeable distortion. Despite these faults the picture shows in how striking a manner the different refractivity of the specimens influences their appearance in the photograph. The quartz, with an index far lower than the liquid, has a broad pale border extending beyond its true outline, and the junctions of the facets are strongly marked in black. With the topaz, where the index is not much below that of the immersion medium, these features are less pronounced. The mean index of the spodumene would slightly exceed that of the liquid for sodium light, but the greater dispersion of the monobromonaphthalene ensures that for the blue and violet light for which this film is most sensitive the index of the liquid is still slightly greater than that for the stone. With chrysoberyl the reversed effect becomes clearly apparent, resulting in a narrow *black* border and *white* outlines to the facets ; while in the zircon the heavy dark border and broad white facet edges form a striking demonstration of its high refractive indices. Here the strong double refraction adds to the complexity of the pattern formed by the facets.

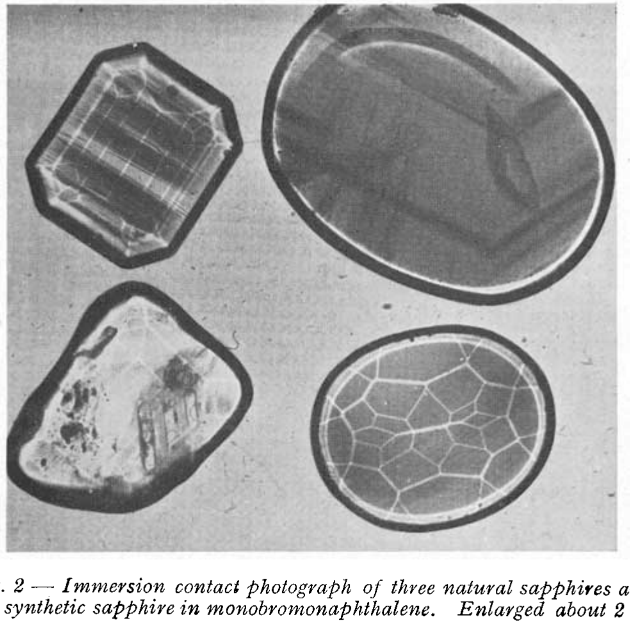

*Fig. 2 — Immersion contact photograph of three natural sapphires and one synthetic sapphire in monobromonaphthalene. Enlarged about 2 ×.*

In Fig. 2 three natural sapphires and one synthetic sapphire are shown immersed in monobromonaphthalene. In this case the stones were chosen to demonstrate how clearly internal features are revealed by this simple process. The colour zones of the top two flat stones are plainly seen. The irregular stone on the bottom left is a Ceylon sapphire containing large three-phase inclusions, while the oval synthetic sapphire shows only faintly its curved colour bands, merely because the angle of rest of the stone in the dish is not the most favourable direction for displaying these features. Note the approximately equal dark rim which surrounds these stones, despite their very different styles of cut. Careful inspection of the other photographs will reveal internal markings in some of these stones also.

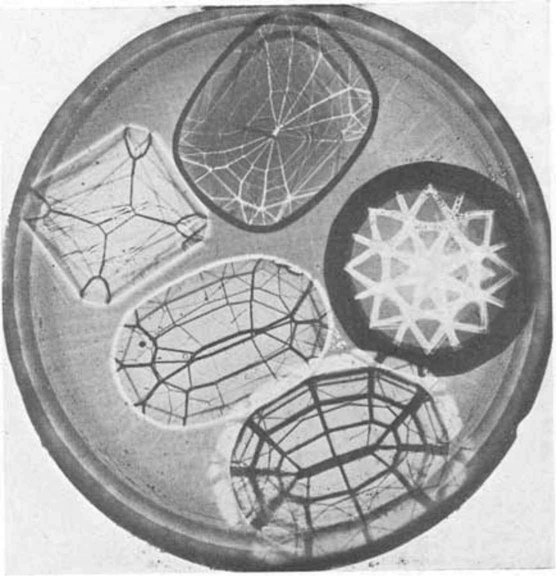

*Fig. 3 — Immersion contact photograph of quartz, spodumene, chrysoberyl and zircon in monobromonaphthalene. Enlarged 2×.*

These first two pictures were taken on Ilford " Line " film (a slow and fine-grained emulsion) at about 4 feet below a 60 watt frosted bulb, the exposure time being 3 seconds. In the remaining two pictures shown an attempt was made to obtain sharper results by using a cell with a thinner glass base than the rather massive Whilems cell used in the other experiments, and by masking the light with black paper, allowing only a narrow beam from a 1-inch aperture to reach the immersion cell. Comparison of Fig. 3 with Fig. 1 will show that there is, in fact, a slightly better definition of the facet edges. In Fig. 4 the same five stones are shown immersed

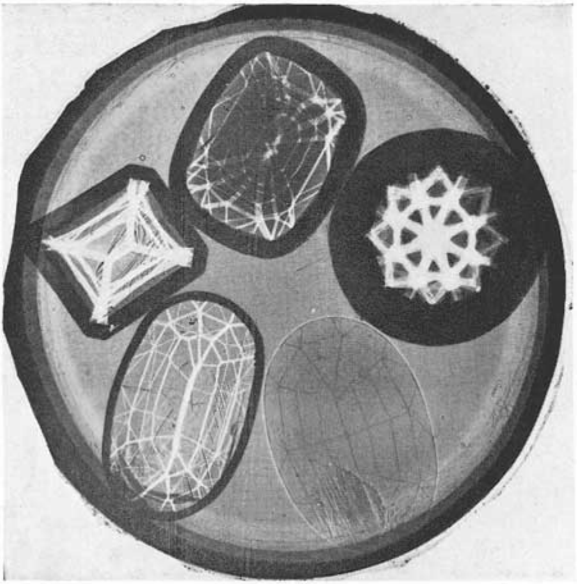

*Fig. 4 — Immersion contact photograph of same five stones in ethylene dibromide.*

in ethylene dibromide, the lower index liquid causing them to show very different relief. Ethylene dibromide matches quartz almost exactly in sodium light, but its higher dispersion makes its index just a fraction higher than that of the stone for blue-violet actinic light to which the film is most sensitive ; hence the faint bright rim and fine dark facet edges displayed by the specimen. The other stones show increasingly wide dark borders, as expected, except that the steepness of the facets in the spodumene makes it appear to have about the same refractive index as chrysoberyl in this picture.

One further photograph is reproduced in Fig. 5, in this case to indicate the sensitivity of the immersion contact method. The stones in this instance are synthetic emerald (the larger stone) and South African emerald immersed in bromobenzene. Here the liquid is clearly shown to have a higher index than the synthetic (for the operative wavelength) and a lower index than the natural emerald. The difference between the mean index for the two stones as measured on the refractometer is about 0.035.

I am hoping, as time permits, to carry out many other experi-

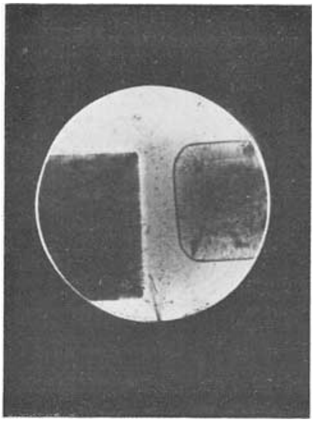

*Fig. 5 — Synthetic emerald (left) and South African emerald in bromobenzine. About 3×.*

ments with this method, and to try out various possibilities. If monochromatic light were used it would sharpen the effects considerably, since there is continuous variation of the relation between the refractivity of the stones and the liquid with the wavelength of the light. With suitable colour-filters and liquids of known dispersion a fair range of indices could be covered without having to use a multiplicity of liquids. Results under ultra-violet light also might be revealing in certain cases. However, such elaborations are only suitable for the laboratory worker, and it should be emphasized that perfectly effective photographs giving a clear guide to refractive index, and forming a record of the size and the disposition of the facets of any unmounted stone can be obtained without any equipment beyond a glass cell, a few liquids and a packet of contact paper.

Nor is a dark-room really necessary ; any room in which a single overhead light can be switched on and off will serve after dusk, since contact paper is not unduly sensitive. It must be remembered that the results on contact paper, as on a film before printing, will be the exact reverse of those shown in the illustrations to this article.

It is not, of course, suggested that the contact photograph method can replace other immersion techniques for refractive index determination, of which there are several variations particularly suited to the needs of gemmologists ; but for its simplicity, the unequivocal nature of its results, its beauty, and its value for purposes of record, I am confident that the process has much to commend it.

# NOTAE — UT INFRA

*by D. S. M. Field, A.G.A.*

DESPITE the efforts of the American Gem Society and other praiseworthy American trade organizations to discourage such practices, another name has been added to the long list of fanciful and often misleading trade terms for synthetic rutile. The word " *Diamothyst* " is now appearing in advertisements sponsored by a New Jersey (U.S.A.) firm engaged in the retailing of the opal-like synthetic gemstone. Many of the claims made in the advertisements are grossly exaggerated and scientifically inaccurate: " Harder than zircon . . . Diamothyst is .7 on the Moh's (sic) scale of hardness, and diamonds are .9 . . . a stone that only an *expert* working under a *good light* can detect from a real diamond." In conclusion, the advertiser assures the buyer that: " Legally, we cannot refer to the Diamothyst as a *diamond,* so we ask you to order in the three most popular *diamond* shapes . . ." (The italics are the advertiser's.) Of course, no mention is made of the fact that the so-called " Diamothyst " is nothing more startling than synthetic rutile.

Incidentally, increased production and improved faceting machinery have brought about a sharp drop in price to five dollars per carat for cut rutile—purchased in wholesale lots of a dozen stones. Indications are that the American price will eventually stabilise rather above the level of synthetic blue sapphire, the most expensive of the synthetic corundums.

A Toronto firm is currently outfitting with furnaces, etc., for the production of synthetic rutile in Canada. The source of their raw material will be the huge titanium deposits in the Province of Quebec. The Toronto factory, which is scheduled to commence operations on a small scale this year, will be the first of its kind to operate in Canada.

* * *

Lo! The archaic jargoon. Taking advantage of the publicity enjoyed by the synthetic rutile hucksters, at least one New York dealer is seeking to promote the sale of white (colourless) zircon under the old and obsolete name " jargoon." His advertisements read something like this:—

> " NATURAL JARGOON—rivals diamond in brilliance and fire. NOT A SYNTHETIC STONE! Nature *is* always right . . . and the Jargoon . . . a natural mined gemstone proves it! Two hundred million years in creation, the jargoon is so white, so fiery . . . yes, so *brilliant* that it is the closest rival of the diamond! Mined from the gem-bearing gravels of Ceylon . . . it glows on your finger with the same splendour that made it a favourite with Sultans . . . caused it to be included in the British Crown Jewels! " (The humble Indo-Chinese zircon blushes—and hangs its modest head in shame!)

* * *

A report from Brazil tells of a little-known thermal colour change in gems: blued golden beryl.

The colour of the treated stones is said to be pale blue, similar to that of the best aquamarines. It is not known whether *all* golden beryls are so affected when subjected to controlled heat treatment. The treated stones came from Minas Gerais.

* * *

Advice from Brooklyn, New York, regarding a top-secret synthetic diamond project in Russian territory, will be found in the following letter published in an American magazine for men:—

> " I wish to pass on some information given me by a Russian citizen when I was with the American Occupation Forces in Vienna, Austria. . . . About eighteen months ago I became acquainted with a Russian girl also stationed there. . . . Once she noticed my diamond ring and said, ' What if I told you that diamond might be worthless very soon? ' She went on to say that her brother was a mathematics professor in Moscow. He had been on a secret project based at the mouth of the Yakutsh River . . . left his wall safe unlocked one afternoon and she went through his private papers. She learned that the project was to manufacture diamonds out of raw carbon, with the aid of an atomic explosion . . . on the theory that, under heat and pressure, carbon—in the form of graphite—could be made to rearrange its structure to conform to the crystalline pattern of the diamond. The diamonds were

> in chunks weighing up to hundreds of kilograms. . . . At a certain spot in the Arctic Ocean there is a great subterranean (sic) valley about four miles deep and the pressure is tremendous. . . . When an atomic explosion occurs at these depths strange forces come into play. . . . Their modus operandi called for huge buoys, to which were attached long cables. . . . At the bottom were the containers holding the graphite, placed in moulds. I asked my girl friend if she didn't feel she was breaking her brother's trust. She said that he had died of pneumonia six weeks before. . . .'' (The letter was unsigned.)

* * *

Notwithstanding the fact that neither the edible oyster nor the clam is capable of producing a pearl desirable for use as a gem, stories of alleged finds of valuable pearls in oyster stews and clam chowders quite frequently appear in the sensational press.

As every gemmologist knows, true pearls are to be found in only two types of shell-fish: the fresh-water mussels (Unionidae) of North American and European streams, and the pearl-bearing molluscs (Margaritifera) of tropical and sub-tropical seas. An exception to this rule is the abalone (Haliotidae) ; but the lovely vari-coloured pearls of this strange shell-fish are rare indeed and seldom met with in the trade.

The confusion in the public mind no doubt stems from the fact that the popular name given to the margaritifera is '' oyster,'' when actually the animal does not belong to the same zoological family as the edible oyster (Ostrea edulus), and is entirely different in shape and size of shell and in the type of pearl it produces. The concretions produced by the edible oyster and the clam are similar in form to pearls, but, as they are not nacreous, are of *no value as gems* and should not be classed as such.

The heat of cooking has frequently been given as the cause of the '' dead '' appearance of '' pearls '' found in stews and chowders. Actually, however, while the cooking certainly would not enhance their appearance, it is their natural lack of nacre that causes them to appear lifeless and dull and to be unsuitable for jewellery use. It is, therefore, sheer nonsense for an '' expert '' to say that a pearl of this nature would have been valuable had it not been subjected to cooking heat.

Proprietors of certain sea-food establishments have been known to introduce cultured pearls (sometimes ready drilled!) into edible oysters before serving them to customers, perhaps hoping to profit from the ensuing newspaper publicity. (Newspaper reporters seem to love this sort of thing!) And we often hear of jewellers (who should certainly know better) setting fabulous prices on them. So a fallacy persists and, despite refutory articles in responsible trade journals, the stories continue to plague the gemmologist and conscientious jeweller whose job it is to present the *facts*, even when it means that the sale of a setting is lost and a customer is disillusioned.

Consider, for instance, the let-down a certain citizen of Rochester, New York, is going to experience when he tries to sell a " black pearl " that he reportedly found in a restaurant dish called " Clams Casino." It is said that an " expert " has valued it at 11,000 dollars. Evidently this " expert " has never heard of the G.I.A. and the American Gem Society, whose efforts over the past two-score years have done so much toward eliminating a good deal of the ignorance and misrepresentation in the North American jewellery trade.

* * *

With further reference to the American Gem Society, their official approval of the term " *topaz-quartz* " for citrine is apparently confusing not only to the public, but to some jewellers as well. In Canada, a well-intentioned member firm is advertising " Genuine topaz (quartz)," a construction which would possibly mislead some persons to believe that *genuine* topaz *is* quartz, which is certainly not the case.

In this instance, the adjective " genuine " is undoubtedly used for the sole purpose of differentiating the natural stone from the synthetic varieties advertised on the same page. Nevertheless, in the writer's opinion, it should have been borne in mind that " citrine " is an attractive and quite proper name for the particular gemstone represented, and, while *topaz-quartz* is admittedly a somewhat happier choice than " quartz-topaz," the use of qualifiers that are actually the names of distinctive gem varieties is bound to be confusing to the lay mind.

# THE
# DIAMOND INDUSTRY
# 1950

*by W. F. Foshag and George Switzer**

THE year 1950 was a record-breaking one in the diamond industry. Sales of diamonds by South African and other producers were the greatest in history, with total sales nearly one-third greater than the previous record year in 1948, and nearly double those of 1949. In his Christmas message, Sir Ernest Oppenheimer reported: " The year 1950 has been a most prosperous one for the Diamond Industry. The demand for both gem and industrial stones has exceeded all expectations and previous records, and the buoyancy of the market has taxed the ability of the producers to maintain an adequate supply. Even with the help of the reopened Premier and Jagersfontein mines production has not been able to meet all demands."

The rapid changes in the world situation have brought about a decided change in the diamond industry, both in the gem and industrial fields. The early lethargy of the market was changed to one of avid demand by the outbreak of the Korean War. Even before this event an improvement became noticeable, due in part to the stabilizing effects of the Diamond Trading Company's action to maintain prices upon the devaluation of sterling currencies in 1949, and to the moves by various governments, notably that of the Union of South Africa, to eliminate the manipulations between hard and soft currencies, the so-called switch operations, as they affected the diamond market. Political uncertainties and the fear of inflation induced a rapid increase in the demand for gemstones. This demand fluctuated with the vagarious changes in the military outlook, interest waning somewhat upon Allied successes, and increasing upon Allied setbacks.

In the industrial field, too, the outbreak of the Korean War again emphasized the importance of the diamond in industry.

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* Extracted from " The Diamond Industry, 1950," by permission of the **Jewellers' Circular-Keystone.**

American and other rearmament programmes greatly increased the demand for industrial stones. By 1950, reserve stocks were reduced to eight million carats. No general serious shortage developed during the year, although the market tightened on some types, notably crushing bort. The present outlook is for greatly increased demand, which will be partially offset by increased production from the Belgian Congo, and the reopening of the Premier Mine. The reopening of the Premier Mine was a fortunate move, increasing the supply of higher qualities of industrials.

Other factors, such as the development of the Alberta, Canada, oilfields, created new demands for industrial stones. New recovery processes, heavy, media and electrostatic, have now proved their value, resulting in more efficient recovery of stones and lower recovery costs. They will undoubtedly find wide application in the mining industry. Not only will producing mines improve their recovery, but marginal producers may become profitable.

The diamond cutting industry shows some progress toward a more desirable degree of stability, but is still beset with difficulties, due in part to a disparity in manufacturing costs between various centres. Unemployment in some centres, notably Antwerp, remains a disturbing factor. A decided tendency for the dispersal of the manufacturing industry from the old-established centres is evident.

## Diamonds in Fashion

Fashions in 1950 showed relatively little basic change. Diamond jewellery was light, flexible and mobile. Designed on the theory that diamonds in motion look bigger than diamonds in repose, mountings were hinged to move loosely and large single stones were made to sway in pendant fashion or in rows as a shimmering fringe.

In mountings, curved lines were the most popular, but with fewer naturalistic flowers and abstract objects. The butterfly motif began to emerge towards the close of 1950.

In forms of diamond jewellery, the necklace remained the most important single piece. Earrings changed from the long pendant type to large button clusters on the lobe. Diamond wrist watches became increasingly popular.

In 1950, the most significant motif in precious jewellery was the cluster, a large centre stone surrounded by one or more rows of brilliants in matched sizes. The cluster mountings may be marquise, square, oval or round. The metal tops are made rather elaborate, so that with the addition of a few small diamonds, a fairly large piece may sell for a comparatively low price, some for under $100. The most popular usage of these clusters was as dinner rings.

Towards the end of the year, the metal restrictions imposed or on the horizon made new designs uncertain. Gold was being used extensively due to the shortage of platinum.

More fancy cut diamonds were used this past year than at any time since the 1920's. Ample supplies were available of unusual shapes such as pentagon, kite, trapeze, triangle and half-moon. The bulk of the diamond jewellery sold in America, however, is mounted with the standard brilliant, the emerald cut, occasionally the marquise, and the baguette.

### WORLD PRODUCTION

Accurate figures regarding diamond production are not available for all countries. Exact figures received from official sources are given in most instances. Where estimates are given they are believed to be fairly reliable.

WORLD PRODUCTION OF DIAMONDS, 1947-1950,
BY COUNTRIES, IN METRIC CARATS
(Including Industrial Diamonds)

| Country | 1947 | 1948 | 1949 | 1950 |
|---|---|---|---|---|
| Africa: | | | | |
| Angola ... ... | 799,201 | 795,509 | 769,981 | 538,867 |
| Belgian Congo ... | 5,474,469 | 5,824,567 | 9,649,896 | 10,147,471 |
| French Equatorial Africa | 107,076 | [4]118,300 | [4]122,928 | 111,460 |
| French West Africa ... | 53,749 | 77,970 | 94,996 | 126,346 |
| Gold Coast ... ... | [1]852,493 | [2]850,000 | [1, 4]972,976 | [2]950,000 |
| Sierra Leone ... ... | 605,554 | 465,518 | 494,119 | 655,474 |
| South-West Africa ... | 179,554 | 200,691 | 280,134 | 488,422 |
| Tanganyika ... ... | 92,229 | 148,169 | 191,787 | 195,274 |
| Union of South Africa: | | | | |
| Lode ... ... | 918,042 | [2]930,000 | 964,266 | 1,516,194 |
| Alluvial ... ... | [3]286,692 | [2, 3]270,000 | [3]289,756 | [3]231,674 |
| Total Union of South Africa ... | 1,204,734 | [2]1,200,000 | 1,254,022 | 1,747,868 |
| Brazil[2] ... ... ... | 275,000 | 250,000 | 250,000 | 200,000 |
| British Guiana ... ... | 24,669 | 36,562 | 34,790 | 37,462 |
| Venezuela ... ... | 61,634 | 75,513 | 56,362 | 60,389 |
| Other Countries[2] ... ... | 3,500 | 3,500 | 3,000 | 3,000 |
| Grand Total (Round Figures) | 9,734,000 | 10,047,000 | [4]14,174,991 | 15,262,033 |

[1] Exports

[2] Estimated.

[3] Includes an estimated 100,000 carats for State Mines of Namaqualand.

[4] Revised Figure.

### CUTTING—ENGLAND

A rapidly expanding diamond cutting industry has developed in the past ten years in England. The industry was formed in 1940 when refugees came from Amsterdam and Antwerp. It has now been firmly established and is allotted regular sights by the Diamond Trading Company.

The industry employs approximately 700 men, principally in London and nearby districts. The diamonds cut are mostly the larger sizes, ranging from one carat (rough) upwards.

### INDUSTRIAL DIAMONDS

Developments during 1950 in the field of industrial diamonds centred chiefly about greatly increased use by manufacturers geared to production for defence requirements, and a resultant short supply. Because of these factors there has been a sharp rise in prices.

At the beginning of World War II there existed a huge stockpile of industrial diamonds throughout the world. Heavy demands during and subsequent to the war reduced this stock to a low level.

The world production of industrial diamonds in 1950 was approximately 12,500,000 carats, an increase of about 15 per cent. over 1949. Of this amount some 9,600,000 carats were mined in the Belgian Congo. Reopening of the Premier Mine in South Africa should materially increase the supply of high-grade industrials.

### SCIENTIFIC RESEARCH

Experiments on the colouration of diamonds by irradiation by radium and in the cyclotron were reported on by Martin L. Ehrmann ("Gems and Gemology," Summer, 1950, p. 295) and Frederick H. Pough and A. A. Schulke ("Gems and Gemology," Spring, 1951, p. 3). Colour changes brought about by cyclotron bombardment are usually from pale brown to green, white to bluish green, and yellow to yellow green. Occasional changes from yellow to golden brown were observed. The colour appears to be permanent but is only present as a surface skin. No permanent induced radioactivity was observed.

Diamonds subjected to neutron bombardment in an atomic pile were stated to have been quickly blackened but passing through an intermediate green colour. (Reported by Pough and Schulke as a personal communication from D. E. Blackwell, Cambridge, England.)

## *Further Notes on*

# TAAFFEITE

### *by C. J. Payne, B.Sc., F.G.A.*

IN Vol. III, No. 2, of this journal the writer described a new mineral, but at that time the analysis had not been completed. Since then the mineral has been described in the " Mineralogical Magazine," Vol. XXIX, No. 215, pp. 765-772.

It has been decided to call this mineral Taaffeite in honour of its discoverer, Count Taaffe, much to the relief of the writer, who had been calling it that since about 1946. Various other suggestions were made but none of them were satisfactory. Naming a new gemstone is not easy and it should be borne in mind that most stones have very ancient and time-honoured names which are really pleasant. Minerals, on the other hand, frequently have horrible unpronounceable names, which do not matter perhaps, because the ordinary public do not come into contact with them.

The refractive indices of Count Taaffe's specimen have been taken again (previously only ω could be measured accurately). The two stones had the following indices:—

Count Taaffe's: ω 1.7230 ; ε 1,7182 ; ω—ε 0.00475.
B. W. Anderson's: ω 1.7208 ; ε 1.7167 ; ω—ε 0.00412.

Dr. M. H. Hey made an analysis on 6 mgs. (i.e. 0.3 cts.) of the stone as follows (" Min. Mag.," XXIX, 215, p. 772):—

| | |
|---|---|
| $Al_2O_3$ ... ... | 70.0 |
| $Fe_2O_3$ ... ... | 5.9 |
| MgO ... ... | 13.4 |
| BeO ... ... | 11.0 |
| | 100.3 |

This gives a rough formula $MgBe(Al_2O_4)_2$ if the iron is ignored. It shows that Taffeite is intermediate in composition to spinel and chrysoberyl.

The ideal formula given according to the contents of the unit cell is $Mg_4Be_4Al_{16}O_{32}$.

The formula for spinel giving the content of the unit cell is $Mg_8Al_{16}O_{32}$, and of chrysoberyl $Be_4Al_8O_{16}$. Setting these formulæ out together they appear like this:—

Spinel: $Mg_4Mg_4Al_{16}O_{32}$ cubic
Taaffeite: $Mg_4Be_4Al_{16}O_{32}$ hexagonal
Chrysoberyl: $Be_4Be_4Al_{16}O_{32}$ orthorhombic

and one can see the relation between the three.

More careful densities have been made on the two stones, giving for Count Taaffe's 3.613±.002. B. W. Anderson's stone was slightly lighter—3.60.

The complete data on the mineral can be summarised:—

Name: Taaffeite.
Composition: $Mg_4Be_4Al_{16}O_{32}$.
Habit: Unknown.
Crystal System: Hexagonal Trapezohedral (Class 62).
Cell dimensions: c/a 3.21 a 5.72Å c 18.38Å.
Space group: $D_6^6$—$C6_3$ 2.
Hardness: 8.
Refractive indices: $\omega$ 1.723-1,721, $\varepsilon$ 1.718-1.717, uniaxial negative.
Specific gravity: 3.61-3.60.
Origin: Unknown (believed to be Ceylon).
Remarks: Only two specimens known. The ratio of c/a 3.21 is virtually the same as the ratio of crystal axes ; these cannot be measured until a crystal is found giving the pyramid and prism necessary. B. W. Anderson's stone, weighing 0.86 carat, is on view at the Natural History Museum, South Kensington.

## A POCKET POLARIZER

A pocket-sized polarizing apparatus designed for gem testing. The apparatus consists of a tube, about 3½ inches long, equipped with a reflection mirror at one end above which is a lens and a polarizer employing a sheet of polaroid. The top of the tube contains a rotatable cell for liquid and stone, over the top of which can be swung to a second polaroid disc to act as the analyzer. The apparatus is to be marketed. Three illustrations.

*From Gemmologist, Vol. XXI, No. 246, pp. 1–3. January, 1952.*

# PHOTOMICROGRAPHS

*by L. C. Trumper, B.Sc., F.G.A.*

AN interesting side of gemmology is the creation of a collection of photomicrographs of inclusions in gemstones. Since no two stones can possibly be the same in this respect, the number of variations is infinite. Large numbers of most excellent photomicrographs have already been published by Dr. E. J. Gübelin, a master of this particular technique, and by many others also.

As it is possible that most gemmologists look upon this as a difficult job, it is the main purpose of the present article to show not only that this is not so but that in fact the procedure is a very simple one. Briefly, it consists in focussing the microscope correctly and then centring the camera (any camera) with the lens as close to the ocular or eyepiece of the microscope as possible. The lens of the camera is focussed at infinity (in the case of a box camera there is nothing to do) and then it is merely a question of a little experimenting to find the best exposure.

Now to elaborate the simple procedure outlined above so that the best possible results may be obtained. Clearly the first essential is a means of satisfactorily and firmly holding the camera over the microscope so that the axis of microscope and camera are in the same line, that is, correctly centred. Let it be said at once that since the gemstone will in most cases be immersed in a fluid it follows that both microscope and camera will need to be vertically one above the other, and therefore the stand will have to provide accordingly unless a totally reflecting prism is employed above the microscope eyepiece or ocular.

My own first experiment (Fig. 1) was to construct a rigid wooden stand for the purpose with a fixed position for both microscope and camera which automatically did the necessary centring. This can only be built after careful measurement of the height of microscope focussed upon an average stone with camera superimposed. The disadvantage of this method is first the difficulty of initial focussing, because the stand is in the way, and secondly the

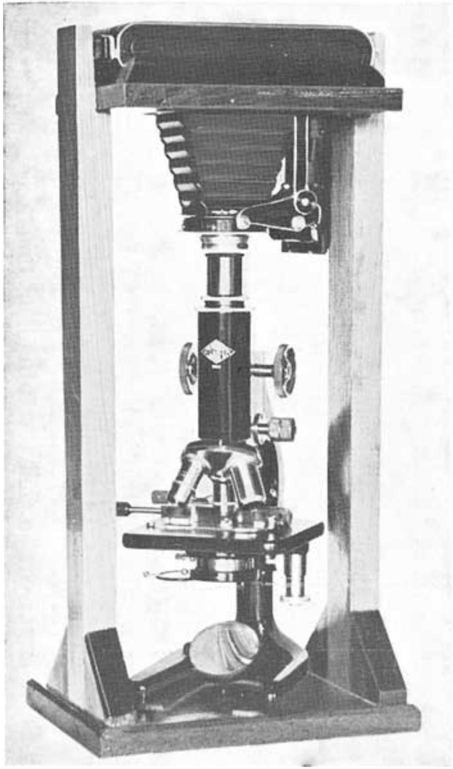


Fig. 1 — *Fixed Stand for Photomicrography.*
*Camera: Kodak Special.*
*Film size: 2½″ × 4¼″.*

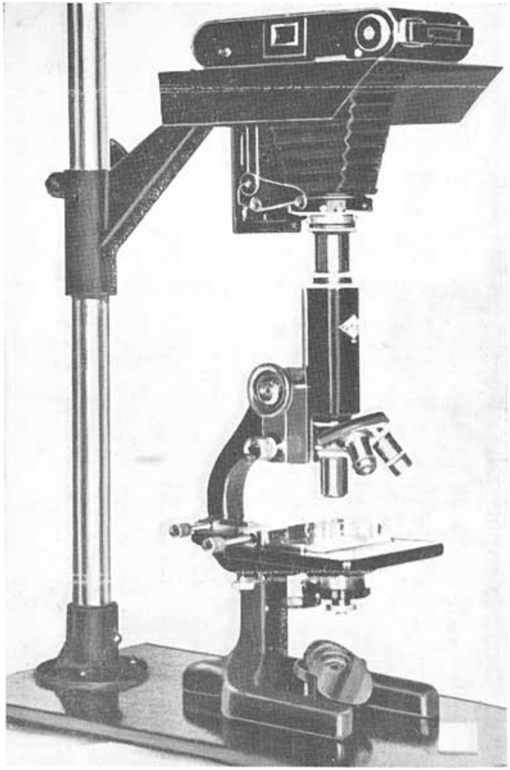


*Fig. 2 — Adjustable Stand for Photomicrography.*
*Camera: Kodak Special.*
*Film size: 2½″ × 4¼″.*

severe limits to anything but a very small raising or lowering of the micropscope tube and the necessity of keeping to the same power of objective and ocular. The rigidity is, however, a great advantage. The rigid wooden stand has been superseded by a stand adapted quite simply from standard photographic enlarger parts. As will be seen, this stand (Fig. 2) consists of a good-sized and rigid baseboard, vertical pillar and a sliding arm with a clamp and clamping screw. A suitable metal table with a rectangle cut out of it was made and attached to this sliding arm into which my camera could be lowered and which thus held it firmly. The metal table must be dead horizontal.

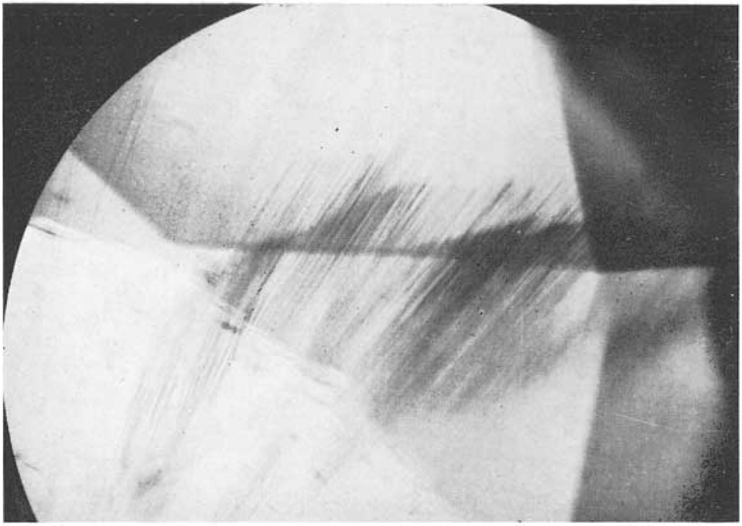
As to the camera, any camera will do so long as the aperture is not smaller than F.11 and " time " control is used so that exposures in the region of 10-20 secs. can be employed using any suitable average speed film.

If, however, you intend buying a camera for the purpose, then get a size that will take photographs as nearly square as possible, such as 2½ in. x 2¾ ins. or 2¼ ins. x 2¼ ins., as this will economize in film. A good lens is always desirable, but neither complicated focussing nor shutters are any advantage. Actually, the lens plays no part at all and for this reason an aperture of not less than about F.16 should be used to avoid the risk of cutting off part of the microscope field.

If you stop down, this will not enable a longer exposure to be made as in photography generally, but will have the effect of gradually reducing the field photographed and, instead of a clean circular edge, will result in a partially fogged border. On the other hand, too large an aperture, i.e. larger than that of the ocular, will result in unwelcome reflections which may partially fog the film.

As to the film, the only recommendation I would make is to keep to the same make and speed and always make a detailed record of every photo taken, giving (a) the subject, (b) the film, (c) the focus (it will always be infinity for photomicros, of course), (d) objective, (e) ocular (should these latter two be variable), (f) exposure, (g) stop, (h) light at time, (i) date and time, (k) remarks.

In the remarks column, after the film has been developed, indicate any faults so that you will build up a record which will



*Demantoid Garnet — Stop F.16 : Focus — Infinity : Exposure 20 secs.: Film — Kodak Verichrome : Objective 2/3 : Ocular × 6.*

tell you at any time exactly what exposure to make, which lenses to use and so on.

Again, any microscope will give results. I have taken first-rate photomicrographs with a microscope built about 1880 and bought for 25s. Here again, however, better equipment will give better results, so that the more orthodox type will be dealt with here. The microscope is focussed in the ordinary way. Use the concave mirror in preference to the plane mirror and the abbé sub-stage condenser, if so fitted.

Lowering the condenser will frequently enhance the definition, particularly of transparent inclusions.

The most useful objectives for gemmological work are 1½ ins. and ⅔ in., as these allow sufficient working distance. Eyepieces or oculars of × 6 and × 10 will meet most requirements. Some experimenting will be essential to get the best results. If possible, arrange camera and microscope with a suitable object and, with the back of the camera off, fit either a piece of ground glass or stretch tightly a piece of thin tissue paper or greased paper in the position normally occupied by the film.

Shielding from extraneous light by using an opaque sheet over head and camera, try every possible combination of objectives and oculars and record the fields of view obtainable. It will be found that a given combination will just fill the largest possible circle of film, whereas a higher powered ocular will result in part of the circular field being cut off.

Using a Kodak 616 size camera with 2½ ins. x 4¼ ins. film, the following magnifications were obtained experimentally:—

| Objective | Ocular | Diameter of Microscope Field | Area covered on Film | Magnification Direct Print | Magnification On enlargement to 4″ Diameter |
|---|---|---|---|---|---|
| 1½″ | × 6 | 22/100″ | 2¼″ dia. | × 10.5 | × 18 |
| 1½″ | × 10 | 17/100″ | 3″ (part) | × 17 | × 23 |
| ⅔″ | × 6 | 83/1000″ | 2¼″ dia. | × 27 | × 48 |
| ⅔″ | × 10 | 63/1000″ | 3″ (part) | × 47 | × 63 |

The stone whose inclusions are to be photographed is immersed in a glass cell containing a liquid having as nearly as possible the same R.I. as the stone. Glass cells specially made for this purpose comprising a ring of glass fused to an optically flat glass slide may be obtained from Rayners.

Suitable liquids are the following:—

| | |
|---|---|
| Toluol | R.I. 1.49 |
| Clove Oil | 1.54 |
| Bromoform | 1.59 |
| Acetylene tetrabromide | 1.63 |
| Monobromonaphthalene | 1.66 |
| Iodonaphthalene | 1.70 |
| Methylene iodide | 1.74 |

A liquid not too near in refractive index that of the stone will give some contrast and will show up the facets to some extent should this be required, thus showing the position of the inclusions relative to the stone itself. Furthermore, if you have not got the most suitable liquid almost any liquid is better than none.

To get the desired inclusions in focus takes a good deal of patience and repeated positions of the stone must be tried. When all is ready with the microscope in the correct position on the baseboard, give the exact focus a final check and then very carefully

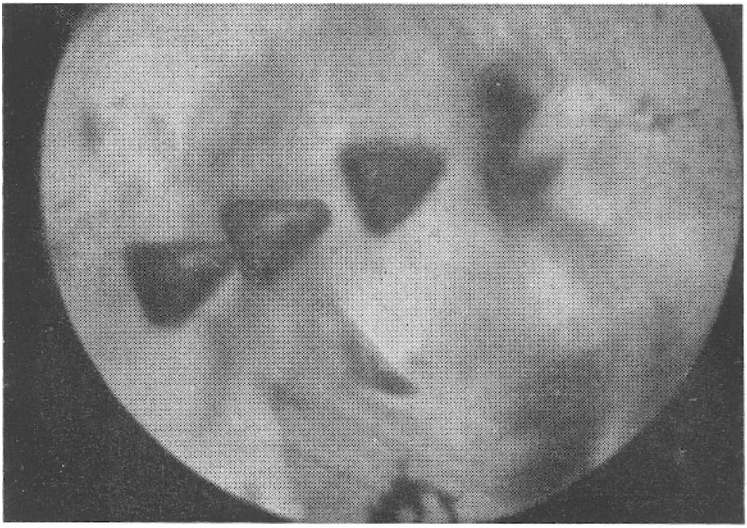


*Fig. 4 — Ceylon Sapphire — Stop F.16 : Focus — Infinity : Exposure 3 secs. : Film — Ilford Fast Ortho : Objective 2/3 : Ocular × 6.*

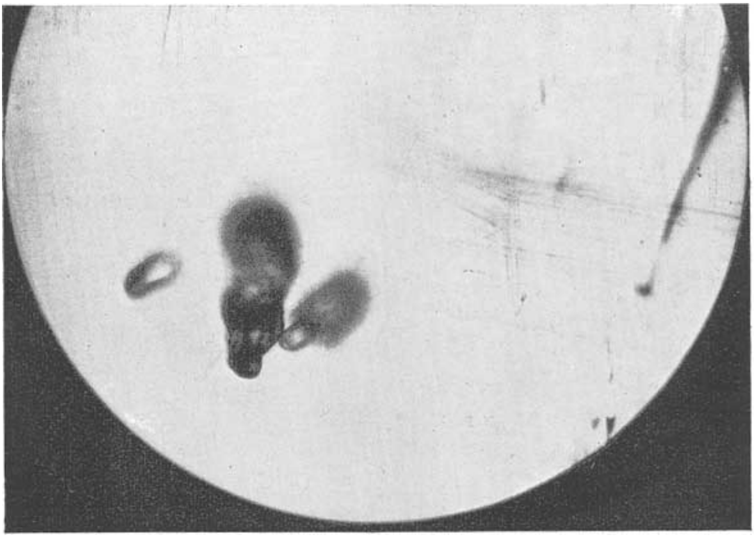


*Fig. 5 — Almandine Garnet — Stop F.16 : Focus – Infinity : Exposure 20 secs : Film — Kodak Verichrome : Objective 2/3 : Ocular × 6.*

swing the camera into position with the lens of the camera as close as possible to and immediately above the ocular of the microscope. This must be done with the greatest possible care otherwise the stone may be jolted out of position. This can easily occur as inevitably the immersion liquid and stone being of nearly the same density as well as of the same refractive index the stone may be almost in a state of suspension in the liquid.

Even if this does not occur, the slightest jar may upset the very critical focus, particularly with high powers.

Assuming that all is well, all that remains is to make the appropriate exposure, again taking care not to shake either camera or microscope whilst so doing. On completion of the exposure, carefully swing the camera back out of the way and at once look into the microscope to see that during the process nothing has moved and that the inclusions are still in focus. If movement has occurred, then there is only one thing to do and that is try again. In any case, after checking turn on the film before doing anything else. Always turn on the film after taking a photograph.

Clearly the chosen exposure depends on many factors, including light at the time, film speed, objective, ocular in use and the colour and depth of the stone itself The following may, however, serve as a guide:—

Kodak Verichrome film, 1½ ins. objective, ×6 ocular, average light from daylight (not direct sunlight):

| | |
|---|---|
| Colourless Stones | 4 secs. |
| Pale Blue Stones | 5 secs. |
| Medium Blue Stones | 6 secs. |
| Medium Yellow Stones | 7 secs. |
| Medium Green Stones | 8 secs. |
| Deep Orange Stones | 9 secs. |
| Pale Red Stones | 12 secs. |
| Medium Red Stones | 15 secs. |
| Deep Green Stones | 20 secs. |
| Deep Red Stones | 30 secs. |

For Dufaycolor film double the above exposures, though only in exceptional circumstances is there little, if any, point in colour film for photomicrographs, due to the fact that the higher power washes out the body colour and very few inclusions are coloured.

# EXPERIMENTS WITH THE SOXHLET EXTRACTION APPARATUS

*by Kenneth Parkinson, F.G.A.*

WHILST in attendance at the Association's Gemmological Exhibition last October, I was attracted on more than one occasion to the exhibit of a Soxhlet Extraction Apparatus, which was working continuously all the week with the object of improving the colour of a faded turquoise.

At the end of the week, I could see no improvement in the colour of the turquoise and so dismissed the idea of obtaining such equipment for myself as being unnecessary and useless. After reading Mr. Webster's article on the matter in " The Gemmologist " and realizing that it was not an expensive item, I decided to obtain similar equpment, even if only to " play with " ; but my very first experiment convinced me strongly of the possibilities and I felt satisfied that it would pay for itself in very short time.

Some time ago, a friend of mine, after having repaired a small diamond ring, had dropped the ring whilst still hot into some cold acid and found on removing it that, owing to capillary action, some of the filth in the acid had entered an external flaw or fracture.

The fracture, though only just noticeable in the first place, was very distinctly visible after having been in the dilute acid and was, in fact, so bad that it had to be replaced by another stone, as all attempts to restore its former appearance had failed.

Knowing all the details of the trouble, I asked for this diamond on which to experiment and, using carbon tetrachloride only, found after about fifteen hours that the stone had improved to such an extent that I was sure the experiment had been a success. There was still a trace of the impurity but an improvement was obvious.

I gave up the experiment on this stone as reasonably satisfactory as I wanted to try the apparatus with other stones, not thinking at the time that it would have been quite in order to put two or three stones in the Soxhlet tube at once.

I took a fair-sized turquoise from my stock and another one of smaller size but of exactly the same faded colour so that I should have a colour shade to go by later, and putting the turquoise in the Soxhlet tube, decided to attempt restoration of the colour, again using pure carbon tetrachloride.

After refluxing had taken place for a whole day, I removed the stone and put it alongside the smaller one which had been of the same shade of colour, and found that it had improved to the extent of about two or even three shades, but I was disappointed to find that several ugly dark stains had appeared on the surface which were not apparent in the first place and for which I could find no explanation.

A little water from the condenser had found its way into the carbon tetrachloride due to the rubber tubing not having been a tight enough fit on the inlet. As this might have caused the stains for some reason, I ran off the water and started again with clean solvent.

Two days later there was little or no further improvement in the colour and the stains were still present. As the stone had been subject to refluxing for over twenty-four hours, this was also put on one side, although the colour had definitely improved, and I could only put the stains down as being caused by the stone being more porous in some places than others.

Some years ago I heated some pieces of rock crystal and then plunged them whilst still hot into red and green dye to give them an iris effect, and as I still had some of these I thought they would prove easy and interesting items on which to experiment further.

After a full day in carbon tetrachloride, I was sorry to find the dye still there, though possibly not quite so deep in colour, although there seemed to be no trace of the dye in the solvent.

This seemed to be a definite failure, although I thought that perhaps prolonged action might improve them but it would hardly be worth the time and trouble.

I turned again to the small diamond which I had tried with some definite degree of success in the first place, but this time I tried concentrated hydrochloric acid, with the result that after only three or four hours not a trace of the impurity could be seen.

I might mention that the fumes which managed to escape were so choking at first that I had to stop, but by plugging a wad of wet cotton wool in the top of the condenser the trouble was overcome to a great extent, but was still too choking to use in a closed room.

This naturally gave me the encouragement to try hydrochloric on the rock crystals, but before doing so I was advised by a chemist to try glacial acetic acid.

This is solid at normal temperatures, but after thawing it out I was pleased to find that after only three or four hours again, all trace of the red and green dye had disappeared and the stones were as clean as could be possibly expected in view of the numerous fractures due to being plunged into cold liquid whilst still very hot. All the fractures were there, of course, but the stones were once again white and clean.

My attention again turned to the turquoise, but realizing that treatment with either hydrochloric acid or glacial acetic acid would probably result in complete disintegration of the stone, I decided to try methylated ether. The fumes from the glacial acetic acid were just as bad as the hydrochloric acid.

The foregoing experiments were carried out with the old type of Soxhlet apparatus with an external looped tube and a badly fitting cork through which the water in the first place had entered, and realising that a more modern type with an enclosed looped tube would be better, I purchased a different but simple type of Soxhlet extractor with a loose inner tube and syphon to take a 22 x 80 mm. thimble. This allows the rising vapour to keep the condensed liquid and the stone at a much higher temperature.

Owing to the highly inflammable nature of methylated ether, I had to keep an eye on the experiment all the time, and, even so, gave up the experiment after two or three hours in case of accident, especially as no improvement was apparent.

The stains were still in the turquoise but the colour was about three or four shades better, but I put it on one side again and decided to experiment with some other material.

It was a week before I saw the turquoise again, when, much to my delight, I found that the stain had completely disappeared but the stone had almost returned to its original colour. The stains had apparently been due to some minute cracks on the surface into which the solvent had penetrated and showed deeper colour than the rest of the surface and had taken a week to dry out.

# Gemmological Abstracts

CHUDOBA (K. F.). ***Charakteristische Bestimmungsmerkmale der Diamanten.*** (Characteristics of diamonds.) Gold und Silber, Vol. V, No. 2, pp. 14-15, February, 1952.

Unset stones are easily recognizable as diamonds by their hardness, specific gravity and optical properties. Difficulties may arise in distinguishng cut and set diamonds from other colourless stones. The following characteristics help in the determination. " Fire " (dispersion)—only zircon displays a similar " fire." Rutile is suspect because of excessive dispersion. Hardness leads to sharper and more durable edges on cut diamonds than on other stones. It also accounts for a better surface which reflects a clear image when used like a mirror. Good surfaces, however, are also found on zircons. In many cases rough parts are seen on the girdle of brilliants showing sometimes growth marks. Internal signs of cleavage are also characteristic in diamonds. Apart from these details the overall effect of the optical properties is significant, especially the effect of high and single refractivity which reduces the apparent depth of the stone. In addition, the " total reflection " is apparent in well cut brilliants. The author does not mention one important characteristic the connoisseur looks out for, namely the polishing marks on brilliants which indicate that no " flow layer " has been formed. E. S.

SCHLOSSMACHER (K.). ***Die Williamson Diamant Mine.*** (The Williamson Diamond Mine.) Gold und Silber, Vol. V, No. 2, pp. 15-16, February, 1952.

Details of the locality and workings of the Williamson Mine. Daily production 535 cts. Yearly production:—

| | | | |
|---|---|---|---|
| 1947 | ... | ... | 12,229 cts. |
| 1948 | ... | ... | 148,169 cts. |
| 1949 | ... | ... | 191,787 cts. |
| 1950 | ... | ... | 195,274 cts. |

Estimated value of the 1950 production: £2,100,000. E. S.

LIDDICOAT (R. T.). ***Heavy media separation proved effective.*** Gems and Gemology, Vol. VII, No. 4, pp. 116-119. Winter, 1951-2.

A suspension of ferrosilicon which is kept at a specific gravity of 2.87 at the top, and at the bottom at 2.97 to 3.05. The ferrosilicon has a density of about 7, but when ground to proper grain size and mixed with water acts similarly to a heavy liquid. Diamond-bearing material crushed to less than 1 inch to plus ten mesh, which constitutes about 80% of the feed from crushers, is fed into the heavy media (ferrosilicon suspension), when the blue ground, with a density of about 2.7, is floated off, while the heavier diamond, zircon, garnet, etc., sinks. Method said to be highly effective. Other methods of recovery described. Six illustrations.
R. W.

CROWNINGSHIELD (G. R.) AND ELLISON (J. G.). ***The determination of important optical properties without instruments.*** Gems and Gemology, Vol. VII, No. 4, pp. 120-124. Winter, 1951-2.

The detection and estimation of double refraction, and the dispersion, of gemstones without instruments. The stone is held up to the eye and light from a small bright source examined through the stone. In doubly refractive stones the spectra of the source may be seen doubled and their separation allows estimation of the amount of birefringence. The length of the spectra indicating the dispersion. A modification of the sunlight and card test. Two llustrations. R. W.

STRATTON (V.). ***Australian sapphire fields not fully exploited.*** Gems and Gemology, Vol. VII, No. 4, pp. 125-128. Winter, 1951-2.

A general survey of the conditions in the Central Queensland sapphire fields. Seven illustrations. R. W.

TRUMPER (L. C.). ***Rhodolite and the pyrope almandine series.*** Gemmologist, Vol. XXI, No. 247, pp. 26-30. February, 1952.

The results of an examination of a number of rhodolite garnets and comparison with other garnets of the pyrope-almandine series. The occurrence of rhodolite at Macon Co., N. Carolina, is described and mention is made of another occurrence in Greenland. Eight photomicrographs, one graph and one table. R. W.

PARKINSON (K.). ***Kashmir sapphires.*** Gemmologist, Vol. XXI, No. 248, pp. 39-40. March, 1952.

The term " Kashmir sapphire " so often seen in jewellers' windows are more likely to be good Ceylon stones. The term " Kashmir sapphire " being used in a similar manner to " Burma ruby " and " Siam ruby " as an adjective for colour rather than for locality. True Kashmir sapphires are not plentiful for the mines are inaccessible for most part of the year. The few sapphires mined are of fine quality. R. W.

SCHLOSSMACHER (K.). ***Synthetische Sternrubine und -saphire.*** Synthetic star rubies and sapphires. Gold und Silber, Vol. V, No. 2, p. 16, February, 1952.

Hitherto these synthetics contained rutile needles in a surface layer only. Now a titanium containing compound is added to the raw material. The boule is heat treated afterwards at 1,000-1,500 deg. C., when the titanium oxide crystallizes in the form of needles within the whole structure of the corundum lattice. E. S.

SWITZER (G.). ***Present states of the turquoise industry.*** Gems and Gemology, Vol. VII, No. 4, pp. 113-115. Winter, 1951-2.

A report on the sources of gem turquoise and the quantity and value of the rough material. Now only Iran (Persia) and the U.S.A. important producers. A note on imitations is given. Two illustrations. F. T.

WEBSTER (R.). ***The Soxhlet extraction apparatus.*** Gemmologist, Vol. XX, No. 244, pp. 224-227. November, 1951.

A description of the apparatus devised by Franz Soxhlet for the extraction of a soluble substance by a continuously re-distilled solvent and its suggested employment for removing extraneous matter from cracks and flaws in gemstones. Three illustrations.

P. B.

LEWIS (M. D. S.). ***The diamond—before and after.*** Gemmologist, Vol. XXI, No. 246, pp. 4-8. January, 1952.

Before the 16th century diamonds were not employed in jewellery, and the trend was in coloured stones and enamels. When the fashioning of diamonds became an art the styles of jewellery changed. The history of the fashioning of diamond and its use in the Renaissance, 17th and 18th centuries is given. Rock crystal not used for gems in mediaeval times. Three illustrations.

R. W.

# COLOUR PERCEPTION IN GEMMOLOGY

*by M. D. S. Lewis, B.Sc., F.G.A.*

MOST gemstones owe their colour to selective absorption. Light enters the stone where some wavelengths are absorbed, the residual rays being reflected back to the eye in which they have the property of causing the sensation of colour. What happens within the stone is a matter of physics and chemistry which can be accurately specified and measured, but when the light reaches the observer's eye two other factors—physiology and psychology—must also be taken into account.

Suppose a lady in an attractive orange-coloured dress and wearing a magnificent emerald brooch makes a dramatic entry into a room. A keen male gemmologist might perhaps only " see " the deep velvety green of the emerald and remain quite oblivious to the colour of the dress, in spite of the fact that orange light is entering his eye. A fashion writer might probably enthuse over the orange-coloured dress and remain only vaguely aware of a large ornament accompanying it. A female gemmologist would probably " see " both green stone and orange dress. In each case the physics of the light is identical ; the same proportions of green and yellow light enter all three pairs of eyes, yet the colour perceptions are different. " Colour," says R. M. Evans, is often a matter of " attention, intention and memory." This difference in " colour perception " arising through varying mental attitudes is not the only one. Assuming each of the three observers to have normal sight, the male gemmologist will experience the " normal " green of the emerald and the fashion writer will likewise see the " normal " orange colour of the dress, but the female gemmologist will experience neither. By gazing simultaneously at green stone and orange fabric the " adaption " of her eyes will change and she will probably experience the phenomenon known as " simultaneous colour contrast." To her, the emerald will seem more " bluish " green and the orange of the dress will appear to contain a greater amount of red.

Already a difference has arisen between " colour " and " colour perception," but at this stage the impatient reader will probably declare that he does not care about the female gemmologist's eyes ; everyone knows that this emerald is green and the dress is orange-coloured. This is reasonable enough, because the word " colour " has come to be identified with the appearance to an average observer in daylight under normal conditions. The colour actually perceived, however, may be quite different under varying circumstances. Although we may prefer to imagine that the redness of a ruby resides in the stone rather than in our own eyes, this is, of course, not the case. If the illumination on a ruby be gradually reduced the colour changes through brown to black ; if it is illuminated by blue light it will probably appear blue, whilst in spectrally pure green light it may appear black. Obviously redness is not a constant property of ruby.

To elucidate some problems of colour we must therefore examine them against the wider background of " colour perception." In doing so we transfer the scene from the gemstone to the observer's eye where, in addition to the physics of the light, we must take circumstances into account. Theoretically and practically the subject is of importance in gemmology. The purchaser of a coloured stone does not usually care about the position of absorption bands, but is interested in the colour actually perceived. An understanding of the subject would be essential in any workable system of colour specification and measurement. It embraces theories of cutting, illumination and colour contrasts, whilst it provides an explanation of a number of gemmological phenomena.

It is generally accepted that there are three aspects or attributes of " colour perception." In gemmology obviously the most important is " hue," which is largely determined by spectral distribution. This is the attribute by which green is distinguished from red, blue from yellow, and so on.

Now consider two synthetic red corundums each made by adding chromic oxide to alumina. Suppose that one contains a very minute quantity of colourant and is pale pink, whilst the other is deep red owing to a larger content of chromic oxide. In both cases the absorption spectrum will be typical of chromium and obviously spectral distribution is similar, yet we get two quite different colour effects. The " hue " is the same but something else varies. This second attribute is known as " saturation " and refers to the intensity or concentration of hue.

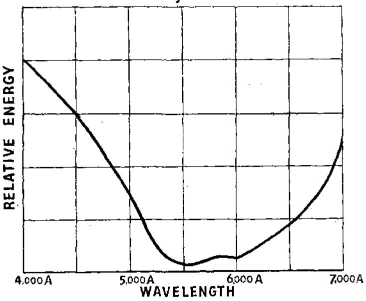
Now imagine a well-kept grass lawn of uniform texture illuminated by strong sunlight. The colour will be bright green and at every point " hue " and " saturation " will be constant. Suppose a large tree to throw a deep shadow in one part ; within this area, yet another colour effect—dark green—is seen. This third attribute is " brightness " and is connected with the total quantity of light reaching the eye.

Colour perception has thus three attributes—Hue, Saturation and Brightness—and all three are needed to specify the appearance of any colour. Hue and Saturation are purely mental concepts and cannot be measured outright. No one can define exactly how " blue " is a sapphire ; it can only be compared in blueness to another blue object.

## HUE.

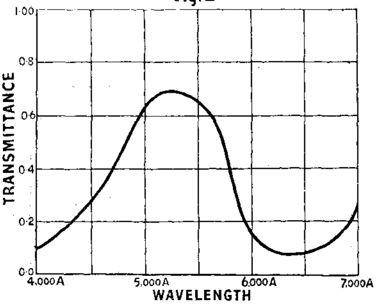
As already stated, " Hue " is the attribute of colour perception by which we distinguish red from blue, green from yellow, etc., and is dependent on spectral distribution. The great importance of absorption spectra in practical gemmology naturally focuses attention on the position of absorption bands, but what really determines colour is not the light absorbed, but that which is transmitted. An absorption spectrum seen in the spectroscope or as a photograph often gives little indication of the actual colour. The areas of red, blue, etc., are quite arbitrary, depending on the instrument used. Partial absorption can take place over a wide range without producing an obvious band and a photographic plate is mainly affected by blue and violet rays, whereas the eye is most sensitive to yellow-green light. What really counts as regards colour perception is the relative energy of the transmitted rays. This is measured by placing a suitable receptor in successive parts of the spectrum so that the energy in the various wave bands is converted into heat or electricity and measured. A graph is then drawn to connect wave length with relative energy. Fig. 1 shows the spectral distribution of light from a hypothetical purple gem. The most important feature in this type of graph is the area underneath the curve. Between 4,000Å and 5,000Å this is larger than under any other 1,000Å stretch of curve, so " blue " energy will predominate

Fig. 1



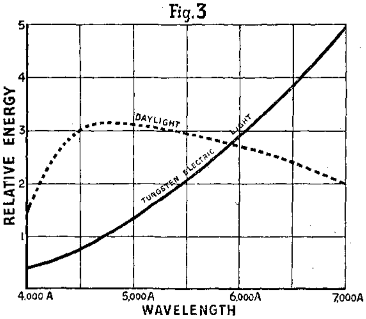
*Relative energy curve for light transmitted through a hypothetical purple gemstone.*

Fig. 2



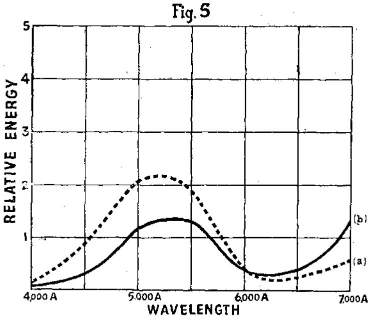
*Transmittance curve of hypothetical green gem material.*

Fig. 3



*Spectrophotometric curves showing relative energy distribution for daylight and tungsten electric light.*

Fig. 5



*Approximate relative spectral distribution curves of:*

*(a) Daylight transmitted through gem material of Fig. 2.*

*(b) Tungsten electric light transmitted through gem material of Fig. 2.*

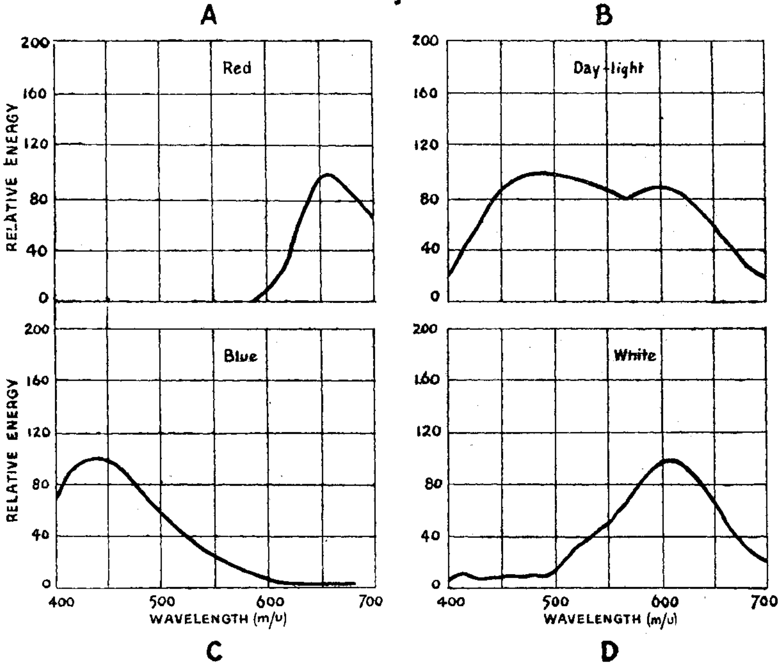
*(a) Will probably appear blue-green, whilst (b) will appear yellow-green.*

*These are the approximate product curves of Figs. 2 and 3.*

admixed with a lesser amount of orange and red (approximately 6,000Å-7,000Å). The area under the graph in the green and yellow wavelengths (approximately 5,000Å-6,000Å) is relatively very small so the colour impression will be bluish-purple. At this stage a distinction must be made between coloured objects and coloured light. The above graph merely depicts the quality of the light which has passed through and left the gemstone. As will be seen later, it does not necessarily completely define the selective absorption characteristics of the stone. Whilst we speak of the energy of light we cannot do so of an object. In this case we relate percentage transmission with wavelength and this is done by measuring in series, the percentage absorption of monochromatic lights and again drawing a curve. Such a graph is seen in Fig. 2 and this would correspond with the Relative Energy-Wavelength curve for the transmitted light, only if light falling on the gemstone had equal energy in each region.

The absorption spectrum of a gemstone shows that some wavelengths of the incident light are absorbed whilst others are permitted transit. If these permitted wavelengths are not present in the incident light there naturally cannot be any transmission in these regions. For this reason the colour displayed by a gemstone depends on the illumination. There are three main types of illuminant in general use—sunlight or daylight, tungsten electric and fluorescent light. Fig. 3 shows the spectral composition of daylight and tungsten electric light, from which it will be observed that daylight is fairly well balanced in energy distribution whilst electric light is relatively poor in blue and rich in red rays. The amount of blue energy in sunlight or daylight is variable, depending on time, place and atmospheric conditions. Fig. 4 shows that fluorescent lamps can have almost any kind of spectral distribution. To evaluate the resultant effect of any illuminant on a coloured transparent object one must combine the Relative Energy curve of the incident light with the transmission curve of the substance. This is done by multiplying for each band of wavelengths percentage transmission by relative energy. Fig. 5 shows the different effects of daylight and electric light on a gemstone. The two relative energy curves in Fig. 3 have been respectively combined with the transmittance curve in Fig. 2 and the resultant product curves are shown in Fig. 5. These specify the spectral distribution of daylight and electric light after transmission through the stone, which will appear bluish-green by day and yellow-green by electric light. The actual hue assumed by a gemstone must therefore depend both on the spectral distribution of the illumination and its own absorption characteristics. For this reason it is possible a gemstone might appear in some quite unnatural hue under fluorescent light. For

Fig. 4

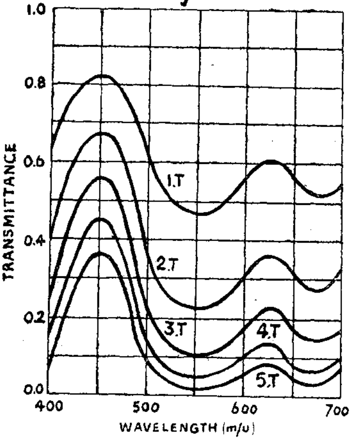


*Spectral distribution curves for several types of fluorescent lamps. From "An Introduction to Colour" by Ralph M. Evans (Chapman & Hall Ltd.).*

example, a good alexandrite, green by day, will appear red under tungsten electric light, but if the illumination were provided by a fluorescent light of spectral composition corresponding to Figs. 4B or 4C, it would certainly not change in colour but might even appear more green.

Assuming an isotropic stone to be perfectly uniform in colour, it might be supposed that the " hue " or spectral composition would be constant for all directions of view and independent of the depth or thickness. This is not necessarily so, particularly if there is more than one absorption band. The relationship between thickness and " hue " is governed by Lambert's Law, from which it may be deduced that where " T " is the transmission for a particular wavelength for a particular layer, then $T^n$ is the transmission for " N " layers. Thus, if for a certain thickness the transmission

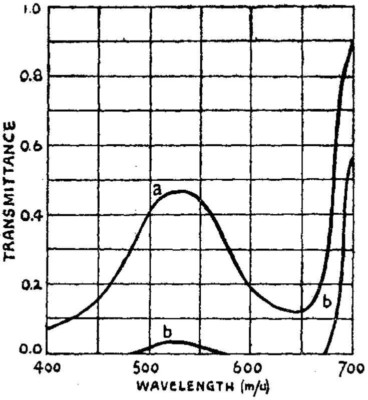
Fig. 6



*Transmittance curves of five thicknesses of a coloured transparent material.*

*From "An Introduction to Colour" by Ralph M. Evans (Chapman & Hall Ltd.).*

Fig. 7



*Transmittance curves for a selective material of (a) a given thickness and (b) five times the thickness.*

*From "An Introduction to Colour" by Ralph M. Evans (Chapman & Hall Ltd.).*

of a certain wavelength is 20%, it will fall to 4% for a double layer. If for another wavelength it is 50%, then the transmission for the double layer will only fall to 25%. In other words, the shape of the transmission curve may change with increasing thickness. This effect is not to be confused with the increase of saturation which naturally accompanies increasing depth ; even with constant hue a thin layer of the darkest material will appear pale in colour, but here the difference is only one of intensity, not of spectral distribution. In Fig. 6 curve IT represents the transmission of one thickness of coloured material. It will be seen that "blue" energy is predominant, there is a deficiency of green and considerable reinforcement of orange and red, which will probably produce a violet-purple colour. Curve 5T shows the percentage transmission of five thicknesses. Here green and red have almost vanished so the resulting hue must be nearly pure blue. Fig. 7 shows this change more strikingly. Curve (a) obviously refers to a green object, but in a piece five times as thick the area under the red end has become greater than that under the green region, so the overall colour impression will change from green to red.

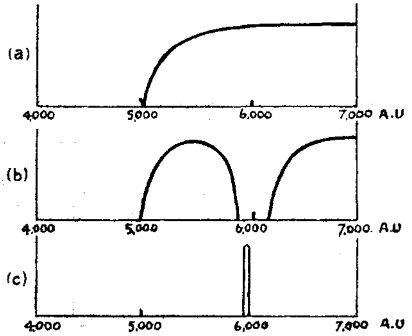
Although this phenomenon must occur to some extent in most transparent substances, it is insignificant in normal gemstones, firstly because they do not absorb very strongly and secondly because they are not thick enough. Some glasses incorporating rare earth oxides do show this phenomena and are markedly " dichromatic," the colour changing with thickness.

There are two ways of causing or modifying " hue "—subtractively or additively. The colour of gemstones is subtractive because some part of white light is subtracted to leave a coloured residue. Thus, if a stone absorbs strongly, say, in the middle part of the spectrum, it amounts to a subtraction of green and yellow from white light, leaving substantially blue and red transmission, which gives the sensation of purple. Physics by itself cannot forecast the precise colour sensation of a subtractive mixture. In the case of more than one subtractive process the only wavelengths finally appearing are those common to both transmissions. Suppose a blue stone to be examined through a yellow glass, what hue will be likely to result? Blue stones usually transmit blue and a certain amount of green light. A yellow glass will probably transmit in addition to yellow some red, orange and green rays. Green transmission is the only one common to both systems and this would therefore be the hue of the light which reaches the eye.

Additive hue results from the combined effects of coloured *lights* which reach the eye simultaneously. Any colour can be matched by the mixture of three primaries—e.g. red, green and blue—in suitable proportions, although white light may have to be added to the original. This is a fact of the utmost importance and is the basis of widely used systems of colour specification and measurement. Suppose two approximately monochromatic lights are mixed. If they are far apart on the spectral scale, i.e. one in the red and the other in the blue, their effect is to give purple. If nearer together—say one in the orange and one in the blue, or one in the red and the other in the blue-green—the tendency is to give white or grey. If closer still, say one in the red and one in the yellow, we get an intermediate—in this case orange colour.

Additive colour enters gemmology in questions of illumination. It is important to remember that when coloured light is reflected at another coloured surface it remains unchanged in hue. Thus, green light reflected from a yellow surface will still remain green.

Fig. 8.



*(a) A subtractive yellow — e.g., a solution of yellow dyestuff.*

*(b) A subtractive yellow, obtained by adding a neodymium salt to (a) and so removing all the true yellow from the transmitted light.*

*(c) Spectral yellow, such as is obtained by suitably filtering light from a mercury arc lamp.*

*Three yellows which under suitable viewing conditions would be undistinguishable by the human eye.*

*From "Colour in Theory and Practice" by H. D. Murray and D. A. Spencer (Chapman & Hall Ltd., London, W.C. 2).*

If a room is illuminated by sunlight through a window, outside which stands a leafy tree, an extra amount of green light will mix with that of the sun. If within the room there are yellow walls and a red carpet, these will also add their quota of yellow and red energy to the general illumination. The spectral distribution of light may therefore vary greatly from room to room and for this reason dealers usually prefer to examine stones in their own offices where they have become accustomed to the vagaries of the light.

The unaided eye has very little power to analyse light. Fig. 8 shows the spectral composition of three different yellow lights which are visually indistinguishable from each other. Light represented by curve 8 (b) is particularly interesting as it contains no yellow rays whatever of wavelength approximately 6,000Å, yet monochromatic light of precisely this wavelength will cause identical yellow sensation.

The dependence of " hue," not only on the spectral characteristics of a stone but also on the nature of illumination, has already been mentioned. It has also been seen that illuminants differ very widely in spectral composition. It must therefore seem strange that, after all, the hue of most stones does not appear to vary greatly under normal conditions. An emerald usually looks like an emerald in daylight, electric light, fluorescent light, fog, twilight, etc., in spite of the fact that light transmitted by the stone under all these extremes of illumination must vary greatly in spectral composition. Why, then, does the " appearance " (that is to say, the colour perception) remain so constant?

This brings us to one of the most important facts of colour perception—the adaptation of the eye.

Without attempting to discuss physiology, it can be said that as regards colour the eye behaves as though it were governed by three receptors sensitive to Red, Green and Blue respectively. If it receives a blue stimulus the sensitivity of this receptor is depressed, whilst that of the green and red receptors increases relatively. It would appear that the eye is normally adapted to daylight and when we change over, say to electric light, which has excess of red energy, there is a change of adaptation and we become relatively less sensitive to red and more so to blue and green, thus tending to neutralise the change. Whenever there is a change of illumination the eye tries to adapt itself in such a way as to keep the appearance that of daylight. It must be stressed that this is purely a physiological and psychological effect. If we were to make a strictly physical examination of the light transmitted by a stone in daylight and again in artificial light, we might get very different results, but within limits the actual appearance would remain fairly constant due to the ready adaptation of our eyes to changed conditions. In the case of alexandrites and some synthetics the shift of hue with changing illumination becomes too strong for adaptation to cope with and quite a new appearance results. The adaptation of the eye is surprisingly great and often dominates situations in which colour is involved. Some electric light is decidedly yellow, yet a sheet of white paper illuminated by it still looks white. If the light reflected by the paper were examined spectrophotometrically it would show high relative energy in those wavelengths which normally produce a " yellow " stimulus. From every physical point of view the paper should look " yellow," yet the eye adapts itself in such a way that we still obtain the " normal " daylight impression of whiteness.

Adaptation accounts for the phenomena known as " after images " and " colour contrasts." At the beginning of this article a somewhat far-fetched and hypothetical situation was described in which a female gemmologist experienced colour sensations different from those of her less observant companions. When she looked at the emerald the sensitivity of her green receptor was depressed and her blue and red receptors became relatively more active. The orange-coloured dress reflected mainly red and yellow light. This red component then exerted greater effect on her perception through increased activity of her red receptor. Therefore she " saw " the dress in a redder light than the others. When she looked at the orange dress her red receptor became depressed by comparison with her blue receptor. The emerald therefore appeared more blue-green. The effects of surroundings on colour can be worked out in this way from first principles. Suppose we have some greenish-blue turquoise and wish to make it appear more blue. We can do this by decreasing the sensitivity of our red and green receptors, thereby increasing blue sensitivity. Spectral red and green lights unite to give yellow-orange ; therefore by surrounding a greenish-blue turquoise with yellow-orange its apparent blueness should increase. These few remarks on adaptation emphasize the subjective nature of colour.

This may perhaps be the place to mention " white, grey and black," which actually are not colours as they have no hue. Strictly speaking, the term " white " can only be applied to a surface which reflects all wavelengths of the visible spectrum with no change in spectral distribution or intensity. If the spectral distribution of the reflected light remains unchanged but its intensity is less then greyness will result. Blackness is experienced when the intensity is too low to produce a stimulus on our visual mechanism.

There are three stages in the perception of " hue." Firstly, some kind of illumination must enter the stone as without illumination there is no colour. The physical properties of this light can be stated unambiguously. The second stage is the interaction between light and stone and the result depends both on the spectral distribution and energy of the light and the absorption properties of the stone. The modified light which issues from the stone can also be completely defined in physical terms, but when it enters our eyes we leave physics behind because we are in the field of physiology and psychology, where another and most important factor has now to be considered—the differential sensitivity of the eye to various wavelengths. The " Relative Energy-Wavelength " curve should always be " weighted " by optical sensitivity in order truly to evaluate colour sensation. This, however, involves the more difficult concept of luminosity, a discussion of which will be left until later. To quote R. M. Evans* once again: " Colour is what you *do* see, not what you are supposed to see."

### SATURATION.

Saturation is that attribute of " colour-perception " which differentiates between shades and tints of the same hue. It may also be defined as " percentage of hue " or, in the case of pigments, " freedom from white." Consider again the making of a batch of synthetic red corundums in which the same colouring matter is used throughout but in decreasing quantities. A series of red stones will result, all alike as regards spectral composition and hue but varying in intensity of colour. Those containing a relatively high proportion of chromic oxide will be deep red, but as the amount of colourant is reduced the colour will fade to pale pink. The saturation of the colour refers to its place in this scale.

Saturation is probably the most interesting attribute of gemmological colour and, like hue, is largely subjective, often depending on circumstances. If a stone has a certain hue—due to its spectral composition—there is not much to be done about it ; it can be made to appear slightly different through physiological or psychological agencies, but a sapphire cannot be made to look like an emerald. It is of greater importance and often easier to alter the apparent saturation of a stone—to change a poor ruby red into a deeply saturated one. This is not to infer that the stone has to be " faked." It has been repeatedly stressed that colour perception is a mental sensation, depending not only on the stone but also on what goes on in our eyes.

At this stage we must pause to consider what we really want in a gemstone as far as appearance is concerned. The fundamental and primary reason for the wearing of jewellery was (and probably still is) the attraction of attention to parts of the human body. Attention is always drawn to something which is changing relative to its surroundings or to something which is already different from its environment. The colourless gemstones compel notice through their ceaseless variations in reflective and dispersive effects, whilst the deeply coloured gems differentiate themselves from their surroundings through outstanding saturation of colour. Some stones, of course, attract attention through chatoyancy, asterism or adularescence.

In all questions concerning the appearance of gemstones it is essential to realise that two different kinds of light always travel from stone to eye. No gem is normally viewed solely by transmitted light except when under microscopic examination. It is always seen by a combination of reflected and transmitted light. Of the light which strikes the surface, some is reflected immediately back to the eye without change. Normally this is white (or, more correctly, colourless), but if not, it undergoes no change in colour on reflection at the surface. If one arranges red, blue and green stones so that an electric light bulb is reflected in the tables, the image has substantially the same yellow colour in each case and by concentration on the image one can become quite oblivious to the colour of the reflecting surface. The remainder of the incident light—that is to say, those rays which are not reflected at the surface—penetrates the stone and there undergoes selective absorption or dispersion before reflection back to the eye. These rays which have penetrated into the stone are essentially transmitted light, in spite of ultimate reflection from the back facets. The all-important point to remember is that this transmitted light is never seen in its original purity. Before it can reach the eye it is always diluted by light reflected at the surface, which is, of course, the unchanged illuminant.

In the case of colourless stones the properties most valued are " brilliancy " and " dispersion." Brilliancy is mainly provided by light reflected at the surface and to a certain extent must increase with the number of facets on the stone. It is essential that at least one facet shall reflect light strongly to the eye from whatever position the stone is viewed. Dispersive effects (fire) are provided by light which has penetrated the surface. If only brilliancy were concerned it would be advantageous to cut the stone in such a way that the maximum proportion of light is reflected at the surface, but from the point of view of " dispersion " as much light as possible should enter the stone. It is the function of the lapidary to dispose the facets in such a way as to keep a nice balance between these two often conflicting properties in a colourless stone. It is reasonable to assume that the larger the table the more light can enter the stone, and if the incident rays were always vertically parallel and the table of the stone always horizontal this would certainly be the case, athough other factors such as total area of surface must exert influence. The table of a stone can, however, be enlarged only at the expense of the side facets and therefore with some detriment to brilliancy.

With pale coloured stones a very interesting situation develops. The colour is not sufficiently saturated to satisfy by itself and a certain amount of brilliancy is needed in addition. This is probably why aquamarines and pink topazes, etc., are cut with a large table and numerous small side facets. The former allows maximum entry of light to provide colour and the latter tend to increase brilliance.

With densely coloured stones everything is different. We want deep saturation above all, not brilliance, which now becomes a definite nuisance. Surface reflections are here undesirable, firstly because they distract our attention from contemplation of colour and secondly because they dilute a saturated colour through the addition of white light. The greatest compliment we can pay an emerald is to say that it is of a " deep velvety " green. Now velvet is a material reflecting the minimum of white light. The incident rays are trapped in the long tapering fibres, repeatedly reflected downwards to the interior of the fabric, undergoing additional selective absorption each time. Thus, a velvet green is a deeply saturated colour.

If we have a rough emerald, how can we ensure that when cut it will show maximum saturation? Only by preventing as far as possible dilution with white light. To do this we must provide it with smooth, well-polished facets, *few in number*. We may be unlucky to see a reflection in one facet, but by moving our head slightly we shall avoid it, whereas if there were many facets there would be no position from which some reflection could not be seen. By sacrificing side facets we can also have a large table to allow maximum entry of light. It is suggested that this is the theory underlying the " emerald-cut." Some readers may now perhaps wonder why smooth, well-polished facets are essential for maximum saturation of colour. Why not leave the stone rough and so avoid these brilliant but unwanted surface reflections? The answer is that we *cannot* do away with surface reflection, which must always occur to some extent when light strikes any surface. Consider the simplest possible case in which a well-cut and polished emerald is illuminated by parallel light from the sun falling on the table facet. In one direction, and *one direction only*, we shall get specular reflection. We shall probably see an image of the sun, we shall be dazzled, our attention will be distracted and we may even become quite oblivious to the colour of the stone. Even if we do see some colour it will be quite desaturated through heavy admixture with white light. All of these unpleasant effects, however, will only occur in one unique position. There will be almost an infinity of other positions from which we can enjoy the full saturation of colour without dilution with white light. Of course, the situation is never as ideal as this. Even if the sun is shining strongly a large proportion of diffuse illumination from the sky and surrounding objects will also be present. Neither does indoor illumination usually provide parallel rays and, even if it did, diffused light would come by reflection from walls and ceiling, etc. Nevertheless, it is a fact that a single concentrated source of light gives maximum saturation which decreases rapidly as illumination becomes more diffuse. It is also true that maximum saturation is obtained when a coloured surface is viewed perpendicularly, because in this direction our eyes will receive the minimum of surface reflected light.

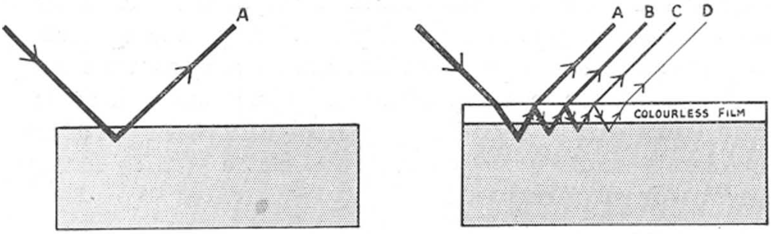
This explains why a badly worn stone improves in colour on repolishing. A rough surface is one containing numerous tiny facets scattering light at all angles. There is no position from which undiluted colour can be received. By repolishing we accept these annoying surface reflections as inevitable but " canalise " them in one direction. We then step aside and by-pass them. For the same reason a faint layer of dust will desaturate a colour out of all proportion to its obscuring power. The minute particles scatter white light in all directions.

It should be noted that stones of relatively low refractive index should show maximum saturation. Surface reflection increases with refractive index. A diamond will reflect about 17% of the light striking the table perpendicularly ; with emerald the proportion drops to about 5%. The effect is therefore cumulative, for not only does more light enter an emerald to produce colour, but it is also less diluted after emergence from the stone. Even if a diamond were found naturally coloured green by chromium, or a synthetic rutile were made in an emerald green colour, the saturation could not equal that of a good emerald because the very high refractive indices of these two stones would cause too much surface reflection.

Assuming that colour is due to the interaction between a ray of light and a colouring ion, it seems obvious that " more " colour will result by increasing the number of colouring ions. In most natural stones this can be attained by cutting them as deep as possible. The same result, however, is often achieved more easily by making the rays of light travel greater distances within the stone so as to meet more colouring ions in their path. By a suitable disposition of the back facets the rays of light which have entered the stone are repeatedly internally reflected, thus lengthening the light path and increasing saturation. Indian lapidaries are very skilful in bringing out this effect. By cutting an almost colourless stone in such a way that a small coloured area is located near the culet, most of the rays which enter the stone are made to pass, perhaps many times, through this spot, thus emerging effectively coloured.

One way of improving saturation would be to cut the material in concave form. The interior of a coloured bowl tends to show greatly enhanced saturation as the rays of light are repeatedly reflected from one side to the other before emergence, and with each reflection increased selective absorption occurs.

Fig.9



*Rays of light undergoing selective absorption in a coloured substance. The ray "A" has only been reflected once and may therefore show incomplete saturation.*

*The addition of a colourless film to a coloured surface increases saturation. Through repeated selective absorption the reflected rays "B," "C," "D" become progressively more saturated.*

Another method would be to deposit a layer of colourless material on top of a coloured surface (Fig. 9). Many of the rays which would otherwise escape from the coloured material are then reflected downwards at the air-film interface into the coloured medium again, thus acquiring increased saturation. This effect is even more marked when the original coloured surface is rough as the newly added film substitutes a smoothly reflecting surface.

If a stone is badly worn and it is required to form an estimate of the colour after repolishing, a good, though perhaps optimistic, idea could thus be obtained by placing a drop of liquid on the surface. This effect is really quite different from that obtained in the new-coated stones on which the film is so thin that interference colours result, or, in other words, a new hue is produced. When the added layer is comparatively thick there is no change in hue, merely increased saturation.

Adaptation of the eye plays an important part in saturation. The " colour-contrasts " and " after-images," referred to earlier, result from the depression of one or two of the colour receptors in the eye. In effect this usually induces a complementary sensation. Thus, if we gaze at a blue object and then look at a neutral background the complementary colour of yellow is seen. To display coloured stones to their best advantage they should in theory be shown against a background of complementary hue, which will provide the most effective contrast. Thus, an emerald would seem to require a purple background since this colour gives an " after-image " of green, which, when added to the normal hue of the stone, increases the apparent saturation. Likewise, a green background might be most suitable for amethysts. It is, however, an unexplained fact that a grey background often seems to improve saturation.

Any very thin piece of gem material will appear pale in colour since the light path is not sufficiently long to provide complete selective absorption. As the depth increases the colour becomes more and more saturated until a certain point is reached when added thickness produces no further improvement but only darkens the stone. At this point of maximum saturation, all those wavelengths which the stone is capable of absorbing have been abstracted from the illuminating rays. The absorption bands are fully defined and complete. Added thickness now only reduces the intensity of all wavelengths impartially. General absorption supervenes on selective absorption, the total amount of light reaching the eye begins to diminish and the stone darkens. This brings us to the third attribute of " Colour-Perception."

## BRIGHTNESS.

"Brightness" is the attribute of colour by which we distinguish between lighter tones and darker shades of the same hue and it varies with the physical intensity of the light which produces it. The saturation of a hue indicates its position on a scale at the extremes of which are spectral purity on the one hand and colourlessness or whiteness at the other. The brightness of a hue defines its position on another scale, at one end of which is maximum transmission or reflectance and at the other—blackness. A Burma ruby, pink sapphire and Siam ruby all have the same hue, viz., red." The first two vary in saturation, but the two rubies differ from each other in brightness. The Burma ruby woud be accounted as being of medium brightness, whilst that of the Siam ruby would be decidedly lower and its redness, therefore, would be tinged with brown. Most transparent objects of maximum saturation, including the majority of valuable coloured gems, are moderately bright. If attempts were made to increase their brightness by forcing more light through, their saturation would decrease.

Whilst luminous transmission or luminous reflectance can be measured, the actual sensation of brightness is almost entirely comparative. If one looks at an incandescent light at night the effect is one of blinding brightness, yet the same lamp in daylight appears quite inconspicuous. If the illumination in a room be gradually reduced, there is little diminution in brightness of the objects within, particularly if some little time is allowed to elapse, so that the eye can adapt itself to the new conditions. It, however, the illumination on one object only is reduced, it will assume a " grey " appearance by contrast with the others. Brightness is the most puzzling aspect of colour. If the illumination on a white surface be reduced to half it will probably still appear white, yet if instead black is added so that its reflectance is reduced to a half it will appear a decided grey. In both cases the physical stimulus is the same but the eye reacts to them differently.

It has already been stated that the most deeply coloured stones should be cut to a depth just sufficient to allow maximum saturation. Beyond this, increasing depth merely decreases brightness and the colour begins to move towards black via grey or brown. In some stones which absorb more strongly, however, saturation must be sacrificed for brightness if a pleasing appearance is to result. This applies particularly to red garnets, which from the æsthetic point of view should always be cut thinly and set closed at the back, over some brightly reflecting material. General absorption is so heavy that every device should be used to return as much light as possible to the eye.

The concept of brightness may not present many difficulties to the paint technologist, who deals with opaque surfaces viewed solely by reflected light. Nor perhaps to those who are concerned with transparent objects such as coloured signal glasses or stained glass windows, which are viewed only by transmitted light. To the gemmologist it presents a more difficult problem since a gemstone is always viewed both by reflected and transmitted light. It is difficult to disentangle the brightness of a gemmological colour from what is usually called the brightness of the stone and which is partly determined by the form in which it is cut.

To sum up, colour cannot be defined in physical terms. If it could, then a blind person might know as much about it as anyone else, which would be absurd. It is largely a mental sensation and must, therefore, be assessed against a " psycho-physical " frame of reference. It is determined by the three attributes of Hue, Saturation and Brightness, but these seem such fugitive qualities one might well despair of ever being able to measure them. It says much for the ingenuity of colour physicists that methods have been found of specifying a colour in figures. How this is done and whether it could be applied to gemmology may possibly perhaps form the subject of another article.

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# THE ART OF THE LAPIDARY

MEMBERS of the Gemmological Association learned some of the secrets put into practice by the craftsmen who make gems when they heard two of the leading lapidarists at the British Council Cinema on January 23rd, 1952.

The two craftsmen were Mr. C. L. Arnold and Mr. G. E. Bull-Diamond, both of Charles Matthews, Ltd., the first being a cutter and the second a polisher.

Mr. Arnold began by having a picture of himself at work thrown on the screen and describing the tools he uses. The first thing to consider in cutting a stone, he said, was to study it and decide just what should be done: whether it should be round, oval, trap-cut and so on. Unlike the mathematical methods used in cutting a diamond, coloured stones had to be cut according to the disposition of the colour in them. That was the main factor to be borne in mind, though there were others. The hand and the eye were the important tools. Accuracy had to be judged by the eye and feel guided the worker with his cutting wheel, which was turned by hand.

Demonstrating with two rough pieces of sapphire and ruby how the disposition of the colour lay, Mr. Arnold said a stone could be ruined merely by trying to make it as large as possible. The density and the disposition of the colour determined how the cutting should be done. But after viewing a piece of gemstone and perhaps deciding how it might be cut, the worker did not go right ahead with the cutting. He would rough it up first, and he might change his mind after that, several times, before coming to a final decision.

Mr. Arnold went on to deal with the placing of the facets. The first and most important thing was to have the stone mounted absolutely horizontal to the stick so that the table was straight. The cutting started with the forming of the first facet next to the table, then the one opposite. Then came two more on each of the other sides, and finally an octagon was made and the basic facets were then done. The rest of the cutting was "fairly simple." The most difficult was getting the first square of facets. The cutter could not use any measuring tools and had to rely upon the skill of his eyes and hand. On the back of the stone each facet should be opposite the ones on the front. All the lines of the facets should run straight towards each other, otherwise there would be distortion and the stone would not look at its best.

A carborundum wheel was used for the first roughing up of the stone, but hard stones had to be cut on a steel or copper wheel charged with diamond, which had to be evenly spaced. Examples of unpolished stones which had gained awards at the Crafts competitions at the Goldsmiths' Hall were shown on the screen and Mr. Arnold added that the cutter's work was not necessarily confined to precious stones. Compass bearings and scientific instruments needed by ships, aircraft and land vehicles had agate or knife bearings which had to be made.

Mr. Arnold closed by referring to the new stone, synthetic rutile. He was the first man here to cut it, he believed. It was an entirely new material. At first no one quite knew how to treat it or the best way to cut it. It could not be dealt with like an ordinary stone because it did not respond in the same way, but he believed now that more had been discovered about it than was known in the United States, and having worked out his own method he did not think it could be improved upon. He had seen a number of rutiles that had been cut in America and he could not learn anything from them. The boules varied and he had yet to find one which would cut all the same coloured stones, though the colour might look the same in the boule. He had cut them all ways from the boule, not necessarily through the axis.

Some people might think that only the front of a stone mattered, but it was his experience that the back was most important. It was a mistake to concentrate on the front. The back must be in proportion and the back needed special treatment according to the colour of the stone. More facets were needed on the back for a light stone like aquamarine, while a dark stone might need facets planned to keep the colour out. A pale stone could be made darker by the placing of the back facets.

Mr. Bull-Diamond then spoke on the art of polishing. For this the light touch and hand-driven wheel of the cutter gave way to a firmer pressure and a power-driven wheel. That was why, as a rule, the cutter and the polisher were two different persons, each specialising in one branch of the craft, though they could often do either job. The polisher with his power-driven wheel sometimes used a control to vary its speed. It was important to keep the wheel clean. Dirt would scratch and a scratch on one facet would be multiplied many times. The wheel, running at about 400 r.p.m., must be absolutely true. The wheel was " sharpened up " with sandstone to get " bite," and the polishing was done by rotten stone and water. Copper wheels were general, though a lead or pewter one might be used for a soft stone such as fire opal or rutile and a softer abrasive than rotten stone.

The first and one of the hardest things to do was the table. The table was mounted at 45 degrees to the stick. It might be necessary to grind out cutter's scores. After that the stone could be put straight and the polisher started on the inner facets, first doing the square and then filling this up with the other four. For oval or cushion stones a slightly different routine would be followed. However, after finishing the octagon, the polisher went on to the broads. Sometimes the cutter might not get these facets quite true and would leave it to the polisher to do this.

Mr. Bull-Diamond, after showing some prize-winning examples of polished stones, said that sometimes the polisher had to close a flaw in a stone. It might not be possible to polish a flawed stone in the orthodox way, for a flaw could not be ground out. The whole secret of polishing lay in holding the stone so that the facet was flat. Clean facets, flat facets, true facets. Those were the aim of the polishers. though there were other things that had to be borne in mind. Thus, a zircon had cleavage facets and care might have to be taken. Sometimes, with a tricky stone, Mr. Arnold would put the eight facets on and he would put the rest. Such co-operation made for perfect results.

For a cabochon cut the polisher might use a smoother wheel, working down to a wooden one. Only a small amount of polishing would be done at a time with fine diamond powder until a lovely velvet finish was obtained. Mr. Bull-Diamond showed an 1850 crystal of 3.4 cts. which won a medal then. It had 43 facets, front and back. A crystal, he said, was a difficult stone to polish being, like all quartz, soft and inclined to scratch. For such soft stones pumice might be used on a felt wheel. He went on to speak of the crystal pommel of the Stalingrad Sword which he and his workmate had helped to make. Here the difficulty was in coming down from the oval to the round at the base and the metal that had to go through the centre.

Mr. Knowles-Brown, the Chairman, asked about the heat generated on the wheel, and Mr. Bull-Diamond said it was necessary to keep it cool with water. If the wheel went dry, the stone might be fired. A single mistake could flaw or fracture a stone. He added that rutile behaved differently from any other stone in this respect and it was not the same throughout as were synthetic rubies or sapphires. Like zircon, rutile had hard and soft patches, which were liable to fire. It could not be smoothed out like an ordinary stone by the cutter, and it must be done by the polisher.

Answering another question about the closing of flaws, he said that the lapidary went with the flaw and closed the material to it. It would open more if it was worked across, thus behaving like the grain in wood if it was planed the wrong way. A flaw might go half-way through a stone. The whole flaw was not closed, only the surface. He described how he had closed a flaw in an emerald. It was like a terrific gash to begin with, but when closed on the surface it looked little more than a hair-line.

Replying to a question about wastage, he said it would be about two-thirds of a parcel of stones, assuming that each stone was cuttable. Stones did not lose weight in polishing, which made it appear that a flow took place in the process. Water, sometimes diluted with sulphuric acid, was used to ascertain where the colour was in a stone. The colour, if it was to be retained, should lie across the culet. The colour band should not be penetrated. Then even the smallest amount of colour would still reflect.

Concerning the handling of star stones, Mr. Arnold said these were difficult. The art was to get it absolutely true, otherwise there would be a wave in the legs of the star. On the question of how long it took to cut and polish a stone, he said this varied. It might take half a day or two days. Sometimes a stone might be cut two or three times before it was satisfactory. The polishing of an intaglio was done with tools which the craftsman made himself.

# ASSOCIATION NOTICES

## GEM TESTING LABORATORY

It is gratifying to report that more pearls were tested at the Diamond, Pearl and Precious Stone Laboratory of the London Chamber of Commerce in 1951 than in any previous year. The grand total of pearls examined now stands at rather more than 900,000, and it is anticipated that the millionth pearl will be tested during 1953.

The number of reports issued during 1951, viz., 1,973, constituted an all-time record and there can be no doubt that the services of the Laboratory are being more widely sought after, despite the difficult times through which the trade is passing. A clear idea of the extent of this growth can perhaps be obtained by a comparison of the above figure with that of the best pre-war year, i.e. 1937, when the number of reports issued was 898.

The demand for tests on samples of diamond powder for industrial use has increased and the technique in dealing with problems of this nature has been improved. The quartz spectrograph has proved of great service in this particular work.

In the brief intervals between routine tests work has continued on the luminescence of gem materials. In addition to the standard " Wood's Glass " filter for the quartz-mercury lamp, the Laboratory has now a short wave filter, which increases the range of these investigations.

In 1949 it was reported that a second specimen of a new gem mineral resembling spinel had been found, the first and only other specimen having been brought to the notice of the Laboratory by Count Taaffe, of Dublin, in 1945. The chemical and X-ray analysis of this mineral (which has been named " Taaffeite " in honour of its discoverer) has now been completed in the Mineral Department of the British Museum.

## TALKS BY FELLOWS

Solomon, S. T.: " Gemstones," Tavistock Toc H., November, 1951 ; Plympton Townswomen's Guild, January 8th, 1952 ; Erdington Townswomen's Guild, Birmingham, February 28th, 1952.

W. A. Peplow: " Gemmology." Scientific Society, King Edward School, Stourbridge, March 4th ; " Gems," Business and Professional Women's Association, Stourbridge.

J. Gillougley: " Diamonds," Industrial Life Offices' Association, Paisley and District, March 20th.

Webster, R.: " The Problem of Synthetic Gemstones," Scottish Association of Watchmakers and Jewellers, March 26th, 1952.

## GIFTS TO THE ASSOCIATION

The Council acknowledges with gratitude the gift of a parcel of 30 gemstones from Messrs. George Lindley & Co. (London), Ltd., St. Andrew's House, London, E.C.1.

## SINHALITE—A NEW GEMSTONE

In connection with the note of a new gemstone, which appeared in Vol. III, No. 5, the co-author with Dr. G. F. Claringbull of a paper read to the Mineralogical Society on January 24th was Dr. M. H. Hey and not Dr. W. Hey, as reported. The chemical composition of the new mineral is $MgAlBO_4$.

## COUNCIL MEETING

A meeting of the Council was held at 19/25 Gutter Lane, London, E.C.2, on Wednesday, February 6th, 1952, at 4.30 p.m. Mr. F. H. Knowles-Brown presided.

The following were admitted to membership:—

FELLOWS:

Clark, L. D. S., Oxshott (D.1951)
Dickson, R. W., Glasgow (D.1949)
Dimmer, G., Junr., Chester (D.1933)
Lerman, A., Toronto, Canada (D.1951)
Van der Heijden, C. J., Zoeterwoude, Holland (D.1951)

PROBATIONARY:

Austin, L. F., London
Brack, A. J., London
Caudell, P. M., London
Crouchley, D., London
Denham, F. J., Harrow
Edwards, J., Manchester
Hawtin, S. J., London
Urquhart, I. R., London
Yaghobi, H., London

ORDINARY:

Lee, H., London

The Council decided that it was necessary for all its examinations to be held under the ægis of a University, Education Authority or a recognised Gemmological Association and that arrangements should be made in connection with the two centres where this had not been the custom in the past. It was further decided to amend the bye-laws to enable the examiners for the time being to be members of the Council and, in addition to the officers, to allow the election, in accordance with the Articles of Association, of not more than nine other members, three of whom should retire annually. The audited accounts for the year ended 1951 were submitted and approved for presentation to the twenty-second annual general meeting to be held at Goldsmiths' Hall on April 2nd.

## ANNUAL MEETING

The twenty-second annual general meeting of the Association was held at Goldsmiths' Hall, London, E.C.2, on Wednesday, April 2nd, 1952, at 7 p.m. Mr. F. H. Knowles-Brown presided.

Mr. F. E. Lawson Clarke (Treasurer) presented the audited accounts for the year ended December 31st, 1951, and the Chairman, after commenting briefly about the work of the year and annual report, which had been previously circulated, moved that " the audited accounts and report of the Council for the year ended December 31st, 1951," be adopted. Mr. N. Kennedy seconded the motion, and the proposition was unanimously approved.

The following officers were re-elected: President, Dr. G. F. Herbert Smith ; Chairman, Mr. F. H. Knowles-Brown ; Vice-Chairman, Sir James Walton ; Treasurer, Mr. F. E. Lawson Clarke. The President suitably acknowledged the confidence given to the Officers on their re-election.

As the result of a postal ballot the following Fellows were elected to serve on the Council: Messrs. W. C. Buckingham, N. A. Harper and E. H. Rutland. Messrs. R. V. Blott and R. K. Mitchell were re-elected.

Messrs. Watson Collin & Co., London, were reappointed as auditors.

## DR. G. F. HERBERT SMITH

Arrangements have been made to entertain to dinner Dr. G. F. Herbert Smith, C.B.E., M.A., D.Sc. (whose eightieth birthday will be on May 26th), in the Prince Consort Room, Royal Albert Hall, London, on Tuesday, May 27th, 1952.

The Chair will be taken by Lord Hurcomb, G.C.B., K.B.E., President of the Society for the Promotion of Nature Reserves. The Gemmological Association will be represented by Mr. F. H. Knowles-Brown and Sir James Walton, K.C.V.O., Chairman and Vice-Chairman respectively of the Association, and other Fellows.

Tickets (price ten shillings each) may be obtained from Miss F. O. Elwood, British Museum (Natural History), London, S.W.7.

## AUSTRALIAN EXAMINATIONS

The Gemmological Association of Australia has announced the following results in connection with its 1951 examinations in gemmology:—

### New South Wales

Beale, C. H.
Beckenham, N.
Bunker, Miss Shirley
Cameron, Miss M. E.
Connelly, D. J.
Cromack, R. H.
Evans, Mrs. D. P.
Fisher, K.
Goldring, M. G.
Hansen, W. R.
Kelemen, Miss Eva
Rouse, A.

### Victoria

Klepner, F.
Koller, T.
Rodgers, M. S.
Wylie, J.

### Queensland

Herdsman, Mrs. R.
Joyce, N. O.

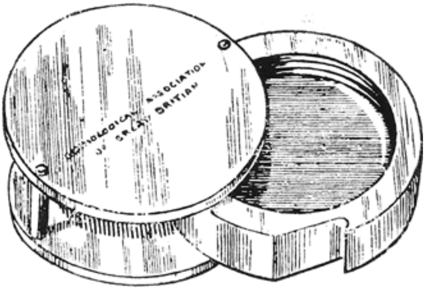
### South Australia

Cox, G. M.
Forster, B.
Grove-Jones, P.
Herring, K. W.

### Western Australia

Elliott, R.
Frost, Michael P.
Jorgeson, W. L.
Lawrence, R.
Parker, R.
Perry, R. H.
Playford, P. E.
Russell, F. G.
Wilson, Alan F.
Wilson, R. W.
Woodall, R.

The Australian Prize has been awarded to Mr. P. Grove-Jones.


GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN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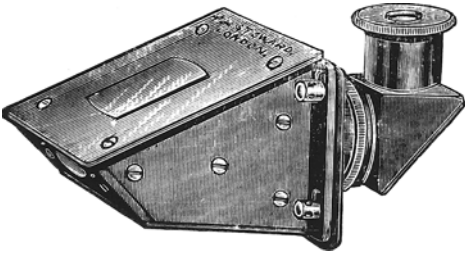

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