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GEMMOLOGICAL ASSOCIATION
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APPLICATION OF PHASE CONTRAST MICROSCOPY IN GEMMOLOGY

By E. J. GÜBELIN, Ph.D., C.G., F.G.A.

THE present article deals with a new accessory to the microscope—the so-called phase contrast equipment, which renders heterogeneous objects richer in contrast and facilitates their examination. The Phase Contrast Method was discovered in 1932 by the Dutch scientist, F. Zernike,* and its further development lead to its adaptation to the polarizing microscope ; the construction of an easily manipulated attachment makes it now possible to employ this method in combination with the conventional microscopic methods also used in gemmology. The Phase Contrast Method is frequently a source of new knowledge and results mostly in greater contrast in brightness between inclusions and inhomogeneities on one side and the host substance on the other, or between individual particles, even if they are of the same substance (=mosaic structure). This new method can, therefore, be used to good advantage in connexion with better examination of details of the interior of gemstones and for research work.

Every microscopist knows from experience that in the transmitted light of bright field illumination microscopic images are often unsatisfactory, because their details are frequently drowned by

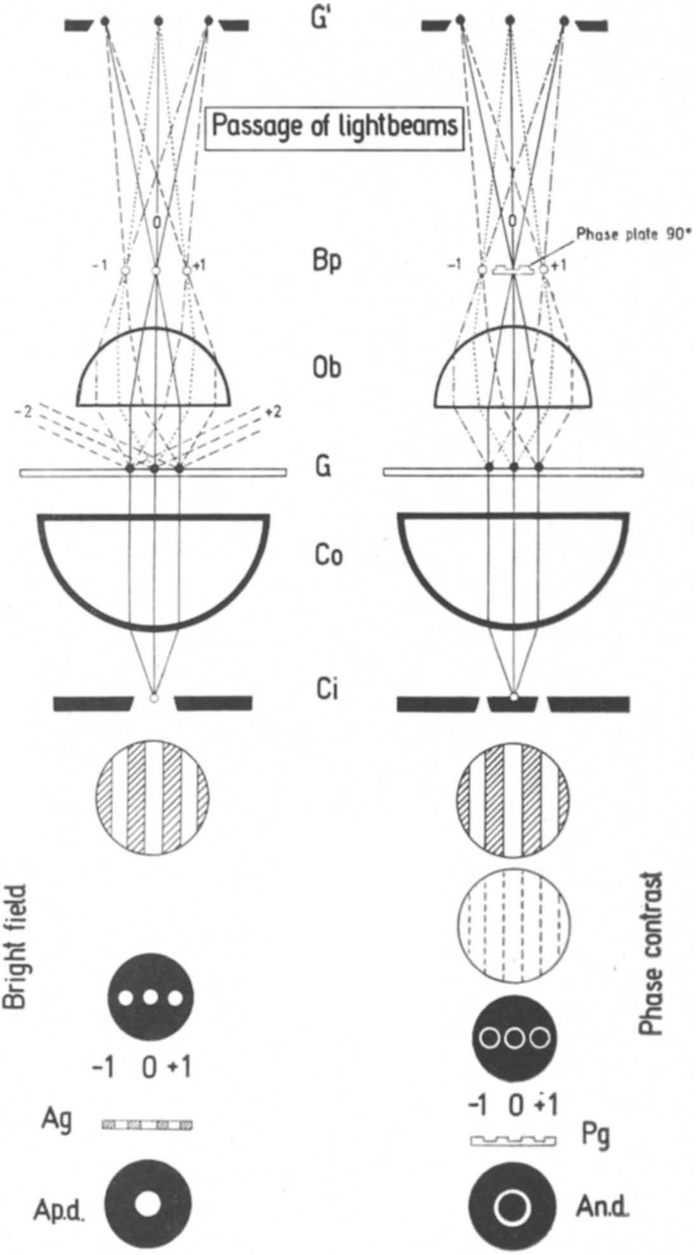
G'
Passage of lightbeams
0
0
Phase plate 90°
-1
+1
Bp
-1
+1
Ob
-2
+2
G
Co
Ci
Bright field
Phase contrast
-1 0 +1
-1 0 +1
Ag
Pg
Ap.d.
An.d.

Fig. 1

the bright light. This handicap can be overcome by increasing the contrast through shutting the condenser diaphragm. Yet this makeshift does not wholly meet the requirements, as the resolving power of the objective is diminished, the microscopic image is darkened and diffraction phenomena may lead to a wrong interpretation of the picture. A considerable intensification of contrast is, however, often ensured by dark field illumination, which makes inhomogeneities and inclusions stand out brightly against a dark background. Yet this method suffers also from the disadvantages that merely the edges of the details are shown, that it gives negative images of the details of the structure, and that with sudden changes of optical continuity certain details are eclipsed, which render examination of the subtlest details impossible.

The new Phase Contrast method enables an increased contrast in details to be observed. The mode of operation of the phase contrast can only be understood if the essential procedures producing the image in the microscope are realized and understood as explained by E. Abbe.

According to the laws of geometrical optics, the objective (Ob in Fig. 1) produces a magnified image of the object G at G′. This image is observed through the eye-piece, which again works as a magnifying glass. It was, therefore, formerly believed that even the smallest details of a microscopic object could be made visible by increasing the magnifying power of the ocular and objective. Abbe has, however, refuted that opinion by pointing out that the formation of the image can only be understood if the nature of light is considered as an undulatory motion (physical

FIG. 1. FORMATION OF THE IMAGE IN THE MICROSCOPE

Ci = Condenser iris
Left : circular = bright field = Ap.d.
Right : annular = phase contrast = An.d.
Co = Condenser
G = Microscopic object (=grating)
Ag = Amplitude grating (corresponds to object of different colours)
Pg = Phase grating (corresponds to completely colourless transparent, non-absorbing object)
Bp = Back focal plane of the objective.
—1 ; 0 ; +1 = Maxima of the diffraction spectrum
(These are the aperture images of the condenser iris Ci formed by the condenser and the object ; O=virtual or direct image ; —1 and +1=the secondary images diffracted by the structure details of the object (on the left they are circular, on the right annular). In the path of rays for bright field illumination two further diffraction maxima —2 and +2 have been sketched, which, however, do not reach the objective and hence do not contribute to the formation of the image at G′. In the path of rays on the right side the light waves passing the maximum O are displaced in their phase for as much as a quarter wavelength by the phase plate 90°.
G′ = Microscopic image of object G caused by the objective Ob and formed by the interference of light waves coming from the aperture images. The second circular plane (disc) drawn a little lower on the right top side represents schematically the image hardly visible of the phase grating, which is produced if the phase contrast equipment is not used.

optics). Those straight rays which seem to emanate from a source of light according to the laws of geometrical optics, in reality only indicate the directions in which the undulation progresses. If such an undulatory motion strikes upon the fine structures of a microscopic object, the impinging light becomes partly diffracted in such a manner that every structure may be considered as a new source of illumination. This plays a vital role in connexion with the formation of the image in the microscope, and, in order to illustrate it, Abbe used an artificial object—a microscopic grating with parallel striae. A beam of light coming from the aperture of the condenser Ci and passing through that grating is split up into numerous diffraction beams, which appear through the objective Ob in its focal plane Bp as so-called diffraction images of the light source (often also called aperture images because the aperture Ci of the condenser functions as image frame of the light source). The whole of these diffraction images at Bp is usually described as a diffraction spectrum. Besides the direct and brightest aperture image O—the maximum of O-order—the diffraction images ±1, ±2, etc., are visible, but their brightness diminishes proportionally as the distance from the optical axis of the microscope is increased. All these diffraction images caused by the microscopic grating may be considered as new light sources, the undulatory motions of which influence one another, i.e., increase one another (thus producing greater brightness) or, vice versa, weaken one another (thus causing less brightness or even complete darkness). At G′—the image of the objective—the mutual interference of the light waves radiating from the diffraction images is of such a nature as to form an image which corresponds more or less accurately with the object G. An image completely corresponding to the details of the object can only be produced if all the light beams diffracted by the structure of the object reach the objective lenses, thus participating in the formation of the image. Under such circumstances the microscope has only to make the details appear so large that they can be recognized.

The grating used by Abbe, which consists of parallel absorbing striae with transparent intervals, reduces the amplitudes resulting from interference of the various diffraction images in the image plane G′, which are caused by the light waves coming from such objects. Thus the microscopic image of the object is formed, being composed of brightness differences and becoming perceptible to the eye as well as the photographic film. Such a grating is called an " amplitude grating " and the corresponding microscopic objects " amplitude objects."

If instead of an object another, also very fine, grating is used which, however, does not consist of absorbing striae, but of completely transparent ones alternately at different heights, the means hitherto known fail to give an efficient microscopic image. Such a grating takes the place of entirely transparent thin microscopic objects. Its structures do not transform the amplitudes of the light but affect only the state of vibration (=phase) of the diffracted beams ; that is, they cause a change of the phase. Contrary to the amplitude grating, which produces brightness differences through interferences of light waves with transformed amplitudes, the image of the phase grating must remain uniformly bright, i.e., the structure of the grating must stay invisible, for neither the eye nor the photo-plate can register minute phase differences. Such transparent objects are called " phase objects."

Actually the microscopic objects occurring normally are hardly ever amplitude objects, or phase objects, in the true sense of the above description. Thus, an absorbing structure differs in most cases somewhat in its refractive power from its surroundings while an element causing phase difference often causes simultaneously a slight absorption. Consequently, the microscopic image of a phase object does not, as a rule, appear uniformly bright but allows some faint, usually very indistinct, structures of the object to be observed. Evidently the actual conditions are such that in the microscopic objects generally examined, either the absorbing effect prevails, or that altering the phase. Therefore, with the new conceptions of amplitude object and phase object, an appropriate distinction has been established.

As explained above, light waves leaving a phase grating cannot be equally constituted with regard to their state of vibration (=phase) as the light waves coming from an amplitude grating. The difference lies in the fact that with an amplitude grating these light waves show similar phases everywhere, but different amplitudes, while with the phase grating they show similar amplitudes everywhere, but different phases. Exact investigations and calculations carried out by F. Zernike proved that the reason for the almost completely contrastless image of the phase grating must be traced back to the fact that the light waves issuing from the diffracted aperture images ±1, ±2, ±3, etc., in the image plane G′ merely show vibrations which are displaced in their phase by a quarter wavelength against those vibrations which originate from the direct aperture image O. The image of the phase grating must, therefore, be equally rich in contrast as the one of the amplitude grating, if it is possible to reverse the phase-shift mentioned. This is possible, indeed, if according to Zernike's suggestion a thin, transparent, so-called " phase plate," which displaces by 90° the phase of the light passing through, i.e., a quarter wavelength, is put into the back focal plane of the objective (at Bp)—there, where the direct image O of the light source is formed. Through this " artificial " intervention in the diffraction spectrum the phase differences caused by the phase grating are, to a certain extent, converted into amplitude differences, through which process details of the phase object, otherwise hardly visible, show up with remarkable contrast.

It proved difficult to apply the normal phase contrast equipment for gemmological microscopy, because, according to the principle of the method, it was built with objectives of very high magnifying power and, therefore, had an extremely short focal depth only. Consequently, the Phase Contrast Method could be used only for very thin or flat objects, and inhomogeneities or inclusions lying deep in a gemstone could not be " reached." A special equipment was then developed by the Zeiss-Winkel optical plant in Göttingen, thanks to the personal interest which Dr. H. Piller gave to this gemmological requirement. The gemmological phase contrast equipment now consists of (1) a special adjustable collector-lens which is placed into the foot of the microscope, (2) three special achromatic objectives—Ph_1 6.3/0.16, Ph_1 10/0.25, Ph_2 25/0.45. They differ from ordinary objectives in that they contain an annular phase plate, so that they produce the phase contrast, but they can also be used for bright field observations as well as dark field observations, which facilitates manipulation and comparison considerably. They have a long focal distance, which is essential for gemmological microscopy. (3) For small magnifications a special tube-like condenser, housing a phase annulus, was developed, which is placed on to the collecting lens. This condenser may be replaced by (4) a disc-shaped substage condenser with revolving disc. The latter bears various phase annuli corresponding to the phase

Fig. 2. Gemmological Phase Contrast Equipment

1. Adjustable collecting lens
2. 3 Phase contrast objectives
3. Tube-shaped condenser with phase annulus
4. Disc condenser
5. Auxiliary Microscope
6. Filter.

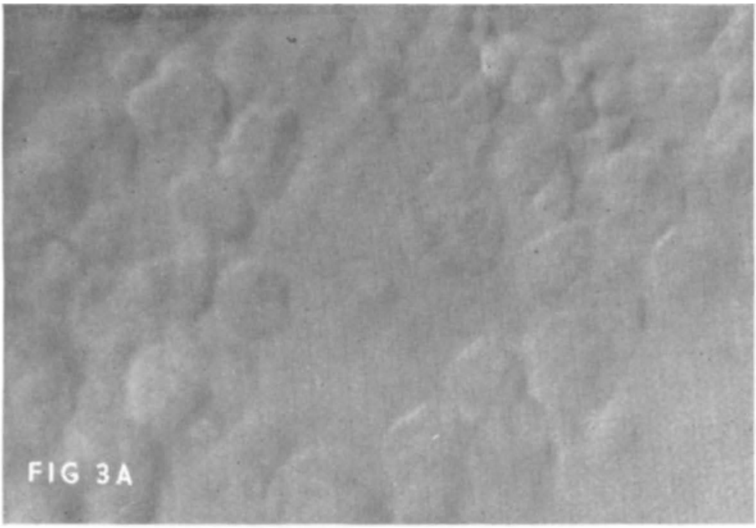

FIG 3A

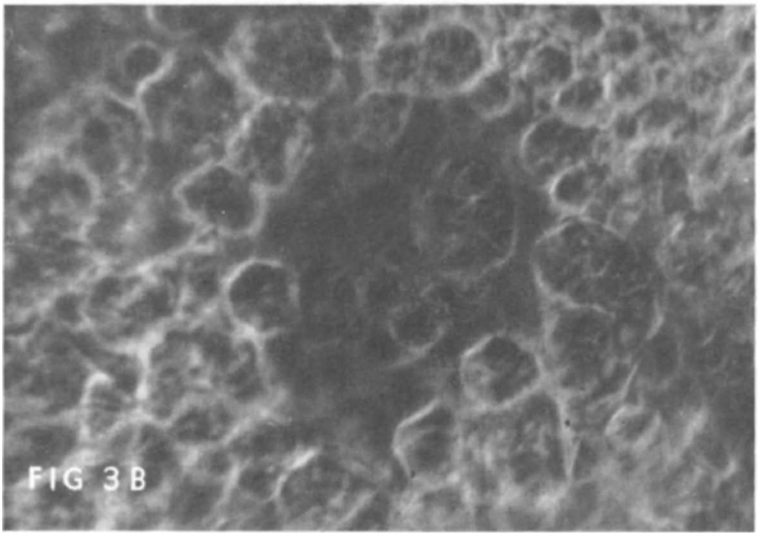

FIG 3B

Bright Field.—Photo ocular 10x. Achromatic objective 6.3/0.16 Huygens. Neutral filter, condenser iris closed to half and extra-focal position of tube. Mag. 63x.

Phase Contrast.—Photo ocular 10x. Achromatic objective Ph_1 6.3/0.16. Mag. 63x.

Ex-solution of calcite in an emerald from Muzo, Colombia. The phase contrast picture not only emphasizes the contrast between unmixed calcite particles and the host substance but also reveals structure details within the calcite grains.

objectives of higher magnifying powers : Ph_2 25/0.45, Ph_3 40/0.65, Ph_4 90/1.25 (Fig. 2). For extraordinary phase contrast effects dark field illumination may also be adopted. (5) By means of an auxiliary microscope placed into the slot of the eye-piece, the image of the phase annulus and the annular image of the phase plate can be focused and brought into perfect concurrence (Fig. 2). For carrying out the experiments leading to the results described here, the gemmological phase contrast equipment was used in connexion with the binocular polarizing microscope by Zeiss-Winkel.

Completely transparent details of a phase object (e.g. inhomogeneities and inclusions in a gemstone) differ solely from their surroundings by their thickness or refractive power. In such an object portions of higher refractive index will appear darker than their surroundings in the phase contrast image†. However, this phenomenon occurs in only a distinct manner if the details that are to be rendered visible have but small phase differences, that is, if they are sufficiently thin and their refractive index differs but slightly from the host substance. Under such conditions the microscopic phase contrast image shows all the details of the structure of the object with a wealth of contrast and with more faithful reproduction than any other microscopic method known heretofore.

DISCUSSION OF ILLUSTRATIONS

Fig. 3 to Fig. 8 manifest excellent examples of the application and importance of the Phase Contrast Method in gemmological microscopy. They represent but a small selection of the very great number of photomicrographs taken during the experiments, which lasted three years, in probing the various possibilities of the Phase Contrast Method for gemmological purposes. The illustrations are arranged in pairs in order to facilitate comparison and to emphasize the great difference of contrast between bright field and phase contrast. The pictures of each pair represent exactly the analogous area within the same stone and are shown with the same degree of magnification. For obtaining the greatest possible contrast effect in bright field, everything within the possibilities of orthodox polarizing microscopy was done, such as closing the

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† This particular appearance of the phase contrast image is called positive phase contrast—contrary to the negative phase contrast, which shows when applying a phase plate of phase retarding effect (instead of a phase accelerating effect) and causes the same portions to appear brighter than the background.

FIG 4A

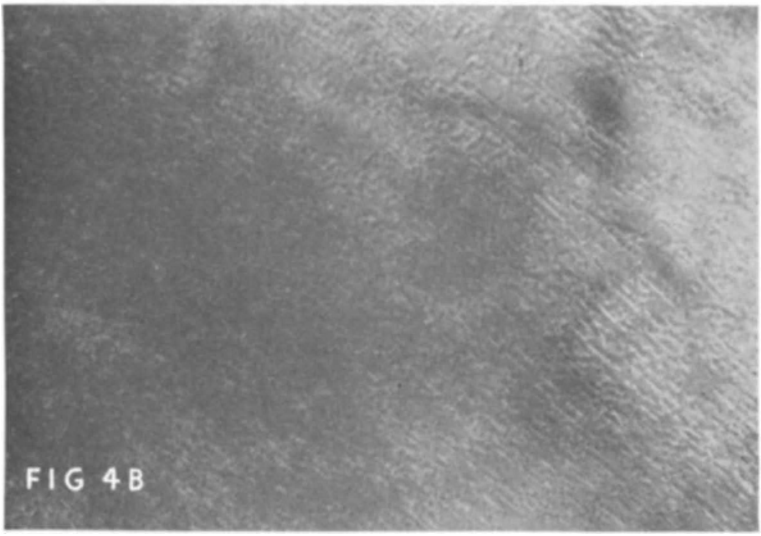
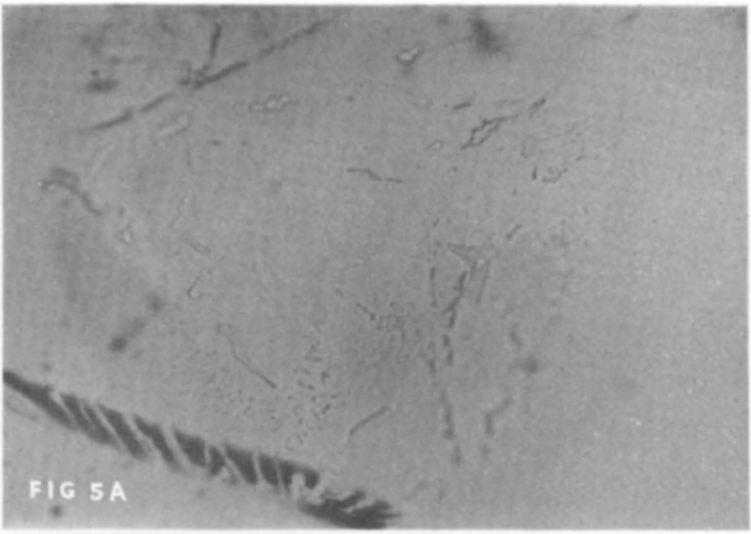


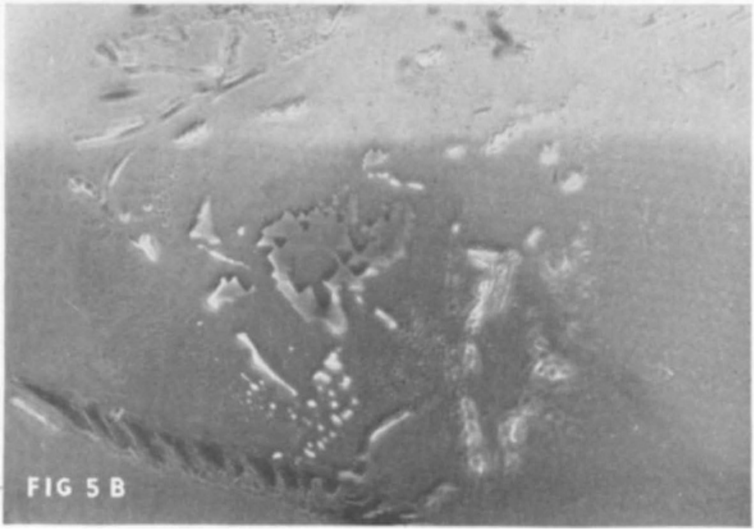
FIG 4B

BRIGHT FIELD.—Photo ocular 10x. Achromatic objective 6.3/0.16 Huygens. Contrast filter. Mag. 63x.

PHASE CONTRAST.—Photo ocular 10x. Achromatic objective Ph_1 6.3/0.16. Mag. 63x.

Very fine sub-structure in an iolite from Ceylon caused by alteration into pinite. These two pictures clearly manifest the great difference of contrast between normal bright field which reveals nothing and the phase contrast which offers interesting information





Bright Field.—Photo ocular 10x. Achromatic objective 10/0.25 Huygens. Condenser iris closed to 1/3 of object aperture. Mag. 100x.

Phase Contrast.—Photo ocular 10x. Achromatic objective Ph_2 10/0.25. Mag. 100x.

Residual drops of the remedying liquid in a healed fissure in a Burma sapphire. The phase contrast picture manifests conclusive details very distinctly where there is hardly anything visible in the bright field.

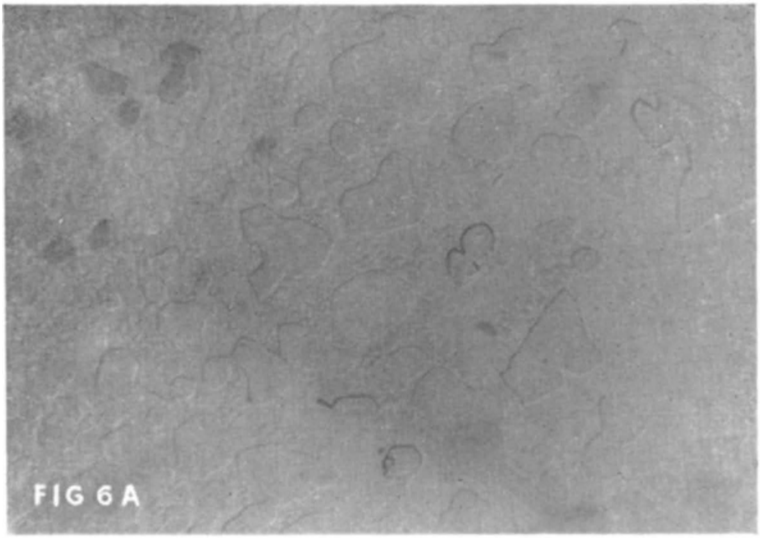


FIG 6A

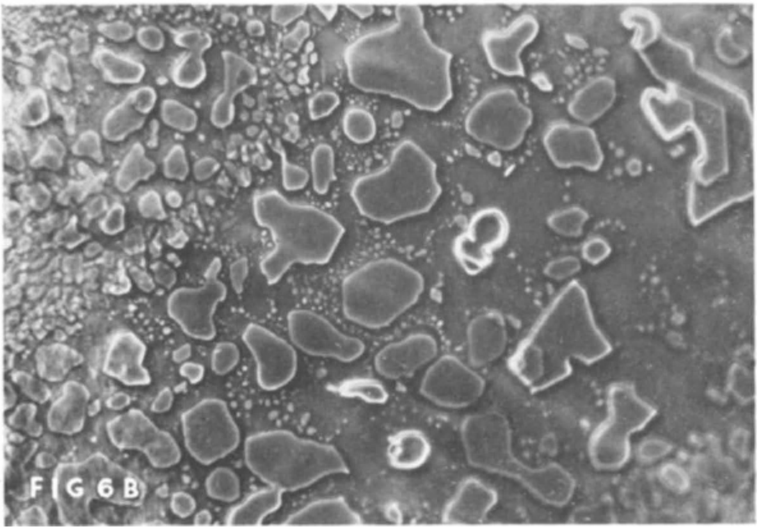
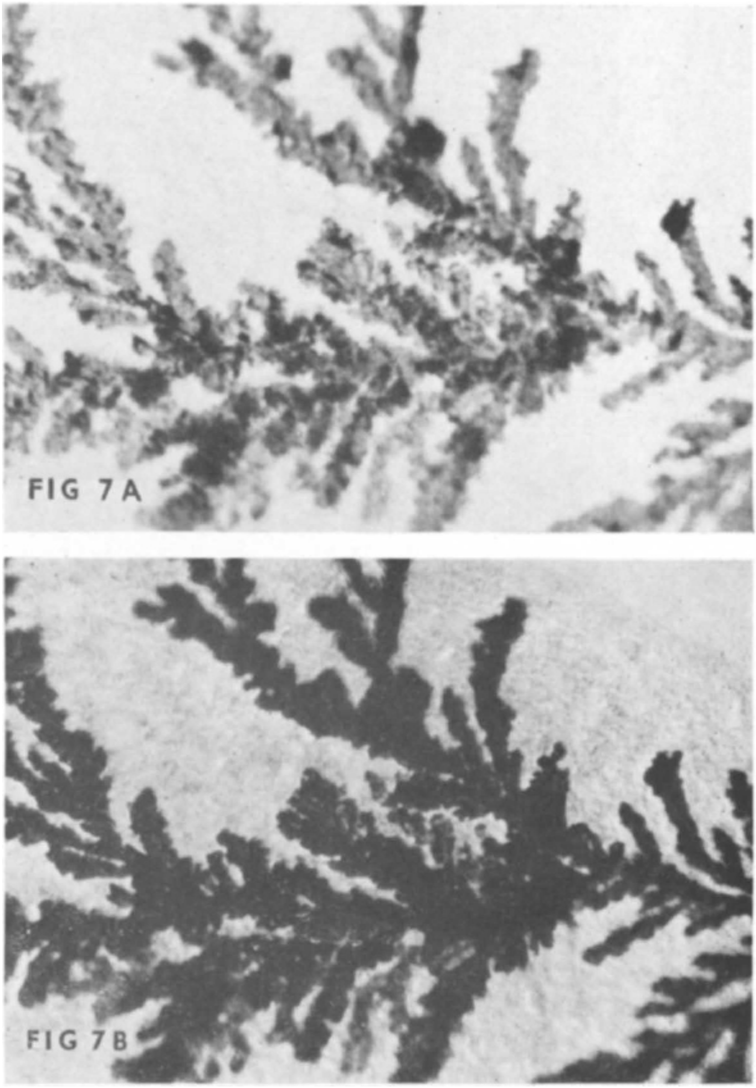


FIG 6B

Bright Field.—Photo ocular 10x. Achromatic objective 10/0.25 Huygens. Condenser iris closed to 1/3 of object aperture. Mag. 100x.

Phase Contrast.—Photo ocular 10x. Achromatic objective Ph_2 10/0.25. Mag. 100x.

Partly healed crack in a yellow beryl from Madagascar with legion of extremely flat liquid drops left over from the exhausted healing liquor. This is a typical example of phase contrast being used for bringing out details.



Bright Field.—Photo ocular 10x. Achromatic objective 6.3/0.16 Huygens. Neutral filter. Mag. 63x.

Phase Contrast.—Photo ocular 10x. Achromatic objective Ph_1 6.3/0.16. Mag. 63x.

Dendritic formation of manganese oxide in rose quartz. The bright field picture does not reveal in any way the intrusion of this foreign matter, while the phase contrast makes it apparent that the dendritic formation developed in a crack and, therefore, is of secondary origin.

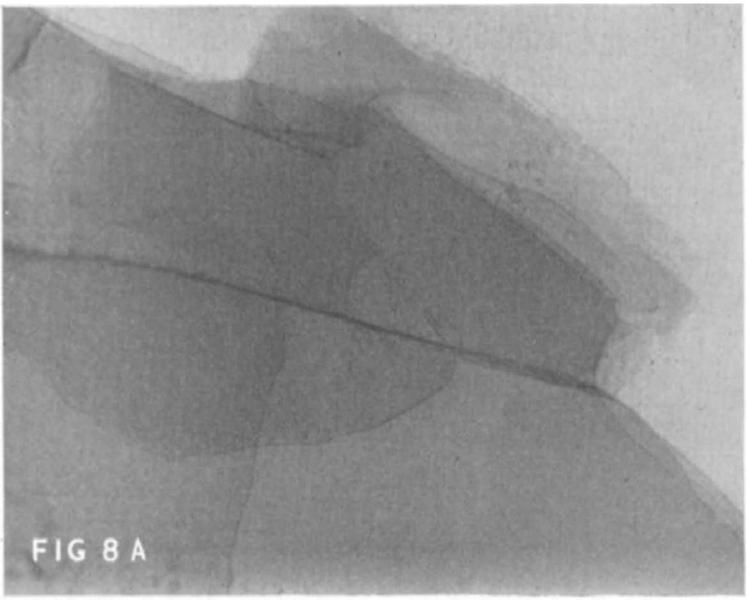


FIG 8 A

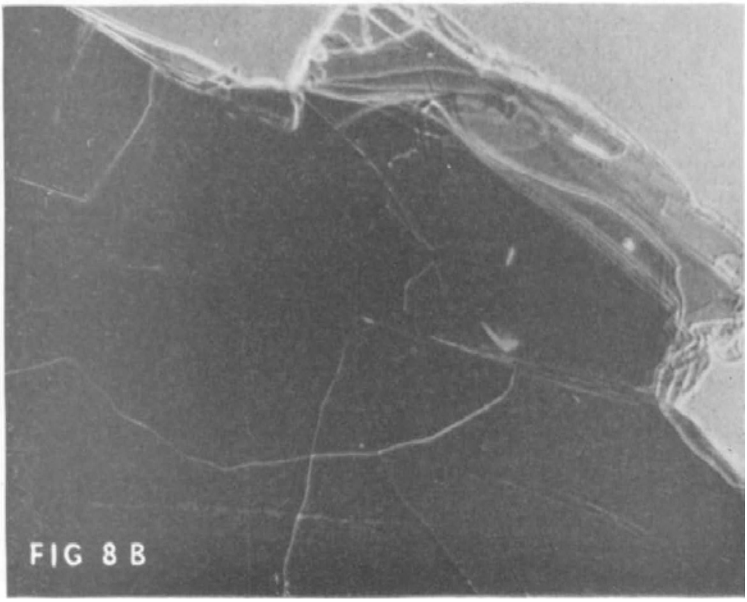


FIG 8 B

Bright Field.—Photo ocular 10x. Achromatic objective pol. 6.3/0.16 Huygens. Neutral filter and condenser iris half closed. Mag. 63x.

Phase Contrast.—Photo ocular 10x. Achromatic objective Ph_1 6.3/0.16. Mag. 63x.

Muscovite flake in a yellow beryl from Madagascar. This is a typical example of how the Phase Contrast Method is advantageously employed to emphasize details of a very flat solid inclusion with but slightly different refractive index, of which the bright field would yield but very scanty information. This proves that with phase contrast extremely minute differences of refractive index (in this case as small as $\Delta = .03 \pm .005$) show up very distinctly, while in bright field they remain invisible.

condenser diaphragm, raising or lowering the tube, using singly polarized light, or using filters. All these experiments showed that within certain limits and for certain purposes the Phase Contrast Method could very well be applied for gemmological investigation, particularly for studying structural peculiarities, such as inhomogeneities, the results of incomplete exsolution, alterations, and partly or completely healed cracks. Among the true inclusions, those with a slight difference of refractive index from the host gem, or those which are extremely thin and transparent, become strikingly visible through the phase contrast. However, the visibility of all those well-known " orthodox " inclusions which have often been described, such as foreign ores and crystals, or negative crystals, two-phase and three-phase inclusions, liquid feathers and so on, is not greatly improved by using the Phase Contrast Method. The Phase Contrast Method, which represents one of the greatest improvements in modern microscopy, opens a new and fascinating field of research in the enchanting wonderland of inclusions in gemstones and a considerable amount of valuable information will be gained. Such inclusions and inhomogeneities as illustrated, and many others, can hardly be seen, let alone be properly studied, in bright field illumination.

I am greatly indebted to Dr. H. Piller for his interest and important help in devising and constructing a gemmological phase contrast equipment.

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* LITERATURE.—For those who are interested in studying more about the Phase Contrast Method or its various possibilities of application, ample information may be obtained from the " List of Literature Dealing with Phase Contrast Microscopy," Series ZW115-S issued by R. Winkel G.m.b.H., Göttingen.

MEASURING DICHROISM—SOME EXPERIMENTS

By E. J. BURBAGE, F.G.A., and THOROLD JONES, F.G.A.

NOTHING is inviolate from the earnest Ph.D. researcher, and probably at least one thesis is already gathering dust in the archives of some State University in Arkansas or Florida attempting a critical appraisal of Chesterton's use of paradox, and this monograph can scarcely fail to have spotlighted into major place the Inversion Type, in which G.K.C. takes a well-known proverb or cliché, and, standing it on its head, shows it to be still valid, and even more illuminating. Thus, from the gnomic but unexciting platitude so drearily familiar in one's schooldays, Chesterton produced the profound truth that, " if a thing is worth doing at all, it's worth doing badly." An aphorism worthy of employment as a touchstone for any venture which one contemplates ! So, having regard to the paucity of objective quantitative information about pleochroism in gemstones, we considered it worth while to make some tentative enquiries into this field, even though the results now presented do not pretend to be other than a first approximation only.

In our view, the dichroscope has never attained the position among gemmological instruments to which its potentialities entitle it. It is not expensive, is fairly robust, has a reasonably wide scope, and does not require any very exacting degree of expertise for its employment.

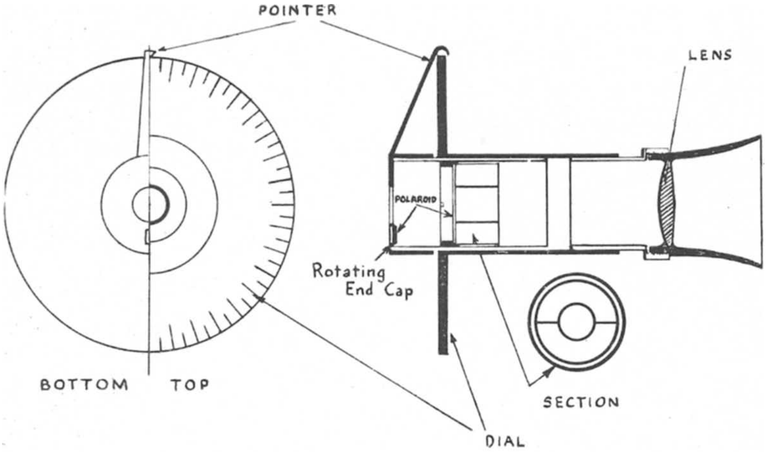
In mineralogical literature, any data relevant to the measured degree of dichroism in a gemstone have usually been implicit in an investigation of the absorption shown by a crystalline plate for various wavelengths. From a pair of transmission curves, obtained when employing polarized light sources of vibration directions mutually at right-angles, a measure of the degree of pleochroism may be calculated. Slawson and Thibault's paper on tourmaline may be quoted as an investigation of this type.[1] Ideally, such an enquiry is best served by using a spectrophotometer, of which the sensitivity can be very great, approaching that of the human eye, but few gemmologists are likely to have access to such an expensive, elaborate, and bulky piece of apparatus, and, in addition, the cutting of sections from rough material is not an activity upon which the average gemmologist is likely to embark very readily.

A modification of the dichroscope for approximately measuring the strength of dichroism in a cut gemstone seemed therefore to be indicated. The calcite dichroscope, the instrument devised by Haidinger over a century ago,[2] and used by de Sénarmont in his researches in pleochroism,[3] is still unrivalled for spotting small differences in dichroic colours, but it is not suitable for alteration to enable measurements to be made. It is reasonably easy to mock-up a dichroscope using polaroid, and variants on such home-made instruments have been devised, described, and shown by Anderson,[4] Thibault,[5] Dollar and others. Such instruments consist essentially of two optically-at-right-angles polaroid strips laid side by side, and some kind of lens for viewing. Having decided to employ this type of instrument, it was then necessary to consider what measurement conventions should be employed, and what means could be used to obtain the requisite data.

A scheme for matching by colour was clearly impracticable, for it would require optical engineering of considerable complexity, and would raise questions of colorimetry and subjective colour vision whose resolution would be outside the scope of the non-specialist. A translation into linear terms, so to speak, by using monochromatic light seemed the most hopeful approach, when the measurements would be of absorptions for selected wave-lengths. A further simplification, admissible in view of the approximate, rather than critically accurate, standards envisaged, would be to employ " narrow-cut " photographic filters. For measuring transmission densities, it was decided to match these against superimposed polaroids, using the trigonometrical relationship between angle-from-extinction-position and absorption, by which, if the light-transmission in the " parallel " position is taken as unity, then at angle θ from extinction it is $\sin^2\theta$. This was effected by using two semicircular discs of polaroid in place of the two strips customarily employed in polaroid dichroscopes. The central area of the polaroid composite was used in displaying the dichroism, and the periphery, separated by an intermediate narrow metal wall, functioned as the " stator " of the photometer. Capping this end of the dichroscope were a metal fitment, embodying a moving " finger " of polaroid functioning as the " rotor " of the photometer, and a dial graduated to enable angular rotations from extinction positions to be measured.

For the narrow-cut filters, the Ilford " Spectrum " range, numbers 600 to 608, was decided upon. These are composite filters giving narrow transmission bands, and their ranges and the relevant data for polaroid are shown in the diagram. Naturally, the limited transmission ranges of these filters mean that they are very dark in colour, and one has to employ a correspondingly bright light source—the Osram " Silverlight " 150 Watt lamp being found very suitable. Also, to increase transmission and to eliminate light reflections, an immersion-cell was used.

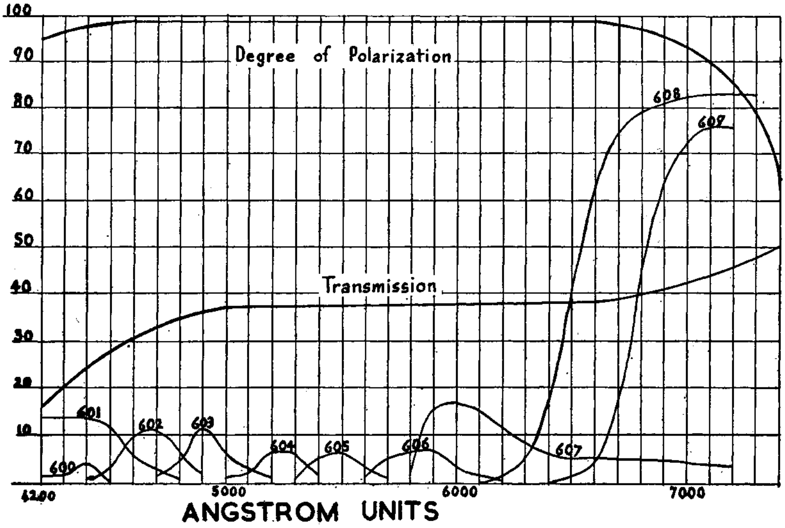
The diagram illustrates how these Ilford filters slice up the visible spectrum into convenient ranges, although these overlap to variable extents, are not all symmetrically disposed about a central axis, and have varying amplitudes. It would be interesting to find their cumulative effect when used in parallel (so to speak) in some such apparatus as the calico-printer's Mutachrome, but the result would almost certainly approximate to daylight or to tungsten-light only by the most careful differential light-control by the iris diaphragms. As a corollary it will be seen that one cannot emulate Hurter and Driffield and their successors in photometry by attaching significance to comparative values of transmissions or densities for various regions of the spectrum, although this limitation does not invalidate the measurement of dichroism. In other words, if, for two filters, absorption values derived by the sine-squared rule are x_1, x_2, and y_1, y_2, the ratios between x_1 and x_2 and between y_1 and y_2 will provide quantitative measurements



of the dichroism for the two regions of the spectrum, although the significance of the ratios between x_1 and y_1, and x_2 and y_2 will be vitiated by the quiddities of the filters employed

If we were attempting something more definitive on the subject of dichroism than these notes, and were gifted with the linguistic panache of a J. J. Sylvester, we might attempt new and more precise terms for the various types of dichroism. Whilst, over here, we do not normally follow the U.S.A.'s practice of classing the behaviour of herepathite and similar compounds as examples of dichroism, a pedant might with some logic object to a degree of imprecision in our own usage in this matter, in that the cases where two different colours are shown is not large, and very often the "twin-colours" are saturated and unsaturated versions of the same colour. The distinction between "true" and "saturation" dichroism was reflected in our results, where we found that in the latter type, a filter of different colour was necessary to exhibit a difference in absorption. It is easy to see why this should be so—in a gem such as blue zircon, dichroic in blue and nearly colourless, a blue filter will transmit blue without change, and will convert the colourless sector to a matching blue.

Few can afford to commission a lapidary to refashion gem material in better conformity with the principal optical directions,



and as our material consisted chiefly of cut stones, we confined our enquiries to those stones which as far as we could judge displayed maximum dichroism when placed table downwards in the immersion cell. Even in these selected stones, it is possible that by experiment or calculation, rotation to positions yielding still more intense dichroism might have been possible, but apart from practical difficulties, this procedure did not seem worth-while for the majority of gemstones showing dichroism. The interrelationship between the dichrometric ratios (if one may so style them) is of greater interest than their actual values, which will in any event depend upon the depth of colour of the gemstone, and generally this will still be discoverable at positions not too far removed from that giving maximum dichroism. This will be true for all uniaxial and probably for many biaxial media, but trichroic biaxial media form a special group, where one would expect the absorption curves to ring the changes in infinite permutations between three limits. To deal adequately with the trichroism of faceted gemstones, one would need to employ some form of universal stage. Trichroic media are not common, and the best-known example among the gemstones, iolite, is very fully documented in " the literature," having engaged the attention of the scientific world for well over a century—certainly since 1819, when we find Brewster somewhat rashly venturing a statement in the Philosophical Transactions[7] that, as far as he knew, dichroism had never been observed in any other minerals than iolite and mica ! A less incurious inquirer, Haidinger, dealt very competently with iolite in his 1845 paper,[2] and some very thorough and careful work was described by Camichel in 1895.[6] Coming nearer our own day, some of us will recall that the late W. T. Gordon of King's College, London, was sufficiently interested in the mineral to have a cube fashioned from it, such that each pair of faces transmitted a different colour. Hence, we felt justified in turning a blind eye to the trichroics, whose only important gemstone member is this interesting but well-documented mineral.

This is a large and fascinating subject, and we have considered only a few aspects of it, although even our limited researches have inclined us to echo de Sénarmont's typically Gallic comment, " Si j'ai fini par entrevoir un fil conducteur dans ce dèdale, ce n'est qu' après de longs efforts." Even so, our stumblings around the maze have certainly proved of interest to ourselves, and if they result in any small measure in the rescue of the sadly under-rated dichroscope from unmerited neglect, they will have been repaid.

It is outside the scope of the present paper to list the " dichrometric ratios " of the dichroic gemstones, and in any event we have as yet far too little data to attempt to do so. It is interesting, however, to consider the order of magnitude of the ratios of one or two stones which we have measured. A synthetic ruby showed no dichroism for filters Nos. 600 and 601 (deep violet and violet) slight dichroism, too small to measure, for 602 and 603 (blue and blue-green), 604 (green) gave ratio 1·84, 605 (yellow-green) 15·4, 606 (yellow) 3·46. We found 607, the orange filter, insufficiently localized in the spectrum to be of much general use, and, like Camichel in 1895, we found it quite impossible to work with red light, and hence the filters of this colour proved of little avail. For a natural pink sapphire we found a localization of the dichroism in the yellow-green and yellow regions, where filters 605 and 606 gave ratios 3¾ and 3¼ respectively. If one of the sectors proved too light or too dark to measure, no calculations were of course possible, even though the other was measurable. This we found less satisfactory than when both sectors proved simultaneously intractable, one giving full transmission, the other nil, when an infinity ratio could be recorded. This result we obtained for a green tourmaline for filters 600, 601 and 602 ; for 603 a calculable value of 25 was obtained.

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7. Quoted in New English Dictionary under entry " *Dichroism.*"

Gemmological Abstracts

CLARINGBULL (G. F.), HEY (M. H.) and PAYNE (C. J.). *Painite, a new mineral from Mogok, Burma.* Min. Mag., Vol. XXXI, No. 236, March, 1957, pp. 420–425.

A singly-terminated transparent, deep garnet-red crystal originally weighing 1·7gm. from a gem gravel from Mogok, Burma, proves to be a new mineral having Al_2O_3 76·2, SiO_2 5·6, B_2O_3 2·2, CaO 15·7, H_2O 0·7, Fe_2O_3 and MnO traces, total 100·4. Sp. gr. 4·01 ; ω 1·8159, ε 1·7875 ; H7½. The hexagonal unit cell has *a* 8·75, *c* 8·50Å., space group $P6_3$, $P6_3/m$ or $P6_322$, and contains approximately 38 O. The name *painite* is proposed in honour of A. C. D. Pain, Esq., who recognized the unusual nature of the crystal.

5 figs. W.S.

KLUPPELBERG (E.). *Beobachtungen an Gaseienschlussen in Glas und synthetischen Steinen.* Observing gaseous inclusions in glass and synthetic stones. Deutsche Goldschmiede-Zeitung, Vol. 55, No. 3, 1957, pp. 107–109. (See Journ. Gemmology, Vol. VI, No. 2, 1957, p. 97.)

A continuation of a previous article. In this part the inclusions in natural and synthetic crystals are discussed with special mention of inclusions in synthetic spinels, which are shown in carefully selected and well-produced microphotographs.

W.S.

CHUDOBA (K. F.). *Zur Bezeichnung synthetischer Smaragde.* On the nomenclature of synthetic emeralds. Deutsche Goldschmiede-Zeitung, Vol. 55, 1957, No. 3, pp. 109–110.

A further discouragement of terms like " cultured," or " cultivated " used instead of the correct designation of *synthetic emerald.*

W.S.

—— *Borazon—ein synthetischer Hartstoff.* Borazon—a synthetic hard material. Deutsche Goldschmiede-Zeitung, Vol. 55, 1957, No. 3, pp. 110–111 (March).

An article of February 13th, 1957, in the *New York Herald*

Tribune is abstracted. It contains the first report on " borazon," the new synthetic developed by R. H. Wentorf, of the General Electric Company. Dr. Wentorf scratched a diamond with borazon, and also demonstrated that diamond was hard enough to scratch borazon. The author (Chudoba) speculates on the chemical composition of borazon, which he thinks is a high pressure modification of BN (having a lattice similar to graphite). Owing to its heat resistance, which is claimed to be greater than that of diamond, the new synthetic material may be of potential importance in industry, once it can be produced in quantity at an economical price.

W.S.

EHRMANN (M.). *Gem mining in Burma.* Gems and Gemology, Vol. IX, No. 1, pp. 3–30. Spring, 1957.

A concise survey of the Mogok Stone Tract as it is to-day. A full account is given of the geography of the Union of Burma and in particular the Mogok Valley. The Burmese people, their dress and their homes are described. Reference is made to the geology of the Mogok area and the methods used in the winning of the gemstones are described in detail. The gemstones found in the Mogok Stone Tract apart from ruby, sapphire and spinel, are peridot, beryl, danburite, scapolite, zircon, fibrolite, topaz, orthoclase, kornerupine, sphene, diopside, iolite, chrysoberyl, apatite, albite and amethyst. The topaz and quartz crystals are found in Sakhangy, 12 miles south-west of Mogok, and the peridots from Pyaung Gaung, which is eight miles north-west of the town of Mogok. The history of Mogok in particular is entertainingly written. There is a good account of the jadeite mines near Myitkyina, which includes the history, geology and geography. The location of the amber mines and the occurrence and mining of amber are described, and the article concludes with a section on the gem trading of India and Burma.

23 illus. R.W.

BURGOON (J. R.). *Diamond mining in Arkansas.* Gems and Gemology, Vol. VIII, No. 12, pp. 355–362. Winter, 1956-7.

Diamonds have been found in almost every State of the United States. The suggested source is the James Bay area of Canada and the diamonds are supposed to have been carried south by ice flows. The Arkansas mine, in Pike County, was found in 1906. It differs from the other sources of diamond in the United States in that this is a pipe mine similar to the diamond-bearing pipes of South Africa. The Arkansas area was first geologically prospected in 1842 and later in 1889 and in both times no diamonds were found and the general view of the geologists was that the pipe was barren. In 1906 John Huddleston took an option on the site of the earlier geological survey and did find diamond, but in very small quantity. Huddleston sold the mine to a group of businessmen who formed the Arkansas Diamond Company. The mine was worked intermittently with the aid of machinery but was not successful and was closed in 1931. The mine was restarted under another company in 1936 but again did not prosper. The mine was sold to the Diamond Corporation of America who put in fresh machinery. The venture was a failure. The mine area is now a tourist attraction and " rockhound " hunting ground. An interesting account with many anecdotes.

5 illus. R.W.

ANON. *Amsterdam " Diamond City*." Netherlands Ind. and Comm., Vol. XI, No. 130, pp. 16–18. May, 1957.

A short history of Amsterdam as a diamond cutting centre and market during the past three centuries. The commencement of the expulsion of Jews from Portugal and Spain in the sixteenth century, and of the Protestants from France led to the settlement of diamond merchants and cutters in Amsterdam. In the early days diamonds came from India and Borneo. Then in 1727 the Amsterdam merchants were granted a monopoly of the diamonds from Brazil. The Brazilian stones were said to be harder to cut than the Indian stones, and a new technique of cleaving was developed to deal with them. The various wars from the Napoleonic to the Franco-German of 1870 caused depression in the industry, but these soon righted themselves. After the 1870 war the diamond supply came from the new South African mines. The Boer War caused disaster to the Dutch cutters, as did the First World War. Neither of these killed the industry, and it soon revived. The German occupation during the Second World War caused damage, not only through the denying of supplies, but through the damage to equipment, and, what was more serious, the loss of life owing to the purges against the Jews, many of whom were diamond merchants and cutters. Despite this severe damage the Dutch diamond industry has again recovered, although new cutters have had to be trained and new premises built. A section is given to the industrial uses of diamond and on the properties of diamond. The glass factory at Leerdam still practices engraving on glass by diamond tools.

5 illus. R.W.

FEHR (F. L.). *Amsterdam, Diamond City.* The Netherlands Ind. and Comm., Vol. XI, No. 130, p. 13. May, 1957.

The last two years of the diamond industry of the Netherlands have been a period of comparative boom, profits, however, being less than those made by other manufacturers in different industries. The piece-work form of payment and new production methods have brought about increased production of fashioned diamonds. The damage caused by the German occupation has now been mostly repaired. A short introduction is given for the Diamond Exhibition, which was held in the Apollohal in June and July.

R.W.

LABOYRIE (J. B.). *The selection of diamonds.* The Netherlands Ind. and Comm., Vol. XI, No. 130, p. 14, May, 1957. (*Extracted Gemmologist, Vol. XXVI, No. 311, p. 116. June, 1957*).

The appreciation of diamonds is influenced by four items, colour, cleanliness, size and shape, and for polished diamonds a fifth requirement is necessary, that of grade of manufacture. In general, cuttable rough diamonds are more expensive than the industrial rough, and in normal circumstances there is a well defined borderline between the two. When the demand for industrials is great, the lower range of cuttables (gem grades) may be bought for industrial purposes, and at higher prices than they would fetch as cuttables. Conversely, when there is a demand for a cheap polished product, the manufacturer starts to buy certain industrials that are still serviceable for cutting, again at a higher price than they would fetch as industrials. Such use of industrials for cutting disturbed the Dutch market in 1956, but has tended to disappear this year.

1 illus. R.W.

WEBSTER (R.). *Strain " knots " in synthetic spinel.* Gemmologist, Vol. XXVI, No. 311, pp. 99–100. June, 1957.

The strain patterns seen in synthetic spinels when viewed between crossed nicols are considered. They are patterns which may be likened to the " zircon halos " seen in many stones from Ceylon, but are only observed in polarized light. The " knots " have been seen in all colours of synthetic spinel, but appear to be more profuse in the yellow-green-coloured materials. The points of disturbance can only be vaguely seen in ordinary light, and no reason is given as to the cause of the " knots."

2 illus. P.B.

MEINCKE (H.). *Control tests of synthetic crystals by the use of isotopes.* Gemmologist, Vol. XXVI, No. 308, pp. 46–51. March, 1957.

Describes the use of non-radioactive isotopes (mainly C^{13}) as a means of characterizing a substance under test and to study their influence on its chemical or other change. From the experiments the conclusions were drawn that considerable admixture of isotopes causes changes in the properties not only of the original material but also of the resulting crystal deposit, so that they no longer correspond to those of the natural material. This fact precludes the use of non-radioactive isotopes for control purposes during changes in substances.

R.W.

ROBB (C. J.). *The jewel cure.* Gemmologist, Vol. XXVI, No. 308, p. 45. March, 1957.

Tells the story of some Irish jewels, which, legend has it, could cure divers illnesses. Generally agates, the two of which most is written are the " Imokilly jewel " and the *Cloch Omra.*

P.B.

WEBSTER (R.). *The pearl.* Gemmologist, Vol. XXVI, Nos. 310–311–312, pp. 78–85, 102–109, 126–128. May–June–July, 1957.

A general article detailing the formation and character of pearl and the location and methods of fishing in the various pearling waters. Mention is made of conch pearls and those obtained from molluscs which live in fresh water. The colours of pearls, their shapes and their preparation for marketing, are referred to,

and the " base " method for the calculation of the price of pearls is explained. Some notes are given on the " doctoring " of pearls by " skinning " and staining and some hints on the care of pearls.
11 illus. P.B.

ANON. *Diamonds within diamonds.* Gemmologist, Vol. XXVI, No. 310, pp. 92–93. May, 1957. (*Extracted from OPTIMA*).

Observations on a diamond inclusion in another diamond. Polarized light shows strain patterns of anomalous double refraction, and thus indicates that the included diamond does not fit perfectly and sets up strain in the host crystal. Such an effect accounts for the occasional shattering of a diamond a short time after leaving the mine, probably owing to the support of the containing rock being removed, or when being cut.
1 illus. R.W.

MARLE (F.). *Une émeraude synthétique.* (A synthetic emerald.) Revue Française des Bijoutiers Horlogers Exportation, Vol. III, No. 71, pp. 45–50. 1957.

An incomplete report of the growing of emerald crystals at the Centre National d'Etude de Télécommunications in Paris. A young scientist, during experimental work on crystal growth, produced emerald using advanced techniques based on the experiments of Hautefeuille and Perrey. Rather vague details of the apparatus used are given, and although a fusion method is indicated it is not conclusively explained whether that is the method used or a hydrothermal one.

R.W.

BERRY (R. B.). *Changing the colour of quartz.* Gemmologist, Vol. XXVI, No. 310, pp. 90–91. May, 1957. (*Extracted from Gems and Minerals*).

Records the results of several experiments in the irradiation of quartz in an atomic pile. Fifty brilliant-cut stones (colour not stated but presumed colourless) were given three weeks treatment in a pile. When removed thirty stones had turned black, fifteen to a smoky hue and five to a beautiful citrine yellow. Subsequent heat treatment at 400°F showed the smoky-hued specimens to give a blue luminescence, after which they reverted to become as clear as before irradiation. The citrine-coloured stones did not revert, and all but five of the black stones behaved similarly to the smoky-coloured stones in that they turned clear after a short blue luminescence. The five exceptions turned to a citrine colour, and these yellow-coloured stones showed no tendency to revert after prolonged exposure to solar radiation. No amethyst colour was reported to have been produced. Some speculations given as to the cause of colour in amethyst and smoky quartz.

R.W.

HALFORD WATKINS (J. F.). *Reasons for chatoyancy and asterism.* Gemmologist, Vol. XXVI, No. 309, pp. 69–75. April, 1957.

Originally published in the Gemmologist for August, 1932, as " Chatoyant phenomena," the article gives a general survey of the legends and the physical causes of asterism and chatoyancy. The article was written before the production of the synthetic star-corundum and is hence somewhat out of date. There is much good information and advice given in the article.

6 illus. R.W.

TRUMPER (L. C.). *Mounting a collection of gemstones.* Gemmologist, Vol. XXVI, No. 312, pp. 120–121. July, 1957.

Some ideas for the mounting of gemstones for display, either by the means of metal pins with adjustable claws or by specially shaped perspex fittings mounted on stems.

4 illus. R.W.

MELROSE (H.). *Spanish Armada pearls.* Gemmologist, Vol. XXVI, No. 312, pp. 117–119. July, 1957.

The story of four pearls (from the photograph they are apparently blister pearls), which have been named the O'Donnell pearls. The shells are approximately 13/16th of an inch in diameter and are said to be identical in formation with a mollusc of oyster type (*Pteria phalaenocea*) which were believed to have become extinct some 35 million years ago. Their presumed history since the days of the Spanish Armada is given.

1 illus. R.W.

LEIPER (H.). *Orienting blue topaz with ultra-violet light.* Gemmologist, Vol. XXVI, No. 312, pp. 133–136. July, 1957.

A reprint of an article published in Gems and Minerals, and also reprinted in JOURN. GEMMOLOGY, Vol. V., No. 3, pp. 135–140. July, 1955.

4 illus. R.W.

TRUMPER (L. C.). *The measurement of fluorescent spectra.* Gemmologist, Vol. XXVI, No. 312, pp. 122–123. July, 1957.

Describes a fitting to take a direct-vision prism spectroscope with wavelength scale, so that the fluorescence spectra can be measured—the scale of the instrument being illuminated by a secondary low-power light source incorporated in the fitting.
2 illus. R.W.

SINKANKAS (J.). *Recent gem mining at Ramona, San Diego County, California.* Gems and Gemology, Vol. VIII, No. 12, pp. 367–373. Winter, 1956–57.

A general review of the gem-bearing pegmatites near Ramona, San Diego Co., California. The area was first thoroughly explored in 1903. Dark green tourmaline, blue, greenish and colourless topazes, morganite beryl, smoky quartz and orange spessartite are mined from this locality. The fine orange spessartite from this area was first found in 1955 in the Little Three mine, one of the seven mines in the area, the others being the A.B.C., Black Panther, Lookout, Hercules, Spaulding and Surprise. Notes on the geography and geology of this area are given.
1 map. R.W.

POUGH (F. H.). *Greened amethyst.* Gemmologist, Vol. XXVI, No. 311, pp. 110–116. June, 1957.

A full description of the heat-treated amethyst which turns a green colour. There is a note on the " burnt amethyst " of " topaz " colour. Occasionally green quartz had been encountered on the market, but the origin was unknown. The discovery of the greening amethyst was accidental. The material amenable to such treatment is said to come from one locality only, that of Montezuma about 37 miles from the Rio Pardo in the State of Minas Gerais, Brazil. The deposit is a vertical vein which was originally worked by trench mining—shaft mining now being used. The amethyst is found in pockets and the individual crystals are more prismatic than ordinarily for amethyst. The colour is of moderate intensity violet and the crystal faces are dull and iron-stained. The heat-treatment is carried out at Rio de Janeiro and the resultant greened amethyst is sold under the name " prasiolita " or " prasiolite."
5 illus. R.W.

PELTON (C. R.). *A study of chalcedony.* Amer. Journ. Sci., 1956, Vol. 254, pp. 32–50.

The author suggests that chalcedony is microcrystalline quartz with submicroscopic pores. The quartz crystallites are somewhat misoriented from fibre to fibre which gives rise to local strain. Water may occur in the pores and optical evidence of strain, etch tests, absorption spectra and heating tests is given. The characteristic brown colour of chalcedony is ascribed to the scattering of light from the submicroscopic pores. S.P.

LEONARDOS (O. H.). *Ocorrencias de andalusita no Brasil.* Gemologia, No. 7, 1957, pp. 10–14.

This paper is of particular interest and ranks with earlier articles as an authoritative account of the occurrence of this rare gem mineral in that country. Principal localities are Minas Novas, Araçuai and Espírito Santo. Apparently crystals of any size are rare, the majority being from 3mm. to 10mm. in length and up to 5mm. broad. The shape of the crystal often compels the cutter to sacrifice the red colour for size and most stones are apparently trap cut, green in colour with some red flashes from the end facets only. Small uncuttable sizes seem to be reasonably common, but anything of good size is very exceptional.

1 Fig. R.K.M.

DE FREITAS (R. O.). *O Zircao na Gemologia.* Gemologia, No. 8, 1957, pp. 1–7.

This paper is chiefly of note for its account of Brazillian sources of gem quality zircon, particularly as Brazil is not generally thought of as a country producing this species.

For those who think of Zircon crystals in terms of simple tetragonal prisms (110) and pyramids (111) the illustrations of habit will come as something of a shock. All six drawings show the second order prism (100) well developed in addition to the normal forms, and four of them show the (311) pyramid, a steep form sometimes known as a zirconoid but not often seen. The last drawing shows the second order prism combined with the first order pyramid to produce a 12 sided crystal closely resembling the cubic rhombdodecahedron.

Generally the mineral appears to be abundant but not in gem quality or sizes.

6 Figs. R.K.M.

HARDY (E.). *Culture pearls.* Gemmologist, Vol. XXVI, No. 307, pp. 26–27. February, 1957.

A general article on the proposal to culture pearls in Malayan waters near Penang and Singapore. The formation of a cultured pearl fishery in Brecknock Harbour, Western Australia, using the large Australian pearl oyster *Pinctada maxima*, is also reported.

R.W.

ASSCHER (J.). *Locating imperfections in diamond.* Gemmologist, Vol. XXVI, No. 310, pp. 86–88. May, 1957.

Before fashioning a stone from a diamond crystal it is necessary to examine it thoroughly for internal imperfections in order to get the best cut-stone from the rough. Windows are polished on the crystal to see inside the stone. The article tells the use of a modified Rayner gemmological microscope for determining the position of imperfections in the crystal. The microscope is fitted with a large measuring drum on the focusing adjustment and a measuring stage. The scheme of operation is shown, and the use of polarized light to locate " inclusions " which are not observable in ordinary light is referred to.

3 illus. R.W.

ANON. *Brief notes about the colourful history of some famous diamonds.* Netherlands Ind. and Comm., Vol. XI, No. 130, pp. 18–21.

Thumbnail histories are given of twenty-nine famous diamonds. Six illustrations are included which have no relation to the text.

R.W.

WEBSTER (R.). *Tumbled gems.* Gemmologist, Vol. XXVI, No. 309, pp. 61–63. April, 1957.

A short description of the tumbling method for the production of baroque gems by churning in a slowly rotating barrel with abrasive and, subsequently, polishing agents.

4 illus. P.B.

CORRECTION. In the abstract of QUICK (L.). *Story of Benitoite.* (Journ. Gemmology, Vol. VI, No. 2, 1957, p. 96), the occurrence of benitoite should have been given as Santa Rita Peak, San Benito County, and not San Diego County.

S.P.

The summer issue of the *Zeitschrift der Deutschen Gesellschaft für Edelsteinkunde* contains a series of articles specially written by international gemmologists to celebrate the seventieth birthday of Professor Karl Schlossmacher, who was born on 10th July, 1887. This special number of the Journal edited by Professor K. F. Chudoba is a welcome and valuable contribution to gemmological literature, and summaries of the articles are given below.

ANDERSON (B. W.). *Refractive index data for some useful immersion liquids.*

When taking " immersion contact " photographs of gemstones, it is noticeable that the relation between the stone and the liquid varies appreciably according to the wavelength of the light used for the experiment. This, of course, is due to the well-known fact that the dispersion of liquids is higher than that of crystals of comparable refracting power.

A fairly precise knowledge of the dispersion of liquids used for this or for any other immersion method is thus essential if accurate work is to be attempted, unless one is content to use sodium light and a very large number of different liquids. Since it is not easy to find the necessary data in the literature, it was thought worth-while to make a series of measurements on some of the liquids most often used by gemmologists. The four liquids, methylene iodide, monobromonaphthalene, bromoform, and bromobenzene, are readily obtainable, and cover almost completely the range in refractive index from 1·80 to 1·56, if different wavelengths are used.

The liquids were placed in a hollow 60° glass prism, and the positions of minimum deviation for prominent lines in the mercury spectrum were measured on a table spectrometer, and the appropriate refractive indices calculated by the usual formula. The mercury lines cover the spectrum well, and mercury lamps are available to most gemmologists, being used extensively for fluorescence work. Colour filters can also be readily obtained whereby at least three well-spaced mercury lines can be isolated in turn, thus yielding three sources of monochromatic light.

In this paper, dispersion curves of the four liquids in question are reproduced, and examples are shown of immersion contrast photographs taken in yellow and in violet light, which serve to illustrate the effects of dispersion.

BIEGEL (K. H.). *Über künstliche Farbveränderungen von Edel – und Schmucksteinen.* (Artificial coloration of precious stones.)

A brief summary of the methods of artificial alteration of precious stone colours mostly applied by stone-cutters and dealers. Distinction is made between real improvements of stones and impregnation with colouring matter. The possibility of introducing colouring metal ions into crystals by electric current especially at elevated temperatures is briefly discussed in connexion with a report on experiments with quartz crystals.

BÖLSCHE (R.). *Neue Beobachtungen am Habachtal-Smaragd.* (New observations on Habachtal emerald.)

In a small aggregate of emerald crystals of varying colour and development from Habachtal (Austria), the presence of " bleischweif" (thinly laminated galena) between the crystals and on their surfaces could be detected. The influence of the " bleischweif" on the formation of the crystals is considered. The zonal striations in one emerald are described.

FISCHER (W.). *Zur Entwicklung der Idar-Obersteiner Edelsteinindustrie nach dem Kreige.* (Post-war development of Idar-Oberstein gem industry.)

The post-war development of the gem and diamond industry at Idar-Oberstein is discussed on the basis of statistical data available from the school for lapidary apprentices. The proportion of apprentices among the lapidary employees is relatively high, if one considers the average of a little more than two employees per workshop. Proposals for a modification of the training are made for those lapidaries working exclusively on synthetic gems. Possibilities for further development are seen in the processing of gems and diamonds for technical purposes and in the increasing economic importance of gem amateurs, especially in North America, who are getting interested more and more in gems which have not yet been worked in Idar-Oberstein on an appreciable scale. Comments are given on the reports of F. H. Pough on the situation of the Idar-Oberstein lapidary industry published after his recent visit there. The share of the practical work in the schools done by apprentices with special reference to the attainments and precision of the work and to the progress of the artistic achievements at Idar-Oberstein, which was greatly emphasized by F. H. Pough, is discussed. The article is supplemented by results of final exams of apprentices in the gem and lapidary industry.

GOEBELER (H.). *Steinschneidekunst.* (Art of gem engraving.)

The terms intaglio and cameo are defined as carved gems with incised and raised engraving respectively. The carving may be done either by simple manual tools, or by rotary tools (drilling and grinding). The material for engraved gems is chiefly yielded by the minerals of the quartz group. Hematite was used for the ancient mid-eastern seal-cylinders. Engravings on emerald, beryl, garnet, peridot and topaz have been rare. Through all ages glass (paste) has been a material for imitating gems. For these glass-pastes a mould of an intaglio or a cameo was impressed on plastic clay to cast the glass, which, after cooling, was brought to its final shape by finishing with tools.

The oldest engravings on gems originated from about 5000 to 3000 B.C. The Hittites, Egyptians, Assyrians, Persians and the ancient Greeks are worth mentioning for their art of carving gems. Remarkable works were accomplished by Greek artists for members of the Roman noble class during the time of the early emperors. Famous examples are the Gemma Augustea (Vienna) and a sardonyx representing the triumph of Germanicus (Paris). Since the time of Constantine the Great engravings on gems representing religious subjects were made in Byzantium. There are only very few carved gems preserved dating from the medieval ages. Our knowledge of ancient glyptography is based on the collections of the important museums and on the abundance of gems in pieces of medieval jewellery.

Towards the middle of the 19th century a rapid decline of glyptography began and the interest in carved gems was lost. Nowadays the art is mastered only by a small number of artists. A revival of glyptography would certainly add an element of special delicacy to the pictorial arts of to-day.

GÜBELIN (E.) *Das Phasenkontrast-Verfahren nach Zernike zur Untersuchung von Inhomogenitäten in Edelsteinen.* (Phase contrast microscopy for observation of gemstone inclusions.)

This paper emphasizes the great advantage of the phase contrast method of F. Zernike over the orthodox operations used previously for improving the contrast in bright field and the adaptation of dark field illumination. The principle of the phase-contrast method is explained and schematically depicted by a simplified diagram. Thanks to the development of a special phase contrast equipment for " bulky " objects the application of the phase contrast method has become possible for gemmological microscopy.

The new method offers interesting possibilities for investigating the interior of gemstones, particularly with regard to inhomogeneities caused by ex-solution, alteration and strain. It also reveals ultra-thin, transparent and colourless inclusions of very slight refractive difference and it discloses the state of healed fissures not visible under ordinary light conditions. Eight examples are shown and explained by means of photomicrographs. Thus the phase contrast method promises to become a source of new and interesting knowledge in gemmological microscopy.

KRAUS (E. H.). *The Development of gemology in the United States and Canada.*

Although some excellent books on gems had been published and courses on gems had been introduced at several institutions of higher education, it was not until about 1930 that a real interest in gemology began to be developed in the United States and Canada.

LIDDICOAT, JR. (R. T.). *Beauty versus excess weight.*

Whilst the diamond cutter usually cuts to the ideal pavilion angles at least, the lapidary often seems to have but one goal : to retain as much weight as possible. This preoccupation with maximum weight retention is difficult to understand. If proportions were given more careful attention, many more people would be attracted to coloured stones.

LIETZ (J.). *Neue Untersuchungen über die Bestrahlungsfärbung von Zirkon.* (New investigations on the radiation colouring of zircon.)

The coloration of colourless zircon from Mongka, Indochina, by UV-radiation is investigated in the visible and ultra-violet part of the spectrum. The absorption was measured at —173°C, and the crystal irradiated at 20°C as well as at —173°C. The absorption spectrum consists of single bands at 1·60, 2·10, 2·60, 3·30, 4·00 and 4·50 eVolt. The first bands to appear at low temperature are those of greater wave-lengths. These diminish with rising temperature and new bands of shorter wave-lengths are produced.

PAYNE (C. J.). *Painite : A new mineral which can be cut as a gemstone.*
This new mineral is referred to in an abstract on p. 172

PLATO (W.). *Ringstein-Prüfapparat.* (Testing of mounted stones.)
Illustrated description of an apparatus facilitating microscopical study of mounted gems both by parallel and convergent illumination.

POUGH (F. H.). *The Coloration of gemstones by electron bombardment.*
Colorations induced in various mineral substances, including a large number of gemstones, by an accelerator-produced electron beam are described and classified. They are distinguishable in degrees of permanence, with diamonds falling in a special class, because, once induced, their discolorations cannot be removed, only altered. The coloration of all other minerals is variable. Some may be changed to a colour which is apparently permanent, except to significant heat, and in others the colour change is only temporary, even though the specimens may not be exposed to light. A last group, so far limited to one mineral (wernerite), appears to lose the induced coloration spontaneously, even though the stones are kept in darkness.

One result of this study, which is a part of a continuing series of experiments with various particle sources, is the recognition that in most cases, the coloration—no matter whether induced by protons, deuterons, neutrons, alpha-, beta-, or gamma-particles, X-rays or electrons—is always the same for any mineral (again excepting diamond). This suggests that atomic spacing and lattice defects are almost entirely responsible for the hues produced, rather than any impurity accidently present. There are however, many discrepancies remaining to be explained, such as the failure of some amethyst to turn smoky like other quartzes, the difference between topazes of various origins, and the inconsistencies in spodumene responses. The explanations proposed by physicists, who so far have worked with only the simplest structures, are found to be inadequate even for their minerals, and do not begin to approach an explanation of the colorations which take place in the truly complex silicate structures.

ROSCH (S.). *Das Grune Gewölbe in Dresden.* (The green vault in Dresden.)
The author's own observations on the treasures in the famous green vault of Dresden. The contents of the vault are described

in greater detail than in the official catalogue published in 1921 and the hope is expressed that the treasures will one day be returned to Germany.

SCHIEBEL (W.). *Interferenzerscheinungen bei Spannungsdoppelbrechung.* (Interference patterns caused by anomalous double refraction.)

The article deals with the strain birefringence in transparent gem-stones and glass imitations by coloured interference phenomena. Certain crystal plates may be used for this purpose between crossed polarizers. The phenomena observed in instances of synthetic spinel and in glass imitations are described. The resulting pictures, which are rather complicated, are interpreted in terms of differences in velocities of light.

SCHMIDT (P. S. J.). " *Das Steinbuch des Aristoteles.*" (The gem book of Aristotle.)

It is a salient feature of the history of mineralogy that the ancient Greeks did not pay much attention to gems. Among the papers by Aristotle there is none dealing with stones. The so-called " Lapidary of Aristotle " certainly is spurious. A critical study of its contents reveals that Aristotle's authorship is out of the question. His pupil Theophrastus, however, gives an idea of what a lapidary would be.

SCHRÖDER (A.). *Zur Optik und Dichte der Edelturmaline.* (Optics and density of tourmaline.)

Some 40 different flawless tourmaline gems have been investigated. All of the stones were cut and faceted. Special regard was given to the correlation between the specific gravity and the refractive index of the ordinary ray for yellow sodium light. The resulting points plotted on a graph were arranged in a continuous curve which could be used in determining other stones of the species.

SCHUTT (E.). *Ist bei der mikroskopischen Echtheitsprüfung eine Immersionsflussigkeit notwendig ?* (Does microscopical observation need immersion liquids ?)

A technique permitting the microscopic study of gems without immersion liquids is described and recommended as a method for testing gems. Studies of inclusions in emerald and gems of the corundum group are given as examples, and possible errors arising from the use of immersion liquids are explained. Such mistakes are avoided in the new method without immersion liquids.

Another technique for the microscopic study of gems using reflected light is described in detail. It is stated that this method should be most suitable in routine work for jewellers and goldsmiths.

WEBSTER (R.). *Short-wave ultra-violet light as a gemmological tool.*

Observations on the luminescent behaviour of gems have been recorded since 1903, and much more advanced work was carried out by later workers, particularly by H. Michel of Vienna. Ultra-violet radiations are stated as lying between 4000Å and 150Å ; the range between 4000Å and 3000Å is termed the long-wave band and between 3000Å and 2000Å the short-wave band, as below 2000Å the rays cannot be usefully employed. Earlier workers used a high-pressure mercury arc with a Wood's glass filter, which passed the strong emission line at 3650Å. The short-wave ultra-violet lamp uses a low-pressure mercury arc in conjunction with a special glass envelope and filter, allowing the strong resonance line of mercury at 2537 Å to pass out, while to some extent absorbing the visible glow and the long-wave ultra-violet radiation. The short-wave lamp was not used much before 1942, when it was extensively employed in the mining of scheelite and willemite. After the war the use of the short-wave lamp was considered as an additional gem-testing instrument, where it is particularly useful for those stones which do not respond to the long-wave lamp but fluoresce under short-waves—for instance, benitoite and synthetic spinel. The lamp is useful in identifying certain types of doublets, and, by a photographic method, for determining the greater transparency to ultra-violet light of synthetic emerald in comparison with natural emerald, which may be used as a means of identification.

NEUHAUS (A.), and SCHILLY (W.). *Über Absorptionsspektren und Koordination einiger chromhaltiger Minerale und Edelsteine.* (Absorption spectra and co-ordination in certain chromium-bearing minerals and gemstones.)

On the basis of a new theoretical approach to the absorption spectra of the coloured complexes of the transition metals (Ti to Ni) made by Hartmann, and on the basis of the great advances made in the field of crystal growth and electronic spectrometry, it appeared useful to consider once again the old problem of the " dilute " allochromatic colouring of minerals and to attempt to arrive at an understanding of the causes.

This is demonstrated in a short systematic discussion, using crystals coloured by chromium ($Cr^{\cdots}$). In conformity with both theory and experiment on chromium-coloured crystals, and irrespective of the colour shown (red, violet, or green), absorption curves were found to follow the same general shape and pattern.

Thus, curves showed two very prominent absorption-maxima (i.e. absorption bans) of medium intensity in the visible spectrum, which were located :

1. For green crystals of the " emerald " type, at 5,400 to 5,700Å and 3,900 to 4,150Å, respectively, including natural and synthetic emerald, uvarovite, smaragdite, fuchsite, chrome-diopside, synthetic chrome-rich spinels, alexandrite and chrome-mullite.
2. For crystals of the " ruby " type, at 6,000 to 6,320Å and 4,200 to 4,350Å respectively, including natural and synthetic ruby, natural and synthetic normal spinel (i.e. without surplus alumina), zinc-spinel and chrome-alum.

This uniformity of the absorption curves is conditioned by (*a*) the symmetry of the co-ordination-polyhedra around the chromium ion, (*b*) by the influence of the polarization changes between the respective central ions and " Liganden," and (*c*) by the distance between the latter. In accordance with this, green-coloured crystals occur when, in addition to aluminium and chromium ions, another strongly polarizing ion exists in the lattice, as for instance, silicon in the silicate minerals, while on the other hand red-coloured crystals occur when there is an absence of such strong central ions, which contra-polarize the chromium-oxygen polyhedra, or when these polyhedra are indirectly pressed together by the expansion of the terahedral gaps, as for instance in magnesium and zinc spinels. This leads one to the opinion that the red/green colour effect of the chromic ion is not due to two different types of co-ordination as postulated by Thilo, but to two different states of the chromic ions : the normal state, as in the silicates, and a forced metastable state, as in ruby and normal spinels.

In the light of such an interpretation, as can easily be seen from a study of the genesis of these crystals, it is now possible to understand better than ever before, not only the colour differences, but also many other characteristics of chrome-rich crystals. Thus we can understand better the " thermochromatology " (change of colour on heating) as a direct function of genesis, since heating means expansion of the polyhedra, leading to the emerald (green) type, while cooling means a return to the compressed, metastable ruby type. It also gives some explanation of the double refraction due to strain and the " hardening " (lattice compression) of chrome-rich synthetic rubies.

ASSOCIATION NOTICES

EXAMINATION RESULTS

In the 1957 examinations in gemmology 130 candidates presented themselves for the preliminary and 100 for the diploma examination. Upon the recommendation of the examiners an award of the Tully Memorial medal was not made.

The following is a list of successful candidates, arranged alphabetically :—

Diploma

Qualified with distinction

Blackmore, Howard Loftus, Caterham.
Hinton, Vera Georgina (Mrs.), Staines.
Hopkins, Iris Patience Letitia (Miss), London.
Jank, Robert Alexander, Boscombe.
Weller, Christine Janet (Mrs.), Croydon.
Weller, Raymond John Howard, Croydon.

Qualified

Armbrecht, Bertram John, London.
Cassarino, Joseph A., Rochester, N.Y.
Cook, Walter George, Liverpool.
Cooper, Colin Lester, Lucerne, Switzerland.
Cope, John Richard, Plumtree.
Diss, Geoffrey Dixon, Barrow-in-Furness.
Drapkin, Clive Magnus, Birmingham.
Flapper, Jan, Arnhem, Holland.
Gaudernack, Rolf, Oslo, Norway.
Grimsdell, John Leslie, London.
Hadjizade, Ahron, London.
Hatcher, June Ann (Miss), Birmingham.
Hirschsohn, Clive Louis Richard, Cape Town, S. Africa.
Holland, Norman Alfred, Birmingham.
Jones, Wilfred Russell, Auckland, N. Zealand.
Kelly, William Henry, Glasgow.
Lauder, Angus Davidson, Edinburgh.
Lauvland, Karl, London.
Leake, Douglas Michael, Nuneaton.
MacLeod, Hector MacDougal, Glasgow.
McKay, Robin Ian, Thames Ditton.
Meanwell, Brian Sydney, Birmingham.
Mitchell, Peter John, London.
Pedersen, Erik Martinius, Lillehammer, Norway.
Seager, Philip, Abingdon.
Seneviratne, Dayatissa, London.
Skrede, Agnar, Boerüm, Norway.
Solman, Barbara (Mrs.), Worcester Park.
Strange, Peter John, London.
Warrender, John Stanley, Sutton.
Weatherill, John, Cardiff.
Weaver, Gerald Owen, London.
Weiss, Kurt, London.
Ystad, Per Thomas, Porsgrunn, Norway.

Rayner Prize

Steadman, Ivor Noel, Huntingdon.

Preliminary

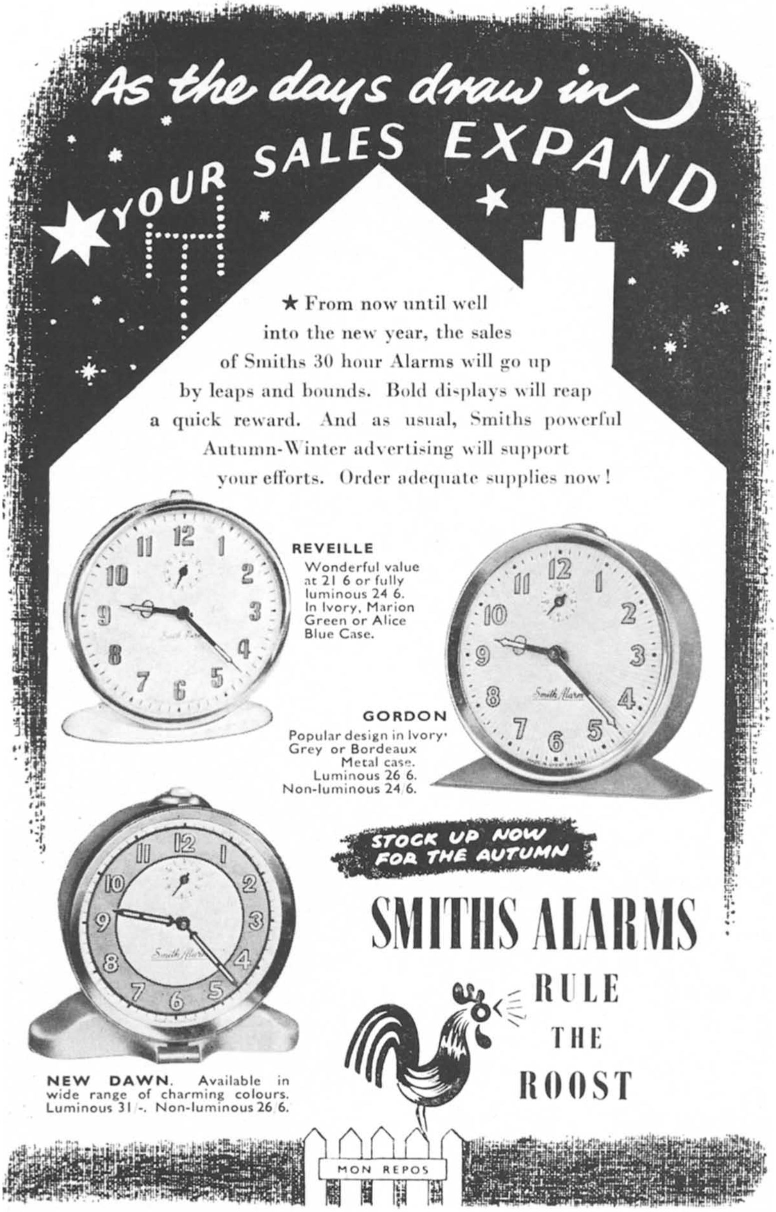
Ainsworth, Michael Barlow, Blackburn.
Aldridge, Patrick Edward, London.
Armstead, John Miller, London.
Atkinson, James Cockburn, Whitley Bay.
Barker, John William, Plymouth.
Barrett, John, Ayios Nikolaos, Cyprus.
Beeson, John David, London
Biddulph, Brian, Leicester.
Buckler, Albert Norman, London.
Cairns, Jean Mary (Mrs.), Birmingham.
Callaghan, David John, London.
Canning, Thomas Alfonso, Edinburgh
Clarke, Eric Michel, London.
Claudi, Fredrik, Oslo, Norway.
Coakley, Brian, Manchester.
Cook, Anthony Jean, Birmingham.
Cook, Peter Bryan, Birmingham.
Cooke, Barrie Ellis, Birmingham.
Copeland, Margaret Edith (Miss), Sutton Coldfield.
Crawford, Andrew, Birmingham.
Donaldson, Robert Gordon, London.
Eakins, Harry, Liverpool.
Falconer, Richard Arthur, New Malden.
Ferguson, Charles Thomas, Smethwick.
Fitzpatrick, Norman Reginald, Glasgow.
Fowler, Margaret Anne (Miss), Birmingham.
Gibbs, John Alfred Robert, Birmingham.
Hall, Edwin Frank, Birmingham.
Hayman, Harry Miller, New Westminster, B.C., Canada.
Hellman, Frank Viktor, Oslo, Norway.
Hirschsohn, Clive Louis Richard, Cape Town, S. Africa.
Hope, Kenneth, London.
Hopper, Peter John, Edinburgh.
Huddy, George, Liskeard.
Hysingjord, Jens, Oslo, Norway.
Kothari, Ramesh Rasiklal, Madras, India.
van Laarhoven, Andréas Martinus, Nairobi, Kenya.
McKechnie, Thomas McLean, Glasgow.
Milito, John T., London.
Mooney, Eugene, Edinburgh.
Moss, Graham, Patrick, London.
Mowbray, Terence, London.
Du Naier, Sidney W. Long Island City, N.Y.
Patrick, John Thomas, Christchurch, New Zealand.
Peplow, William R. H., Stourbridge.
Phillips, Roy Edmund, Sutton.
Picken, Joy Florence (Miss), Bromsgrove.
Plews, William Archibald, Edinburgh.
Prytz, Jens, Oslo, Norway.
Radford, Edward Thomas, Harrogate.
Ree, John, Grangemouth.
Reeves, Roger Charles, Chatham.
Reynolds, Helen Marylin (Miss), Ludlow.
Roberts, David George, Noss Mayo.
Robertson, William James, Edinburgh.
Roots, Jack Leslie, Rainham.
Rosenberg, Heinz, Cape Town, S. Africa.
Rossiter, Bernard Martin, London.
Rowan, Cyril, Upper Hutt, N. Zealand.
Ruff, Nigel Kenneth, Wraysbury.
Rushworth, Jack, Halifax.
Sando, Kolbjörn, Eyvind, Rjukan, Norway.
Seneviratne, Dayatissa, London.
Seneviratne, Seetha, London.
Silva, Sena de, Colombo, Ceylon.

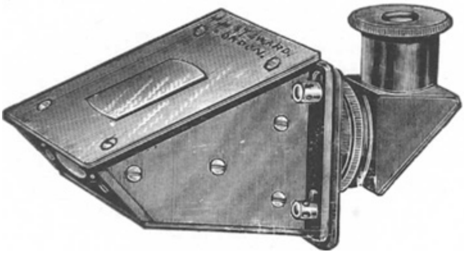
Skinner, Ramon, London.
Smith, Charles, Peebles.
Smith, David John, Brighton.
Smith, Winifred Joan Russell (Miss) Edinburgh.
Spencer, Alan, Liverpool.
Stacey, Frank Roland, Kenton.
Taylor, Joseph, Newcastle-upon-Tyne.
Thomson, Patrick Norman, Port Elizabeth, S. Africa.
Tungate, James Brian, London.
Turney, Eric Robert, London.
Wall, John Sydney, London.
Walton, Joseph Howard, Cirencester.
West, Peter John, Romford.
Whyte, Archibald Gilroy, Midlothian.
van Zeijst, Anton Herman Maria. Groningen, Holland.

TALKS BY MEMBERS

PARRY, G. (MRS.). " Gemstones," Swansea Branch of the British Horological Institute, 13th March.

MESSENGER, S. (MISS). " Precious stones and some superstitions." Young Women's Fellowship, St. Albans, 2nd October.





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