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THREE GLIMPSES OF THE PAST

by

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

BROWSING amongst the writings of older mineralogists is a pleasant and often a profitable exercise for the present-day gemmologist. Many a forgotten or half-forgotten fact is brought to light again and a fascinating insight is provided into the state of knowledge and the indefinable climate of thought of past generations.

The progress of Science has, of course, been enormous during the past century, and we can, from the vantage-point granted us by time, smile with unwarranted but pardonable condescension at the troubles experienced by even the masters of the past in distinguishing gemstones where advances in knowledge or the invention of new instruments or techniques have made these an easy exercise for the beginners of to-day. But, on the other hand, it might be argued that (partly due to the vagaries of fashion, which operate in Science as in all human activities) for every new technique developed an old one has been lost, or has become so rusty and dusty from disuse as to be practically unavailable to the modern worker.

These thoughts have been prompted by the re-reading of three quite unconnected papers written respectively some seventy, fifty and forty years ago, each of which has its own peculiar interest for the gemmologist of to-day.

The first and earliest of these papers formed the Presidential Address given by H. C. Sorby to the Mineralogical Society in 1877, and was published in Vol. 2 of the Mineralogical Magazine. Sorby described a simple method of determining the refractive indices of transparent mineral plates by measuring their real and apparent depth under the microscope, and some curious optical phenomena discovered while making such determinations. The principle of this method had already been given (unknown to Sorby) by the Duc de Chaulnes as early as 1767, but Sorby's investigations were far more thorough, embracing as they did the peculiar behaviour of light in doubly refractive minerals. Quite apart from their theoretical interest, his findings are of first-rate practical importance for anyone who is tempted to use this seemingly straightforward method of refraction index determination. It will be remembered that the method involves the measurement of the vertical difference of focus between the upper surface of a transparent body placed on the microscope stage and the surface of the glass on which it rests, both as seen through the specimen (" apparent depth ") and through air (" real depth "). For isotropic substances the formula R.I. = real depth/apparent depth holds to a close approximation.

With a standard petrological microscope the vertical displacement of the focus can conveniently be measured by means of the calibrated wheel of the fine adjustment, but this has a limited range and the thread, unless very well made, suffers from backlash, so that a more satisfactory arrangement is to have a scale and vernier attached to the stand and body of the microscope. Sorby had such a scale fitted, reading to 1/1000th inch, and by using a No. 2 eyepiece and 2/3 inch objective on isotropic specimens some ¼ inch deep was able to obtain refractive index readings with only slight errors in the third place of decimals.

By the same simple formula the *ordinary* ray of a uniaxial stone can be obtained, *but this is not true for the extraordinary ray nor for either of the two rays in a biaxial mineral.*

Instead of using dust particles or scratches on the glass plate supporting the specimen, Sorby found it more convenient to focus on the image of a ruled grating, limited by a small circular diaphragm, which he fixed below an achromatic substage condenser with a small stop, the image being thrown just below the surface of the glass plate. It was by using this arrangement that the truly " extraordinary " behaviour of the extraordinary ray forced itself on his attention. He found that there were two foci for this ray. In neither was it possible to obtain an undistorted image of the circular hole or the grating, and in neither was a true refractive index figure given by the simple real/apparent depth formula! In biaxial minerals *both* images are found to be bi-focal and again the indices obtained by the formula were in no case true. Sorby demonstrated these phenomena at a Soirée of the Royal Society and the matter greatly interested Sir George Stokes, who investigated the problem energetically from the theoretical standpoint and was able a little later to publish a full explanation of the observed facts. (Proc. Roy. Soc., 1877.)

Thanks to Stokes's explanations, Sorby was able, with suitably oriented crystal plates, to calculate from the data obtained by his method both of the indices in uniaxial stones and all three indices in biaxial stones. Moreover, he could assess the sign and extent of the double refraction. In his hands, in fact, the method became of considerable power and flexibility.

And yet, after being rescued and brought to a new pitch of accuracy by Sorby more than a century after it was first discovered, the whole process was again and almost immediately relegated to the limbo of forgotten things. Relegated, astonishingly, even by Sorby himself ; for after preparing a detailed manuscript on the subject which was intended for the Royal Society, he shelved it for thirty years and only re-edited it for publication shortly before his death. This fuller account of his experiments was published posthumously (1909) in the Mineralogical Magazine ; but the most readily accessible account of Sorby's technique and results is in that valuable source-book, Tutton's " Crystallography and Practical Crystal Measurement " (1922 edition, pp. 1177-1183), which is to be found on the shelves of most Public Libraries.

I have myself always been attracted by the method and have used it from time to time with fair success when, for instance, a rough check was needed on the refractive index of diamond octahedra, for which the technique is more suitable than any other.

Not long ago Dr. E. H. Rutland carried out some tests for me in which the microscope objective remained stationary and the stone itself was raised or lowered into focus on the table of a small spherometer. This worked very well, but was rather cumbersome, and tricky in operation. Recently I have had a millimetre scale and vernier fitted to the body and tube of a Beck No. 10 London Stand which enables readings to 1/20 mm. (roughly 1/250 inch) to be made quickly and accurately. When time permits I hope to indulge in a more detailed explanation of the possibilities and snags for the practical gemmologist of this attractively direct method.

The second of three papers to which I referred above is of far more general interest to readers of this Journal. It forms the text of the two Cantor Lectures on "Precious Stones" delivered by Professor Henry Miers before the Society of Arts in 1896. Sir Henry Miers, as he later became, honoured us in his old age by becoming the first President of the Gemmological Association. At the time these lectures were given he was already one of the leading mineralogists in the country—and it must be remembered that the mineralogists were the gemmologists of those days. These lectures, therefore, give a very clear résumé of the state of gemmological knowledge in this country at the end of the nineteenth century.

In this same year, it may be noted, Bauer's great book, "Edelsteinkunde," was published in Germany, and though it is obviously unfair to compare the exhaustive treatment of the subject possible in a text-book with the brief summary required in two popular lectures, one is afforded an intriguing glimpse of the different methods of approach to the determination of gemstones adopted by contemporary mineralogists of the two nations.

In his first lecture Miers introduced his audience to a number of the lesser known gemstones, including sphene, andalusite, axinite, idocrase, phenakite, cordierite, spodumene and diopside, and projected them on the screen "by reflected light," i.e. by means of what to-day is called an epidiascope. He then gave a brief review of the methods by which stones can be discriminated, starting with hardness, to which he refers in the best modern manner. "It is not a character capable of any accurate measurement, neither is it to be recommended for use by inexperienced persons. I hope to show as I go on, that we have now accurate methods of testing at our disposal which render the trial of hardness quite unnecessary." He then passed on to brilliancy, total internal reflection, dispersion, and the use made of these properties by the lapidary in enhancing the beauty of the rough material. This was followed by an attack (so often made by mineralogists) on colour as a basis for gem distinction ; and one cannot but agree with the instance chosen. " There are, for example, certain red stones which the most skilful experts cannot by their colour alone refer with certainty to ruby, garnet or spinel." But he does *not* add that " ruby, garnet and spinel " just about exhaust the possibilities for gems of this particular shade of red, and that the colour has, in fact, by enormously reducing the field, assisted greatly in the eventual identification of the stones.

Miers then (and this will surprise many readers) proceeds to describe the use of the spectroscope in identifying almandine and zircon—the two minerals in which absorption bands were first discovered by his friend, Professor Church. It seems curious that in the thirty years which had elapsed since Church first announced his discovery, the spectra shown by so many other gemstones should have remained unnoticed. The lecturer knew the value of observation by reflected light, for he says: " . . . it is not necessary to look *through* the stone, it is quite sufficient to place it in a strong light and look *at* it through an ordinary pocket spectroscope. . . In this way we are enabled to identify a jargoon or an almandine merely by looking at it. *There is no test so simple or so easy of application.*" I have to confess that the italics of that concluding sentence are mine.

To summarize the data for specific gravity and refractive index values of the various gems, Professor Miers presented them in the form of a graph showing the close relationship existing between these two properties in the majority of minerals, the main exceptions to the straight line ratio being diamond and sphene, in which the refractivity is high in relation to their density, and topaz, in which it is low. (Two other exceptions, demantoid and fluorspar, are not included in his diagram.) There is a link here between Miers and Sorby, since Sorby at the end of his paper gave, in addition to an excellent table of refractive indices, a list of the values for what he called the absolute refracting power of minerals, and it is very noticeable from this table that the values for $\frac{n^2-1}{d}$ are very nearly constant for the silicate minerals, to which group most of the gemstones belong. The simple graphical representation of specific gravity and refractive index is to be commended to students who find remembering such data a troublesome business.

Miers' first lecture concluded by describing how the specific gravity of an unmounted stone could be determined by means of an accurate chemical balance, Westphal Balance, or by means of heavy liquids. For use in the latter method, methylene iodide was recommended, and for denser stones the fused mixture of thallium and silver nitrate, then recently discovered by Dr. Retgers. This mixture melts at 75° C. to a clear colourless liquid in which zircon just floats ; and, like the more convenient Clerici solution which we favour nowadays, is miscible in all proportions with water.

Miers' second lecture opened with an account of the optical methods of gem discrimination. He first described the minimum deviation method, in which facets of the stone to be measured are made to act as a prism on the table of a goniometer, and then referred to a primitive " reflectometer " of the Bertrand type, which was the crude prototype of the jeweller's refractometer which Dr. G. F. Herbert Smith was to design ten years later.

A curious time-lag is noticeable here. Professor Miers stated that the reflectometer could only measure refractive indices up to 1.66, this being " the greatest index of refraction yet obtained in any transparent liquid." The liquid to which he refers is, of course, bromonaphthalene. It is surprising that so well-informed a mineralogist should have been unaware of the much higher index of that same methylene iodide which he knew and recommended as a heavy liquid, since this value had been established by W. H. Perkin some years previously and was well enough known to Bauer, whose book, as already stated, was published in the same year that Miers gave his lectures.

The delayed-action effect of published information is admittedly not uncommon. Clerici solution, for instance, was first described in 1907, but did not come into regular use until nearly thirty years later ; and only now, more than 100 years after Brewster observed the absorption bands in cobalt glass, orpiment and other coloured substances, is the usefulness of the absorption spectrum method of identification becoming accepted by more than a few enthusiasts.

Miers proceeded by describing dichroism and the dichroscope, double refraction and polarized light, and by means of a projection polariscope showed his audience uniaxial and biaxial interference patterns on the screen. To him, as a mineralogist, this technique seemed obvious and simple, though with faceted stones he admitted that immersion in a liquid of similar refractivity was generally necessary to enable the interference figures to be visible. Pyroelectricity, that curious property shown strongly only by tourmaline amongst the gem minerals, was included by Miers as a practical test, which he carried out by sifting through muslin a mixture of sulphur and red lead on to the specimen while it was cooling after being heated in the flame of a spirit lamp. " This test I have frequently applied and have never known it to fail," he stated. One wonders whether, had a practical gemmology examination been held in 1896, students would have been provided with a supply of powder, muslin sieve and spirit lamp as part of their routine equipment.

The newly discovered X-rays were mentioned briefly as affording a means of distinction between certain gems and their imitations. " True ruby or sapphire or true turquoise are like flesh —transparent to the X-rays ; but their imitations are like bones— opaque to them."

Miers was writing, of course, before the days of the Verneuil synthetics, but Frémy's synthetic stones were familiar to him. " Large numbers of artificial rubies are now used in jewellery. The only respect in which they differ from the natural stone is that they have been formed by a different process. If we desire to distnguish them it can only be by some feature resulting from the manner in which they have been made. From my own limited observations I think it is generally possible to see in the artificial rubies, by means of the microscope, a certain streakiness and also little cavities like bubbles which one does not see in the natural stones." (Those Frémy crystals which I have examined have shown features quite unlike anything seen in natural or Verneuil synthetic rubies ; the gemmologist's skill in recognizing characteristic inclusions seems for some reason not easily acquired by the mineralogist.)

Miers ended his lecture with so powerful a plea for scientific gemmology that I feel I must quote him at some length.

" In bringing to a close these imperfect and fragmentary notes on precious stones, I must call attention to the chief point which it is my desire to emphasize. I have indicated how I should myself set to work to determine the nature of a precious stone. Each observer can use his own contrivances, but they must be in accordance with the principles which I have illustrated. The methods are those of physical science—and they are accurate ; personally, I should hesitate to assert positively the nature of any precious stone except by means of the scientific tests, although I might have an opinion. It may be my own want of expert knowledge which prevents me from feeling confidence in any but these methods ; at any rate, I claim for them that they enable anyone with a little practice to determine with absolute certainty any precious stone even when it is facetted, and, moreover, they supply, not an opinion, but a proof.

" Considering the number of serious mistakes which are made in the trade, and the curious errors which prevail, jewellers would surely do well to learn these methods, to acquire especially such a knowledge of crystal optics as will enable them to determine the refraction of any transparent material. . . The jeweller's trade stands almost alone in failing to realise that such a knowledge has a real commercial value, and ignoring the aid of physical science."

The irrefutable good sense of this appeal was slow in bearing fruit, but there must have been some present at these Cantor lectures who were later to help in the founding of the Gemmological movement in this country.

The third paper on which I wish to comment is also the reprint of an address, not this time by a scientist, but by a well-known dealer in precious stones, J. Chaumet, of Paris. His communication, entitled " Le Rubis," was delivered in 1904 before fellow-jewellers and merchants of the Chambres Syndicales. It gives a most interesting picture of what must be considered the more enlightened views on the subject which held in the Trade at that time.

Chaumet divided rubies into two main categories: natural and manufactured. Natural stones he further divided into (1) Oriental ruby, or simply " ruby " ; (2) Siam ruby ; (3) Balas ruby ; (4) Spinel ruby. Manufactured stones he classified into (1) Reconstructed stones ; (2) Manufactured or synthetic stones proper.

He quoted as an ancient authority the following passage from a book entitled " Dénombrement, facultés et origine des pierres précieuses," by M. L. D. S. D., published in Paris in 1667: " Le vrai rubis est une pierre diaphane, rayonnante et rougissante, teinte d'une couleur écarlate et de la laque indique (indienne) ; son écarlate tire sur la sinople On découvre fort peu de couleur azurée dans le bout de leur feu ; car si l'on en découvre beaucoup, ils seraient appelés balai ; quand ils pesent plus de vingt carats, ceux qui sont parfait meritent le nom d'escarboucles. Les Indiens l'appellent tozez ou menea ; les Perses et les Arabes l'appellent iacu. Il y a quatre genres de rubis: le veritable est appelé rubis ; le rubacelle ; le balai ; le spinelle."

" Sinople " was a word of many meanings, but the reference here is probably to vermilion. That a stone should be called by a different name when it is over 20 carats was to me a new suggestion.

Chaumet recognized as Oriental rubies fine transparent examples from Burma or Ceylon which had the desired pigeon's blood or ox-blood red sometimes tinged with pink. He dismissed from further consideration balas and spinel ruby, which he recognized as having a different composition and which he and his colleagues had no difficulty in distinguishing. But on Siam rubies which (and this was news to me) had made their first appearance on the market between 1870 and 1880, he dealt at some length because of the great difference in value existing between these and Oriental rubies from which, on occasion, they could with difficulty be distinguished.

Chaumet referred to an actual dispute on a ruby of doubtful nuance which was sold as an Oriental ruby for 35,000 francs. The purchaser, suspecting that the stone was not, in fact, a Burma ruby and was thus worth far less than he had paid for it, wished to annul the sale. The matter was brought to court and submitted to the arbitration of the Chambre Syndicale, who, after minute examination of the stone, decided that the ruby was a Siam stone and that the sale should be annulled. The vendor appealed against this and the Court designated three experts to make a report on the specimen. Presumably Chaumet was one of the experts, since the examination was carried out in his laboratory.

He astonished and impressed his colleagues by exposing a Burma and a Siam ruby to the violet rays from an arc lamp ; the Burma stone glowed like a red-hot carbon, the Siam stone remained virtually inert. Examination in a phosphorscope gave a similar result, and by such means the stone under dispute was confirmed as being a Siam stone—even the vendor being satisfied that he had made an error.

How Chaumet projected violet rays ("ultra-violet" is not mentioned) on to the stones is not explained—presumably through some form of prism. Since his day ultra-violet light has been continuously used and widely regarded as a means for distinguishing between rubies from the two localities. The reason for the lower intensity of fluorescence in Siam stones is that they usually contain more iron than Burma stones, which has a quenching effect on the fluorescence. Dark Burma rubies, however, also show weak fluorescence and the method is, in fact, hardly more accurate or sensitive than judgment by eye on a colour basis. The atmosphere of scientific magic surrounding a test in ultra-violet light in a darkened laboratory is, however, far more impressive to the uninitiated and hence carried more weight. Actually, a far more accurate and scientific means of distinction is afforded by examination of internal structures under the microscope.

Chaumet then proceeds to undermine our faith in his scientific ability by quoting the results of his density determinations on the different categories of ruby. We are, alas! only too accustomed to seeing inaccurate figures for the density of precious stones quoted and re-quoted in books of the not-so-distant past, but Chaumet's figures, derived from his own experiments on "more than a hundred" specimens of Oriental, Siam, synthetic and reconstructed rubies, are not merely inaccurate, but show fairly consistent and well-marked divergencies between each group, where no such divergency does in fact exist. May I remind readers that the density values for gem quality corundum are very constant ; to two decimal places 3.99 is the figure for pure corundum and the variation does not exceed the limits 3.98—4.01. Remembering this, what can Chaumet have done to obtain the following results?

Oriental Rubies.—Minimum, 4 ; maximum, 4.06 to 4.08. Very rarely 4.08.

Siam Rubies.—Minimum, 4.20 ; maximum, 4.26 to 4.28. Very rarely 4.28. "I have never met a Siamese ruby giving 4.00."

Synthetic Rubies.—Minimum, 3.60 ; maximum, 3.75 to 3.80. Very rarely 3.80. "On one occasion only a synthetic stone gave me 4.00."

Reconstructed Rubies.—Minimum, 3.70 ; maximum, 3.76, a single case giving 3.87.

Chaumet's figures for " Oriental " rubies are what one might expect, since when using water for hydrostatic weighing there is always a tendency for results to be rather high, and the figure 4.08 has been obtained even by reputable mineralogists.

The values for Siam rubies, however, are quite inexplicable, unless he was working not with rubies at all, but with dense almandine garnets. Unfortunately, though he publishes photo-micrographs of inclusions seen in Burma rubies he does not show any of his " Siam " stones, which might offer a clue as to their authenticity.

With the synthetic and reconstructed stones, the only reason for figures so far below normal could be the inclusion of bubbles of fantastic size and number. One of his photo-micrographs of a reconstructed stone shows something of this kind, but a photograph of a synthetic specimen given for comparison shows the usual cloud of very small bubbles typical of a Verneuil stone.

Incidentally, this is the only clue one has to the fact that Chaumet is referring in his text to Verneuil synthetics and not to the Frémy rubies, as the name Verneuil does not appear anywhere in his paper. The paper in Comptes Rendues in which Verneuil first announced the success of his process had appeared two years previously (1902).

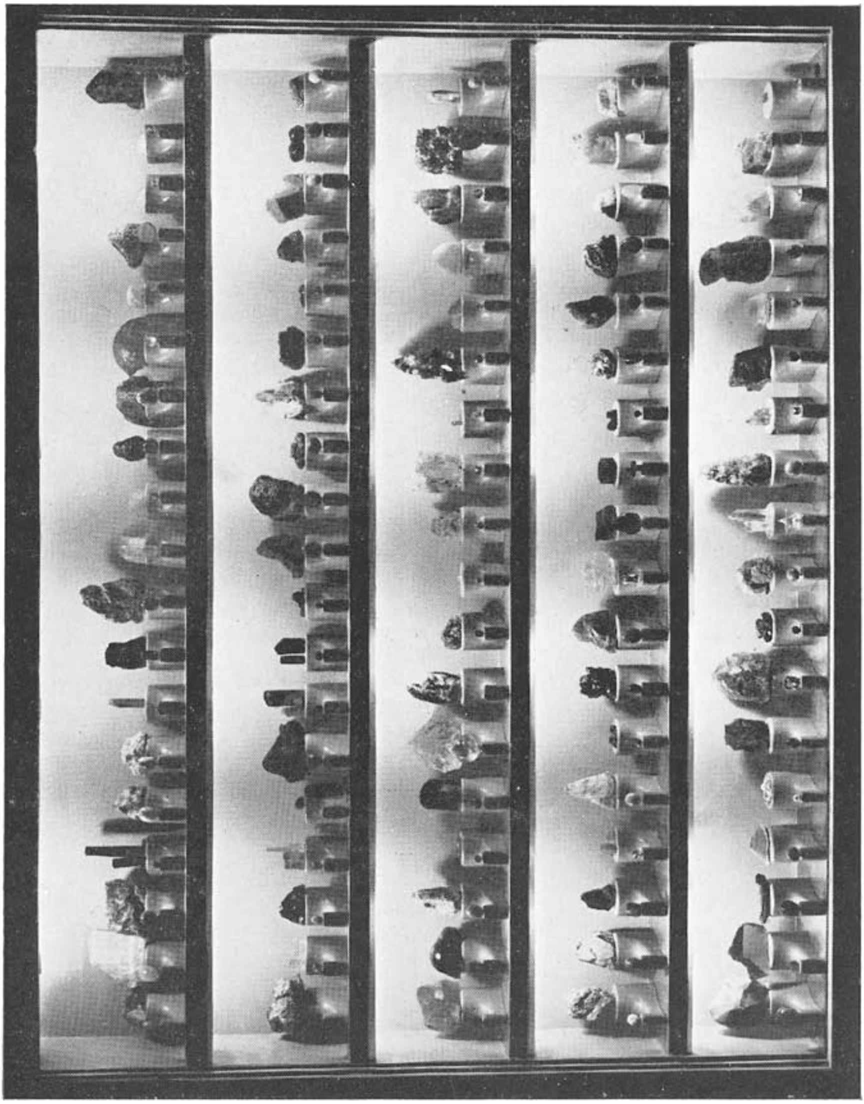
After pointing out quite clearly the main internal features by which natural and synthetic rubies could be distinguished under the microscope, Chaumet made the suggestion that with any important ruby a certificate of authenticity should be issued stating its provenance, weight, shape, colour, density, fluorescence, and notable internal features. With such a certificate could be issued a photograph of the mounted stone together with photo-micrographs of its inclusions. In making this suggestion (and carrying it out in practice in his own business) Chaumet was well ahead of his time. Very similar certificates are issued at the present time by the Paris Laboratory.

My account of these three addresses has already taken more space than was originally intended. I can hardly dare hope that I have interested others as profoundly as the papers themselves have interested me.

A Collection of United States Gems

OVER a number of years, Mrs. Virginia Hinton, of Houston, Texas, the first woman jeweller to receive the coveted awards of Certified Gemologist, of the American Gem Society, and of Fellowship of the Gemmological Association of Great Britain, has collected rough and cut gemstones found only within the confines of the continental United States. This started on a Western trip, where (as she says) a few poor garnets, a broken piece of aquamarine, some quartz and some blue topaz were found and they inspired the idea of a collection. She thought that a possible fifteen varieties might be available. That was the first step ; her American collection now has ninety-two species and varieties and might go to a ninety-six or a vaguely possible one hundred.

Some of this material she has actually dug herself on prospecting trips, some she has purchased from " mountain folk or plains people," and some from reliable mineral dealers. No one, that has not done it, can know the effort required to make such a collection. Each summer and sometimes in fall and winter (she explains the spring is not a good time), long trips have been made by automobile or train to obtain a single good specimen. Hundreds of letters have been written to other collectors and many disappointments have been encountered. Hard trips have been made on horse or mule back to sections where this is the only means of travel, where snakes, mostly rattlers, were very prevalent, and to what has been termed " Our Last Frontier," which is a hideout for those wanted by the Law. She has met many lovable characters and some not so lovable, some with most exceptional education and some with almost no education. This has woven itself into a richness of experience that has endeared each stone to her and often wrapped it up in a story of real life. Some people might think it is only a stone collection, but to Mrs. Hinton it is evidently palpitating and very much alive.



From a professional point of view the collection has been of great value, to this soft-spoken lady of the Southland, in her appreciation and actual knowledge of rare gems, and she is always ready to talk about the beauty, colour, form and crystal structure of her specimens. Her great enthusiasm for gems and for perfection in her daily work as a jeweller led her into the study of display, and she designed unique cast aluminium stands showing the rough material and the cut stone directly in front of it ; also, after many cabinets were built, she now has one that has a series of lights under each shelf. The writer has had the pleasure of seeing and examining this American collection ; the colours were beautiful and the crystal forms varied and interesting. It also made him proud to know that there are so many gems in the United States.

The following is a list of the gems in her collection:—

Amber
Apatite
Azurite
Augelite
Beryl—Aquamarine, emerald, golden, Morganite
Beryllonite
Benitoite
Celestite
Cancrinite
Chiastolite
Chlorastrolite
Corundum—Ruby, sapphire
Diopside
Datolite
Diamond
Epidote
Feldspar—Moonstone, oligoclase, Amazon stone, sun stone
Fluorite
Garnet—Pyrope, hessonite, rhodolite, spessartite
Hæmatite
Howlite
Iolite
Jade—Nephrite
Jet
Kyanite
Lapis Lazuli
Lazulite
Malachite
Opal—Colours, opalized wood.
Obsidian—Colours, silver sheen
Pearl
Peridot
Phenacite
Phenite
Quartz—Rose, moss agate, mocha stone, iris agate, dumortierite, rutilated, Myrikite, chrysocolla, moonstone, hornstone, smoky, jasper, amethyst, rock crystal, fortification agate, plasma, blood stone, carnelian, aventurine
Rhodonite
Rutile
Scapolite
Smithsonite
Shattuchite
Spodumene—Kunzite, yellow, Hiddenite
Staurolite
Spinel
Sillimanite
Serpentine
Topaz—Brown, blue
Tourmaline—various colours
Turquoise
Variscite
Vesuvianite
Willemite
Zeolite—Messacite, Thomsonite

Mrs. Hinton is now trying to replace specimens with finer ones, thus building the quality of her collection. As in all collecting, whether it is silver, pictures or anything else, there are some pieces one never gets, but she says we always have the possibility of new finds being made or some new gem such as Benitoite or Brazilianite being discovered, and if so she hopes to be there.

Mrs. Hinton is manager and buyer for the fine jewellery department in a department store in her city.

SOME TESTS for PLASTIC IMITATIONS

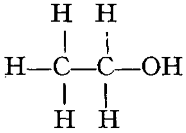
by ROBERT WEBSTER, F.G.A.

THE gemmologist has for some thirty years known of plastic imitations of amber, and has equally well known of the use of a strong saline solution as a means of distinction one from another ; the " light " specimens being deduced as amber and the " heavy " pieces, by implication, as " bakelite." In those early days of gemmology, when any colourless stone which " looked like " diamond was glibly called a " jargoon," so any imitation which was not patently glass was called " bakelite," and truth to tell little damage was done. To-day the position is vastly different, for the chemist has given to art and industry many more materials, and older types in new guises. Indeed, this is truly a " plastics age," and the serious worker is not now content to just describe such pieces as " imitations," as " plastics," or even more crudely as " bakelite." He wants his diagnosis to be completely truthful and accurate, however base the material and however worthless it may appear to be, and this article is the record of some chemical tests, and other data, which experiment has shown to be useful in the distinction between various plastics.

" Plastics," an omnibus name used for a whole collection of synthetic products, are, in general, rigid substances which at some period in their production are plastic, hence the derivation of the " general " name. Only a small number of these substances have an application in gemmology, the majority being used as a vehicle for colour finishes in the paint industry, and these " lacquers," except in two particular cases, are of no concern to the student of gemstones. These materials, most of which can be truthfully described as synthetic resins (and here it may be pertinent to mention that in industry the natural resins are referred to as *rosin,* while the term *resin* implys a synthetic production), are in one classification divided into two divisions, the *thermoplastic* and the *thermosetting* types. The thermoplastic types are characterized by their being plastic when hot and rigid when cold, while the thermosetting types, after once having been moulded by heat and pressure, remain rigid, however much further heat, within reason, is applied.

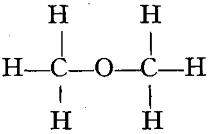
My discussion on plastics must suppose some knowledge of organic chemistry, a subject upon which the average gemmologist knows little ; therefore a few remarks on organic chemistry in so far as it applies to plastics, or synthetic resin formation, is indicated. Organic chemistry, unlike the better known inorganic branch of that science, utilizes relatively few elemental substances, the chief of which are carbon, hydrogen and oxygen ; indeed, organic chemistry has been described as " the chemistry of the carbon atom," and it is partly due to the incredible number of ways in which these three elements can combine together that the enormous variety of organic compounds are possible. Nitrogen, sulphur, phosphorus, the halogens and some metals (the latter having no significance in plastics chemistry) complete the list of chemical elements which enter into compounds in this chemistry of " life." Early chemists, owing to their inability to synthesize organic compounds, concluded that a mysterious agency—the so-called " vital force "—was an essential factor in organic composition, a view that was broken down by the synthesis of urea, a truly organic compound, by Wöhler in 1828.

One of the first things which strike a reader of text-books on organic chemistry, and in articles on plastics, is the peculiar system of shorthand used as formulae. We are all conversant with the formulae employed to show the composition of inorganic chemical compounds—and minerals, e.g. Al_2O_3 (aluminium oxide) ; a molecular formula representing one single substance only. In organic chemistry this does not hold good ; for instance, C_2H_6O represents both the molecule of a colourless gas—dimethyl ether, and the molecule of ethyl alcohol, a colourless liquid better known by the shortened form *alcohol*. That is, they are *isomers* of one another, and the difference is expressed by the use of the typical " glyptic " formulae of organic chemistry, i.e.:—



$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -OH \\ & | & & | & \\ & H & & H & \end{array}$$

ethyl alcohol



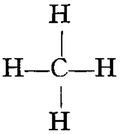
$$\begin{array}{ccccccc} & H & & & & H & \\ & | & & & & | & \\ H- & C & - & O & - & C & -H \\ & | & & & & | & \\ & H & & & & H & \end{array}$$

dimethyl ether

or put into another form which is often employed:—

$CH_3{\cdot}CH_2{\cdot}OH$ (*ethyl alcohol*) or $CH_3{\cdot}O{\cdot}CH_3$ (*dimethyl ether*).

In organic chemistry everything turns on the fact that carbon is tetravalent, that is, has four " bonds " or " arms " available for attaching to other like or unlike atoms, such as the univalent hydrogen with one " arm," or oxygen, which is divalent and therefore has two " arms." Thus methane, CH_4, may be written



$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -H \\ & | & \\ & H & \end{array}$$

and acetylene, C_2H_2, is written as $H-C\equiv C-H$, the valency of carbon being satisfied by a triple " bond " between the two carbon atoms. This is known as an " unsaturated " compound, and although on paper this " triple bond " appears to be a stronger linkage it is actually not so. This is because the four " arms " of the carbon atom must be considered as reaching out in three dimensions at equal angles from the centre, that may be explained as reaching out to the points of a hypothetical tetrahedron (*Figure* 1),

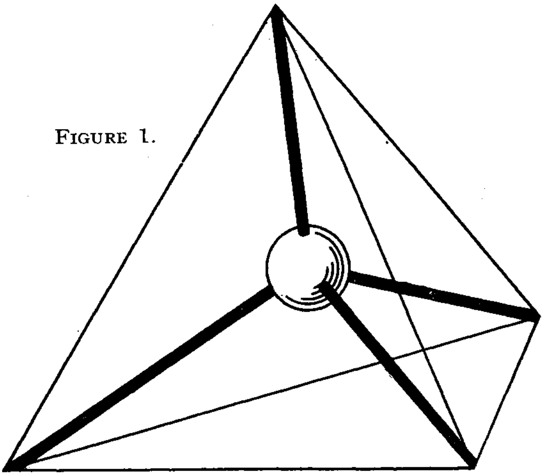
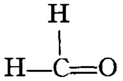


FIGURE 1.

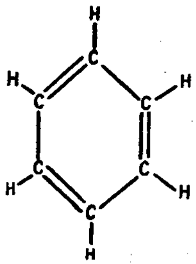
in fact the tetrahedral arrangement of carbon atoms in the atomic structure of diamond, and to bring two or more " arms " together must in fact produce strain. Formaldehyde, H—CHO, a compound of some importance in plastics chemistry, is expressed as:—



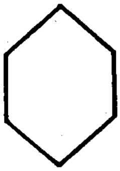
$$H-\overset{\overset{H}{|}}{C}=O$$

where the valences of oxygen and the two single valencies of hydrogen " satisfy " the four " arms " of the carbon atom.

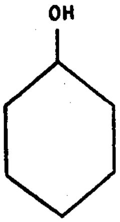
It is now necessary to consider the structure of benzene, C_6H_6, and its symbol, the hexagon, so characteristic of organic formulae, which was postulated by Kekulé in 1867. This worker suggested that the six carbon atoms formed a closed ring in which " double " and " single " bonds occur alternately, thus:—



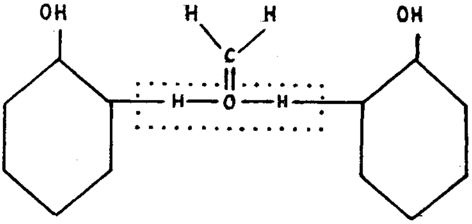
or represented simply as:—



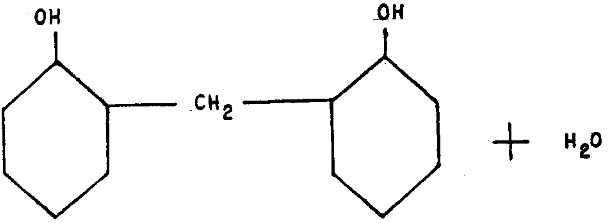
The observant will see in Kekulé's benzene ring an apparently unsaturated compound, whereas benzene is known to be very stable, and it is suggested that the bonds are satisfied in some internal manner connected with the natural angle of the hexagon. Further, any of the hydrogen atoms may be replaced by atoms of other elements and " radicals," such as the hydroxyl (—OH), the ethyl (—C_2H_5), the amino (—NH_2) and the carboxyl (—COOH) among many others. Thus the structure may branch in one of many different ways. Phenol or carbolic acid (C_6H_5OH) is one such substitution, the " graphic " formula of which is:—



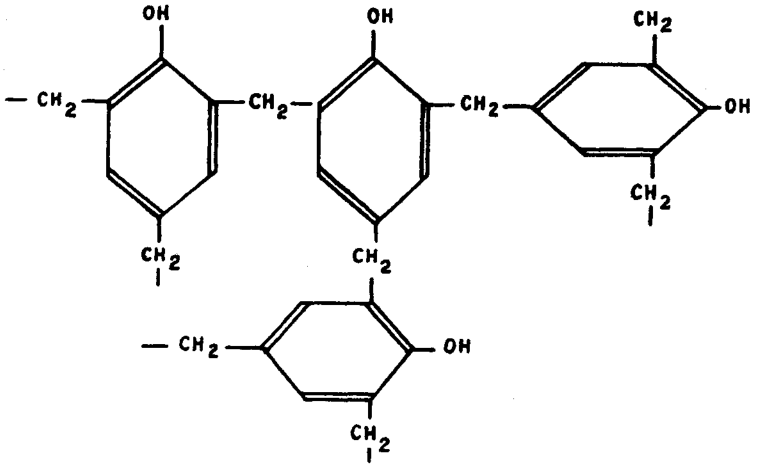
The fundamental processes of plastics depend upon the formation of " macro " molecules in long " chains " or " nets," which, except in the cellulosic plastics, are artificially formed. This formation of long chain molecules is carried out by either " condensation " or " polymerisation." Condensation may be briefly described as the attachment of two (or more) chemical groups by the elimination of water or other simple molecules, and may be illustrated by the formation of resin by the interaction of phenol and formaldehyde:—



gives:—



which by extension gives the net molecules of phenol/formaldehyde resin (the bakelite plastic), which, it must be remembered, are in three dimensions and not two as implied by the drawings in the plane of the paper. Certain condensations, however, particularly demonstrated by the polyamides produce long chain molecules of exceptional length, in fact fibres ; this being popularly known as *nylon*. The final product, Bakelite C, would have a net possibly like:—



Polymerisation produces a chain extension of simple molecules by the joining up of molecules containing " double " bonds, e.g. ethylene, C_2H_4 or $CH_2{=}CH_2$, forms:—

$$CH_2—CH_2—CH_2 \longrightarrow CH_2—CH_2—CH_2,$$

which is formed by, what can best be described as, the spare bond in each " double " bond of the ethylene molecule swinging over to satisfy a similar bond in the carbon atom of the neighbouring ethylene molecule. This " polymerisation " being started by energising agents, such as heat or ultra-violet light, yielding *polyethylene,* a white, tough, but flexible, solid known as "Alkathene " or " Polythene."

The reader will now see that the problems of identification of a given plastic must depend upon the identification of groups or " radicals," because, unlike the compounds in inorganic chemistry, there are no metals to isolate. Indeed, it is to these " radicals " or compounds formed from them by reagents that identification by chemical means is obtained. Particularly is this the case where odoriferous or colourful compounds are produced, and the record of some of the methods which have been found of value experimentally is given in these notes, together with relevant physical and optical data.

THE CELLULOSIC PLASTICS.

CELLULOID.

Nitrocellulose, commonly miscalled cellulose nitrate, is made by the nitration of cotton linters or wood pulp, these being a pure cellulose which consists of naturally formed chain structures produced by the joining of " glucose ring " molecules. The cellulose is treated with sulphuric and nitric acids till the nitrogen content is about 11 per cent., and is " lubricated," or as it is termed " plasticized," with camphor. It is well known that celluloid is extremely inflammable, leaving a fibrous ash, and when rubbed or worked emits the smell of camphor. The density for the purer material is 1.35, but may rise to 1.80 or over when containing " fillings," and the higher values are particularly evident in the ivory and white colours. The refractive index has a range between 1.495 and 1.520, and the hardness, in common with all the plastics, is low, about 2 on Mohs's scale, and further, the material is readily sectile.

Peelings of celluloid heated in a closed tube (a test tube) give off fumes which are acid to litmus and are negative to a test for hydrogen sulphide. The most conclusive test for celluloid, however, is a delicate one for the detection of free nitric acid ; it is a test requiring little preparation and does *no* damage to the specimen providing the spot of reagent is removed immediately after testing. The test is carried out by placing a spot of a 5 per cent. solution of diphenylamine in concentrated sulphuric acid (sufficient quantity for years of use may be made by dissolving .5 gram, that is 2.5 carat, of the diphenylamine in 10 c.c. of sulphuric acid) on to the surface of the specimen to be tested ; if the material is celluloid the pale brownish coloured liquid turns to a deep blue. No such change of colour was found to be produced by any of the other plastics, or by the natural products, amber, ivory, etc.

This test is also available for the detection of the " solid glass bead " type of imitation pearl ; for nitrocellulose is nearly always used as a vehicle for the guanine (fish scales). No colour change is found when the liquid is applied to the surface of real or cultured pearls, but to use this liquid on such material is hazardous, for the acid will tend to remain between the interstices or the crystallites and react with the calcium carbonate with detriment, which, although not being immediately apparent, may become evident at a future time. Likewise, a negative result will be obtained with the hollow-glass sphere type of imitation pearl, unless the reagent is able to penetrate between the inner surface of the glass and the wax filling in order to get at the cellulosic/fish scale essence. NOTE: sulphuric acid should be kept from contact with the skin.

SAFETY CELLULOID.

Owing to the inflammability of ordinary celluloid a " safety celluloid " has been produced, in which the cellulose is " acetylated " by acetic acid and not " nitrated," thus producing a cellulose acetate which burns much less readily with a characteristic blue-edged flame, with the formation of droplets of fused material and the emission of a vinegary smell. The density of the pure material is lower than that for ordinary celluloid ; it is 1.29, which may be increased by " fillers " to 2.00. The range of refractive index was found to be just lower than for celluloid of the ordinary type, that is, from 1.490 to 1.510.

Peelings heated in a closed tube behave like celluloid in giving off fumes which are acid and negative for hydrogen sulphide, and, again like celluloid, the safety material softens with acetone, but *not* with amyl acetate, which does soften ordinary celluloid. The most conclusive test (if a positive result can be obtained) is one depending upon the production of the " ester " ethyl acetate when peelings of the specimen are placed in a test tube with a small quantity of ethyl alcohol (ordinary methylated spirits will do), a drop of sulphuric acid added and the mixture gently heated, when, preferably after cooling and perhaps decanting into water, the characteristic apple-like smell of ethyl acetate becomes apparent, the chemical reaction being:—

$$\underset{\textit{acetic acid.}}{CH_3COOH} + \underset{\textit{ethyl alcohol.}}{C_2H_5OH} = \underset{\textit{ethyl acetate.}}{CH_3COOC_2H_5} + \underset{\textit{water}}{H_2O}$$

OTHER CELLULOSIC PLASTICS.

In recent years several new modifications of cellulose plastics have been produced, such as the mixed ester of aceto-butryate cellulose and the cellulose ethers of ethyl, methyl and benzyl. Of these plastics, none of which have been experimentally worked upon by the author, little can be told as far as the scope of this article is concerned. From manufacturers' literature ethyl cellulose and benzyl cellulose are insoluble in triacetin, whereas celluloid and safety celluloid dissolve in this chemical. Ethyl cellulose is made by the reaction of ethyl chloride upon alkali cellulose and the pure material ; a granular white product is said to have a density of 1.14 and a refractive index of 1.47. How these values would be affected by processing and plasticizing will only be known when experimental determinations are made on finished products.

PROTEIN PLASTIC.

FORMALIZED CASEIN.

The familiar horn-like plastic which is variously known as " Galalith," " Lactoid," " Ambroid," " Sicaloid " (French), and " Casolith " (German), is a product of the formalization of milk, skimmed milk being coagulated by rennet or acid, pressed or extruded, and finally " cured " by formaldehyde (a pungent gas, but actually used as the 40 per cent. aqueous solution known as " formalin "). The density of the casein plastic is more restricted in range than are the cellulosic and bakelite plastics, it being nearly constant at 1.33 (range is 1.32 to 1.39) and the refractive index is 1.55.

Casein chars but does not burn, a smell of burnt milk being perceptible. In the closed tube peelings of casein give off fumes which are alkaline to litmus and positive for hydrogen sulphide. It may be appropriate to mention at this stage a method whereby these fume tests may be easily and accurately carried out with small quantities of test material ; this is by closing the end of the test tube containing the test peelings by a bored cork fitted with a short glass tube (the pourer corks with glass nozzles supplied with bottles of lighter petrol are eminently suitable) into which is inserted a small strip of the moistened test paper—red litmus paper if alkaline fumes are anticipated or blue paper if the fumes are suspected to be acid (both papers could be put in the tube together) ; a strip of filter paper moistened with lead acetate solution (sugar of lead) will detect hydrogen sulphide, the test paper turning brown if the evil-smelling gas is evolved. (*See figure 2.*) This method ensures that all the fumes pass the test paper and thus allow small quantities of material to be used. It is preferable to use as small a test tube as possible.

With casein, however, there is a test more easily carried out and which is quite characteristic for this plastic. A spot of concentrated nitric acid (the jeweller's *aqua fortis*) applied to the surface of casein produces a permanent yellow stain due, presumably, to the production of xanthoproteic acid, and may be analogous to the similar action of nitric acid on the skin. NOTE: Do not test any plastic with diphenylamine solution on the spot where a nitric acid test has been carried out, for some of the free nitric acid will have remained and give a positive blue coloration to the diphenylamine solution, which is a very delicate reagent.

A protein plastic has been made from soya bean, but has been used solely in association with phenol for motor car parts by the Ford organization. No notice is taken of this " hybrid " type as its use appears to be contra-indicated for an ornamental plastic likely to be encountered by the gemmologist.

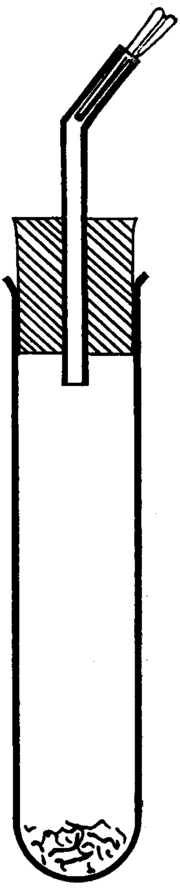


Figure 2. Test tube containing peelings with " restriction " tube fitted and test paper inserted.

THE BAKELITES.

PHENOL/FORMALDEHYDE RESIN.

The plastic to which the name " bakelite " is normally applied is the phenolic resin, which has until quite recently been the one outstanding plastic with which the jeweller had to contend, for most amber imitations are made from this material, and many fine, colourful and transparent stones and " ornamentals " are made from " Catalin," a type of phenolic resin which is cast and not pressure moulded, as are most of the dark coloured bakelites used for utility articles. The chemical composition of this resin has been discussed in the introduction and needs no further comment, nor will it, for the purposes of this article, be necessary to discuss the complex methods employed in the manufacture of the bakelite resins. It may be as well to note that in bakelite condensation the formaldehyde could be replaced by furfural, giving a furfural/phenol polymer which is employed in the United States for a " bakelite " which is sold under the trade name " Durite."

The only two tests known to gemmologists for distinguishing bakelite are those of density and refractive index, and these can be completely successful only when the values of both constants can be obtained and, one might add, with ease. How often can both these values be determined in " set " conditions or when carved? Less sectile and slightly harder than the celluloids, the density of bakelite ranges from 1.26 to 1.67, the higher values being due to " filling," while the cast resin has, according to makers' literature, a density range of 1.27 to 1.35 (experimental determinations on a number of pieces of " Catalin " gave an even more restricted range of 1.32 to 1.34). The refractive index varies betyeen 1.57 and 1.70, but is usually restricted to between 1.61 and 1.66.

Phenol bakelite chars but does not burn, the characteristic odour of phenol (carbolic acid) being given off. Fragments heated in the closed tube give off fumes which are, strangely enough, strongly alkaline to litmus. It would be thought that they would be acid, as phenol is known as carbolic acid, but it is an extremely weak acid and, moreover, is in combination with formaldehyde. The fumes are found to be negative for hydrogen sulphide. There are several satisfactory chemical tests for free phenol and one would expect the distinction of the phenol in bakelite to be comparatively easy, but this is not so, for the phenol is so tightly held in the molecule that insufficient can be released to influence the usual chemical reactions required to determine phenol. It is known, however, that phenol may be detected, even if in very small amounts, by the use of 2.6 dibromoquinone-chlorimide, a bright yellow powder, and experiment has shown that phenol bakelite may be easily identified by testing for the minute amount of free phenol that has been leached out by water, a method which does not cause damage to the specimen.

The method found most effective is to boil the specimen, if small, in a small quantity of distilled water contained in a suitable vessel (say a boiling tube) ; or, if the specimen be large, to take a peeling or scraping and similarly boiling in 1 or 2 c.c. of water in a small test tube (3″ x $\frac{1}{4}$″), allowing to cool and then dropping in the water a *very* small pinch of the yellow powder 2.6 dibromoquinone-chlorimide, and then, from the end of a glass rod, allow to trickle into the tube a *very small* drop of caustic soda solution. The production of a blue colour (bromchlorphenol blue) indicates free phenol and therefore bakelite. Care should be taken to use only the merest trace of caustic soda solution, for phenol blue is an indicator and is only blue between very definite limits of alkalinity (pH 5.5 and pH 4.5), below which the liquid turns green and then yellow, and if acidified a red colour is produced.

AMINO PLASTIC.

UREA/FORMALDEHYDE RESIN.

These resins are obtained by the condensation of urea—$CO(NH_2)_2$, sometimes called *carbamide* (or its sulphur analogue—*thiourea*, $NH_2{\cdot}CS{\cdot}NH_2$), by formaldehyde ; that is, instead of phenol, urea is used, the condensation producing a network structure as in the case of the phenol bakelites, but of a type not definitely understood. Better known under the trade names " Beetle," " Pollopas " and " Scarab," the amino plastics produce colourless resins which can be tinted delicate pastel shades.

Except perhaps in the white coloured material, the urea/formaldehyde resins are rarely incorporated with " heavy " fillers, hence the density is rather more constant, the values being 1.48 to 1.55, although Morrell (*Synthetic Resins and Allied Plastics*, 1937) gives values to 1.60, and the pure material at 1.48. A few pieces of " Beetle " tested for specific gravity gave values not far removed from 1.50, with white material reaching to 1.54. The refractive index has a range of from 1.55 to 1.62 ; here again Morrell gives the higher figure of 1.66 for the upper limit. The hardness is just about 2 and, like bakelite, tends to chip rather than peel, being thus differentiated from the celluloids.

In a flame the urea resin chars and gives off a smell not unlike that of casein, but distinctly more pungent. When destructively distilled, fumes are given off which are alkaline to litmus and show a positive reaction to the lead acetate test for hydrogen sulphide. Ammonia is also given off which can be detected by filter paper wetted with Nessler's solution (an alkaline solution of potassium mercuric iodide which turns brown when ammonia is present and is a delicate test for this compound). The question of separating casein from urea resin is easy, for despite the similarity of these reactions, for urea/formaldehyde resin does not give a yellow stain with nitric acid as is the case with the protein plastic.

ACRYLIC RESIN.

POLYMETHYLMETHACRYLATE.

Well known as " Perspex," the water-white glass-like material so much used for aircraft windows, this plastic can also be obtained in many transparent and opaque colours, and has been used to some extent as " gemstones " for costume jewellery and for the " core " of solid imitation pearls. The resin is a methylated acrylic acid, derived from ethylene, and is polymerized into long chain molecules.

Perspex is very sectile and has a very constant density of 1.18 to 1.19 in the transparent white or coloured material, thus will float on a saturated solution of salt in water. As experiments have been carried out solely on transparent material it is not known with accuracy whether higher densities occur with the pigmented or " filled " material. Text-books seem to give no information on this point, but, by analogy with the rise in density due to " fillings " in the case of other plastics, nothing greater than .2 increase in the density values should be possible. The refractive index of Perspex is near to 1.50.

The acrylic resin burns with a spluttering flame, giving off a sickly, sweet-smelling odour, and when heated in the closed tube gives off a heavy white inflammable vapour which is denser than air, and a liquid, first considered to be water, condenses on the cooler part of the tube. However, experiments with anhydrous copper sulphate proved this liquid not to be water, and by fitting a cork and bent delivery tube to the closed tube, the distillate was collected in a second test tube. It was found to be an amber-coloured mobile oily liquid with a similar smell to the heated plastic. Indeed, what happens is that the polymer (the resin), when heated to about 300° C., softens and undergoes rapid depolymerisation to the monomer—methyl methacrylate. Perspex is known in the United States as " Plexiglass."

POLYSTYRENE (Poly vinyl benzene).

In this plastic, a glass-like material which, like " Perspex," is used for the production of " costume gems " by the injection moulding technique, and for the cores of imitation pearls, the hypothetical group *vinyl* $CH_2 = CH—$ (which is ethylene with one hydrogen atom removed) takes the place of one hydrogen atom in the benzene molecule. This is *styrene* or *vinyl benzene*, and by polymerisation long chains of over 100 styrene molecules are formed, giving to the world a plastic with many outstanding properties—electrical and optical. The British material is known as " Distrene " and trade names for American manufactures are " Styron," " Lustron " and " Victron," and there is a post-war manufacture at the I.G. Farbenindustrie plant at Schkopau.

Polystrene has the remarkably low density of 1.05 (1.05 to 1.07 according to " Lustron " information circular) ; this is slightly less than for amber. The refractive index is 1.59. The material burns with a smoky flame giving off a sickly aromatic odour, and in the closed tube the plastic melts, gives off heavy white fumes which if ignited burn fiercely with a sooty flame. The fumes are neutral to litmus test papers and give a negative result to the test for hydrogen sulphide. However, distinction is made easy owing to the ready solubility of this plastic in such liquids as benzene, toluol, amyl acetate (but not acetone), bromoform, methylene iodide and α-monobromonaphthalene. After immersion in any of these liquids for a second or two the surface becomes sticky, an effect at once diagnostic and destructive, for the refractometer liquid will " do in " the surface of a specimen.

THE ALKYD RESINS (The glyptals).

These resins have an importance in the paint industry and, as far as gemmology is concerned, have, at the moment, no application. The inclusion of this resin is because these alkyds have to some extent superseded the cellulose lacquers, and there is every reason to suspect that they may be used as a vehicle for the fish scale guanine for coating imitation pearls.

The resin is formed by the esterfication of a polybasic acid, usually phthalic acid, and a polyhydric alcohol, such as glycerol (glycerine). By controlling the relative amounts of glycerol and phthalic acid various polymers of different properties may be obtained, but the final polymerisation produces an infusible, brittle glass-like material insoluble in most solvents. These resins are easily tested, for if a small peeling be mixed with twice its quantity of resorcinol and moistened with concentrated sulphuric acid (the mix can be prepared on a 3 x 1 glass slip with the aid of a glass rod on to which the mixture sticks). The end of the rod with the mixture adhering to it is heated over a small flame until the sticky mass on the end of the rod becomes a dark reddish-brown colour. The rod is then stirred round in a beaker of water containing one pellet of caustic soda. The production of fluorescein (the water becomes a fluorescent yellowish-green in colour) indicates the presence of phthalic acid and therefore a glyptal resin.

A SCHEME OF TESTING.

In testing a suspected specimen for the various types of plastic, one, of course, will be influenced by first observations and will duly make such a test as is necessary for proof. If, however, no idea at all is obtained from first impressions, it is suggested that the tests are carried out in this order: *1.* Place a spot of the diphenylamine/sulphuric acid solution on the specimen—if a blue colour is produced the material is *celluloid*. *2.* If previous test was negative, try a spot of nitric acid—a yellow spot indicates that the specimen is *casein*. *3.* If previous tests negative, try the solubility with benzene or toluol ; if soluble then the plastic is *polystyrene*. *4.* If all previous tests negative, try sectility ; if the specimen peels easily Perspex or Safety celluloid is indicated. Try a spot of acetone, and if specimen is soluble the plastic is *Safety celluloid*. *5.* If result of previous test shows no quick solution by acetone, then prove for Perspex by seeing if a small peeling sinks or floats on a saturated salt solution. If it floats, as it should do if all other tests have been carried out correctly, the specimen is proved to be *Perspex*. *6.* If the specimen was found to chip rather than peel, the resin is probably either the phenol bakelite or the urea resin. Carry out the test with the 2.6 dibromoquinone-chlorimide ; a blue colour to the test water proves that the specimen is *phenol bakelite*. The test for ammonia will prove the plastic to be *urea resin*, all other tests having proved negative.

The glyptal resin would only be used as a coating for pearl essence, and here it might be mentioned only celluloid has so far been detected as the vehicle for fish scale guanine. One plastic which has sprung up in recent years has not been considered in this article. It is *poly vinyl chloride*, better known as P.V.C., and has been omitted from this work as it does not form solid rigid substances, but only rubbery coatings ; hence its inclusion was not warranted.

It has been the writer's intention to try and formulate " spot " tests for all the important plastics ; although this has not met with complete success, it is confidently suggested that all the plastics used in imitation jewellery can be differentiated by the tests given, and in the case of the important phenol bakelite, celluloid and casein, new and powerful methods are suggested which do not damage the specimen. In conclusion, it is my pleasurable duty to thank Mr. Harold Lee for his ready help and advice.

A LETTER TO THE EDITOR

Dear Sir,

With reference to the comments in " Marginalia " in Volume II, No. 1, in the Journal, two points about the colour of opal are raised in connection with Murphy's book, " They Struck Opal " :—

(1) Why the colour is always horizonal.

(2) Why the potch turns suddenly to colour.

The answers are not too difficult. The colour is always (with few exceptions) horizontal because opal is a solidified jelly—a silicate gel—found in the viscous state from a colloidal solution and it naturally assumes a horizontal bedding as does a jelly in a household jelly-mould.

Potch changes to colour because the conditions which produce the effect are intermediate between those which produce milky or dark potch and those which result in water opal or hyalite. When these conditions vary only a little the reflections are not possible.

Yours truly,

Australia. (Signed) G. Frank Leechman.

The Question of
DIAMONDS in CANADA

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

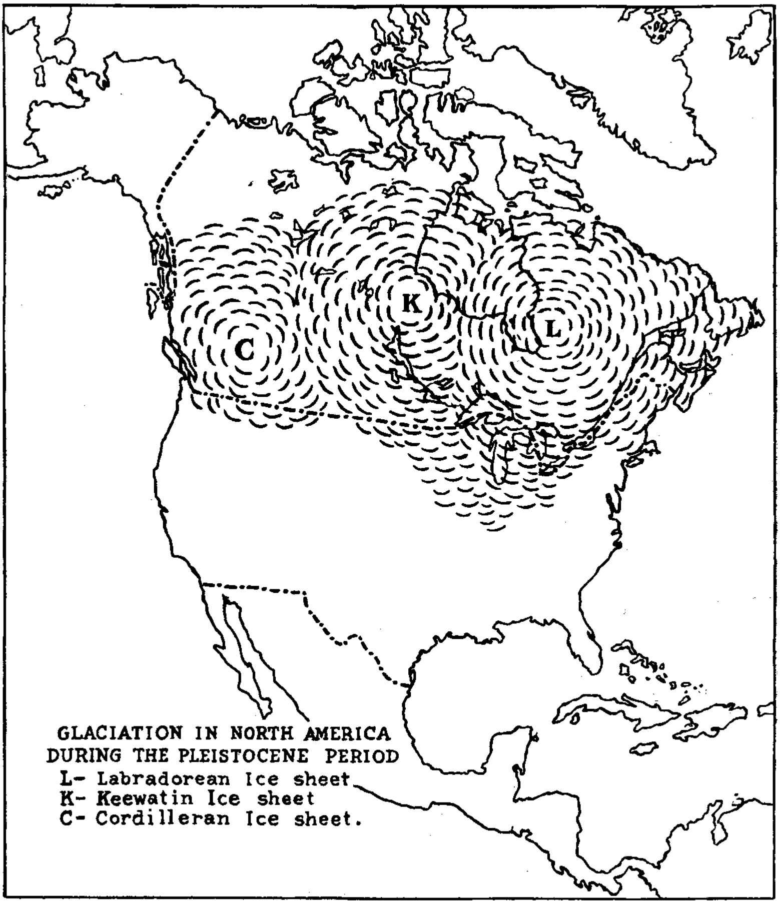
FOR more than half a century geologists and mining engineers have debated the possibility of discovering diamond deposits in Canada.

Interest and curiosity in this question have been aroused by recent claims that gem diamonds have indeed been found in this country ; and in July, 1948, the " Gemmologist " published an account of a proposed expedition into Canada's northlands to be made by international geologists in search of a deposit of diamond-bearing rock.

That the alluvial diamonds found in the northern United States occurred in glacial drift carried thence from Canada has been conclusively established. So, before dealing with the question of Canadian diamonds *in situ,* let us consider the great continental glaciers which, radiating from three main centres in Canada during the Pleistocene epoch, deposited the debris in which the diamonds were found.

Many of us think of the Pleistocene epoch as a period of continuous glaciation and refer to it as the great " Ice Age." There were, however, several other important glaciations in the earth's history, the greatest of which took place in the Permo-Carboniferous period. Moreover, during the Pleistocene, there was not one but a series of glaciations—sometimes separated by long spells of warmth during which the climates of certain sections of Canada was more temperate than it is to-day.

At least four million square miles of North America were covered with glaciers during the Pleistocene epoch ; and the accumulation of ice and snow was so great that, in certain areas, its weight created depressions hundreds of feet in depth. Geologists estimate that some glaciers, at least, were two miles or more in



GLACIATION IN NORTH AMERICA
DURING THE PLEISTOCENE PERIOD
L– Labradorean Ice sheet
K– Keewatin Ice sheet
C– Cordilleran Ice sheet.

thickness ; and one has only to glance at a photograph of Greenland, as it is to-day, in order to get a realistic picture (on a lesser scale) of the topography of Canada during the Ice Age.

The glaciers of North America were developed by the precipitation of enormous quantities of snow over a large section of Canada ; but what caused the accumulation is not yet fully understood. Geologists are generally agreed, however, that not one but many circumstances were responsible, the most important of which was increased altitude ; for the epoch that immediately preceded the Pleistocene was one of uplift in many areas of North America.

As in the case of the Greenland ice-cap of modern times, the continental glaciers of Canada radiated in all directions from a centre of glaciation. There were three such centres during the Pleistocene, and these have been named the Keewatin (K), Labradorean (L), and Cordilleran (C), according to their geographical position (see map).

A fourth centre existed at one time in what is now the Patricia district of Ontario ; but with the advance of the Keewatin and Labradorean ice sheets, the centre was overwhelmed and obliterated.

The Keewatin ice sheet is estimated to have been well over a mile in thickness, with its centre just west of Hudson Bay. Its south-eastern flow joined the Labradorean sheet and extended far into the United States. The south-western border of the Keevatin ice sheet corresponded to what is now the valley of the Missouri River.

The Labradorean ice sheet had its centre just west of James Bay—to the south-east of Hudson Bay—in Ungava territory, Province of Quebec. From this centre it radiated outwards in all directions, extending southward into the United States as far as the city of St. Louis, Missouri. In some areas, the glaciers of the Labradorean ice sheet over-rode mountain peaks upwards of two miles in height ; and are themselves estimated to have been over two miles in thickness—at their centre.

The Cordilleran sheet had its centre in the Rocky Mountain region, from which it extended in all directions. But since it deposited none of the moraines in which diamonds have been found, the Cordilleran glaciers are of little interest to the gemmologist.

Because of the great thickness of the Pleistocene glaciers, many persons mistakenly entertain the belief that they were responsible for the removal of thousands of feet of solid rock from the Canadian Shield.

It is true, of course, that volcanoes and mountains, possibly two or three miles in height, at one time occupied parts of Canada which are now entirely mountainless ; but is a grave misconception to believe that these mountains were destroyed wholly by glacial action. For, while glaciers will most certainly erode rock faster than weather and running water, these subtle agents of destruction were at work for a vastly greater length of time ; and geologists now agree that the mountains of the Canadian Shield were eroded away long before the Pleistocene, and that not more than a few tens of feet of solid rock were removed by glacial action.

Altogether, there were four recognized glaciations during the Pleistocene, each interspersed by periods of glacial recession during which parts of Canada were much warmer than they are at the present time.

During the interglacial stages of warmth, all glaciers (except the alpine glaciers in the mountains of the Cordilleran region of Western Canada) seem to have completely melted away. Evidence of this is to be seen in many parts of the Dominion, especially in the Don Valley and at Scarborough Cliffs, near the city of Toronto, Ontario.

This evidence is in the form of *till sheets* (composed of unstratified rock-flour and boulders), variously weathered and eroded, and with layers of sediments of intermediate deposition lying between them. In each case the sedimentary layer represents an interglacial period.

Some geologists who have made a special study of glaciation in North America believe that we are even now living in an interglacial stage ; for only about twenty-five thousand years (a period roughly one-eighth as long as some of the interglacial stages in the Pleistocene) have elapsed since the disappearance of the last of the continental glaciers from Canada. The question is, of course, beyond the scope of this article, but it is an interesting one.

The glaciers of the Labradorean and Keewatin ice sheets pushed great quantities of mud, sand, gravel, boulders, etc., of every size and shape, ahead of them as they advanced across the land, in south-westerly and south-easterly directions, respectively.

Thus armed, the destructive force of the glaciers increased ; for, frozen into the lower surface of the ice, the gravels, sands, and muds first ground, then polished the subjacent solid rock, and there are even yet many examples of a beautiful red jasper with almost a mirror polish still to be seen in parts of the Canadian Shield.

The softer rocks over which the glaciers passed were deeply grooved and scratched, the depth of the markings being in some measure an indication of the hardness of the rocks bearing the marks. Thus the ice-embedded stones left for us a well-marked trail to show the course of the glaciers that bore them far from the place of their origin.

Many of the stones embedded in the ice sheets were completely worn out ; others only partially so, or not at all. Many that survived the ordeal show numerous striae, often running in several directions across the stone, and indicating that its position in the ice was changed several times during its hazardous journey across the land.

The accumulations of debris carried by continental glaciers and deposited during the retreat of the ice (or otherwise) are known as moraines. Some of these deposits are of special topographical form and bear special names ; but these are of interest only to the geologist. It is sufficient to state here that many moraines deposited by the Labradorean and Keewatin glaciers exist in both Canada and the United States, especially in southern Ontario and in the State of Wisconsin, and it is in these moraines that diamonds have been found. . . .

The first official notice of the finding of a diamond in the United States was given by the late Dr. George Frederick Kunz(1). The diamond in question was uncovered at a depth of sixty feet by a well-digger in Eagle, Waukesha County, Wisconsin. The crystal was yellowish-white in colour, and weighed about 15 carats. The year was 1876.

Commenting on the nature of the gravel among which the diamond was found, Dr. Kunz wrote: " Having carefully examined a quantity . . . I have failed to find anything but the regular debris of glacial drift."

According to the late Professor William Herbert Hobbs, of the University of Wisconsin,(2) the woman on whose property the diamond was discovered kept the Eagle crystal for seven years as a curio, after which (not knowing it to be in fact a diamond) she sold it to a Milwaukee jeweller for a dollar.

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(1) Kunz, in " Mineral Resources of the United States," 1883-84.

(2) Hobbs, in " Journal of Geology," May-June, 1899.

Later, when the identity of the crystal was established and the find made public, the woman offered to buy it back for a dollar and ten cents, and when her offer was refused she brought a suit against the jeweller for the full value of the gem.

In due course, the case was decided by the Supreme Court of the State of Wisconsin—in favour of the jeweller ; inasmuch as he was judged by the Court to have been as ignorant of the identity and value of the stone (when he made the purchase) as was the woman in whose well it had been found. (Obviously this jeweller lived in the Gemagnostian epoch—before the establishment of the Gemmological Association of Great Britain and the Gemological Institute of America.

Eventually, the Eagle diamond was purchased by the jewellery firm of Tiffany's Incorporated, New York City, and it is presumably still held in the Tiffany gem collection.

In 1886, a similar but larger Wisconsin diamond, weighing slightly more than 21 carats, was uncovered near Kohlsville by a farmer while ploughing his field.

During the next three years (1887-89), no fewer than ten small alluvial stones—weighing from 50 to 200 points each—(as well as a number of microscopic crystals) were found by gold prospectors in the gravel of Plum Creek, Wisconsin. These diamonds ranged in colour from yellowish-white through colourless to pale bluish-white.

No further finds of diamonds were reported in the State of Wisconsin until 1893, when two stones were picked up about twelve miles south of the city of Madison, and near Burlington, respectively. The former was a white stone of 4 carats in weight, but no description of the Burlington diamond is now available.

Three years later (in 1896), a 6½ carats white diamond was found in the possession of a German-American farmer living in Saukville, Wisconsin. It should be mentioned, however, that this stone had been in the farmer's possession for fifteen or sixteen years, making the year 1880 the probable date of the find.

Diamonds of gem size and quality have also been found in the States of Michigan and Ohio. In 1894, an 11-carat crystal was picked up in glacial drift near Dowagiac, Michigan, and another stone (colour and weight not given) was found at Milford, near the city of Cincinnati, Ohio. The Milford diamond is the last discovery mentioned by Professor Hobbs.

Said he: " No less than seventeen identified diamonds, varying in weight from ½ to 21 carats, have been discovered in the region of the Great Lakes of North America. That a considerable number of others have been found, which have not been reported because they have escaped identification, hardly admits of reasonable doubt, when it is borne in mind that three (3) of the stones found (including the two of largest size) remained in the hands of the farming population, without their nature being discovered, for periods of eight and a half, seven, and over fifteen years, respectively. If it were possible to visit all the houses of the lake region, I have no doubt that many diamonds would be discovered in the little collections of pebbles and local curios which accumulate on the shelves of country farmhouses."

All the diamonds described above were found in glacial drifts, except those found in the gravel of Plum Creek, which is very close to glacial deposits. The area in which the crystals were found measures about 600 miles in length and about one-third of that distance in breadth, with the geographical centre at Milwaukee, Wisconsin. In each case the diamonds were found in or near to glacial moraines composed, at least in part, of rocks and stones peculiar to the districts in Canada north of the Great Lakes.

Their exact place of origin is, however, uncertain ; but geologists are generally agreed that the diamonds of Wisconsin came from an unlocated Canadian source. Glacial moraines very similar to the ones found in Wisconsin occur in many parts of Ontario, but they have not yet been examined for diamonds.

The late Dr. Andrew C. Lawson, of the Geological Survey of Canada, suggested that diamonds *in situ* may occur in the Rainy Lake region of Ontaria. Commenting on this district, he said:

" The occurrence of bosses of serpentine suggests the possibility of diamonds, and some enterprising prospector may yet be rewarded for a close examination of the vicinity of the serpentine rocks . . . or of others that may be discovered, particularly if they be found near the cargonaceous schists that sometimes occur in the Keewatin."(3)

Dr. Lawson goes on to say that at several points in the Keewatin rocks he found evidence of extinct volcanoes, several of which were of immense size.

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(3) Lawson, in " G.S.C. Report," 1887.

Carbon-bearing slates are of widespread occurrence in the Keewatin, and on the north shore of Lake Superior, at Thunder Cape, there is a thickness of at least 1,000 feet of carbonaceous slate traversed by dykes of diorite.

In 1900, a writer for the Ontario Bureau of Mines commented on the Thunder Cape area as follows:

" In conditions like these, where carbonaceous slates have been subjected to the influence of molten rock in the form of dykes and sills under great pressure, I think one ought to look for diamonds and expect to find them. The likelihood is not less in a large dyke in a volcano neck, if one of the theories of the origin of diamonds is true ; and we have been treated to too many surprises by new discoveries within the last ten years in Ontario to be deterred or dismayed by the man who says a diamond has never yet been found in a dyke or a sill in a formation of carbonaceous slate. But there are numerous other localities in northern Ontario besides the region of Thunder Cape where in like circumstances diamonds might possibly occur. I mention only one, the township of Balfour, near Sudbury, where a vein of anthracite carbon was discovered four years ago in a formation of fissile slate. Analyses made by Dr. Ellis showed the vein matter to give 7.42 per cent. of fixed carbon and the slate 6.8 per cent. Samples of slate from the same origin, recently analyzed, gave as high as 13 per cent. of carbon."

The actual existence of Canadian diamonds has not yet been definitely confirmed. Canadian geologists are apparently more interested in the search for metals and radioactive minerals. Years ago, microscopic diamond crystals were believed to have been discovered in the massive chromite of Black Lake, Megantic County, Quebec, and in the chromite of Reaume township, north of Porcupine, Ontario ; but in both instances the discoveries still lack official confirmation.

The same is true of the microscopic diamond crystals reported to occur in scattered groups and minute veinlets in connection with chromite and chrompicotite occurring in dunite in the Clinton and Similkameen mining divisions of British Columbia.

In 1948, several reports came out of northern Manitoba and Saskatchewan to the effect that diamonds had been discovered there ; but these, likewise, have never been confirmed.

The Saskatchewan " find " was reported as follows: —

" Saskatchewan may shortly be looked upon as a second South Africa if five diamonds, recently discovered in a wall of blue clay within 100 miles of Flin Flon, prove genuine. A northern prospector, John J. Johnson, has made application to the Department of Natural Resources for ' exclusive prospecting rights for diamonds ' in the province. He claims he has found five diamonds, one as big as a marble. He said a jeweller valued the rough stone at about 300 dollars.

" The Government is giving serious consideration to his request. W. J. Buchan, Director of Mineral Resources, points out that if the diamonds are genuine, it will mark the first time in Canada's history that these valuable stones have been found in this country. They were discovered in ' Kimberlite,' a blue stone in which diamonds are usually located."(4)

Since the above report was published, the writer has made extensive enquiries into the truth of the alleged find of diamonds in Saskatchewan. Here is what was learned:

The government of Saskatchewan drew up an agreement offering the prospector a tax-free concession of 300 acres, with the diamond deposits at the centre, providing that he could show them *one* diamond *in situ*. He refused the offer. If he were sane (and in the opinion of many he was not), this would seem to be too good an offer to refuse.

With regard to the report printed in the " Gemmologist," July, 1948, and based upon an article published in the London " Sunday Express," the Government of Canada has no information whatever relative to the " group of international geologists " who were supposed to be planning a trek into Canada's north country in search of diamonds.

The possibility of diamonds " somewhere east of James Bay " has long been discussed, however, and while the Canadian Government has taken no action as yet, the writer has been officially informed that something may be undertaken within the next two years.

What the results of such an investigation will be, no one can say. Are there diamonds in Canada? Many Canadians would like to find the answer to that question.

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(4) " Trader and Canadian Jeweller," July, 1948.

PUBLICATIONS

The reappearance of " Gemstones," by Dr. G. F. Herbert Smith, is an event which has been eagerly anticipated for some time. Important additions and revisions have been made to the new tenth edition, which further strengthen its position as the most comprehensive and scholarly text-book on the subject—at least in the English language. Most striking is the chapter on crystallography, which has been expanded until, in the author's own words, it almost constitutes a treatise on crystal morphology. The section on organic products now includes ivory (animal and vegetable), bone, tortoiseshell, and in addition to amber, many other resins, both natural and synthetic. Extended treatment has been given to the subjects of synthetic emerald and absorption spectra. The new gemstones, brazilianite and synthetic rutile, are mentioned for the first time, as well as the interesting mineral, zincite. Several pages on the precious metals are added, but somewhat surprisingly no tests of identification or crude assay are given. Also little mention is made of the value and use of the microscope as a gem-testing instrument.

If any further criticism can be made, it is that while much space and time have been devoted to the external form of crystals, their internal architecture has been largely neglected. This is perhaps regrettable, as the properties of gemstones are best understood in the light of their atomic structure. Nevertheless, the field covered is astonishingly wide, extending from the analytical geometry of ellipsoids on the one side to the subtleties of classical translation on the other. Within, lie most of the important facts of some eighty or ninety gemstones and gem materials—their geography and composition, physical properties and identification, their origin and fashioning, history and romance, their counterfeits and trade significance. In this diversity of aspect—a reflection of its author's rare intellectual stature—is to be found the appeal of " Gemstones " to all whose interest in the subject is more than superficial. It is, of course, the indispensable companion to all serious students, particularly those proceeding to F.G.A. standard and beyond.

M. D. S. L.

Gemstones: G. F. Herbert Smith, Methuen & Co., Ltd., London, 1949, 10th edition (revised), XIX + 537 pp., 4 plates in colour, 40 in monotone, 145 text-figs., 35/-.

ASSOCIATION NOTICES

1949-1950 COURSES IN GEMMOLOGY

The 1949-1950 Classes and Courses in Gemmology will commence in September, 1949. Classes will be conducted at the following centres in Great Britain:—

London.—Chelsea Polytechnic, S.W.3.
Edinburgh.—Heriot-Watt College.
Glasgow.—Stow College of Engineering.
Birmingham.—Jewellers' and Silversmiths' School.
Plymouth.—Plymouth Technical Institute.

The Association's Correspondence Courses (Preliminary and Diploma) will be conducted on the usual world-wide basis.

Information about the Courses may be obtained from the Secretary of the Association. Inquiries regarding Classes should be made direct to the schools concerned.

GEMMOLOGICAL EXHIBITION

The 1949 Gemmological Exhibition will be held at Goldsmiths' Hall, Foster Lane, London, E.C.2 (by kind permission of the Wardens), on Tuesday, Wednesday, Thursday and Friday, October 4th to 7th, from 2 p.m. until 8 p.m. each day. Admission will be by ticket, for which application should be made after 15th August.

TALKS BY FELLOWS

B. W. Anderson: " Gemstones." Brighton and Hove Branch of the National Association of Goldsmiths, April 11th.

R. Webster: " Gems of the Sea " (Pearls and Coral). Central Y.M.C.A. ; assisted by T. H. Bevis-Smith, March 26th.

K. Parkinson: " Testing Gems for Identification and Genuineness." B.H.I. demonstration talk, Estate Exchange, Manchester, April 19.

Mrs. G. I. Parry: " Precious Stones." Inner Wheel, Cardiff, May 9th.

E. H. Rutland: " Gemstones—their origin and uses." Artworkers' Guild, 6, Queen Square, W.C.2., June 10th. (Also the " Cutting and Polishing of Stones," by Mr. Bull-Diamond to the Guild on the same day.)

G. A. Blythe: " Gemstones." Southend Toc H., June 7th.

MEMBERS' MEETINGS

The Association is indebted to Sir James Walton, K.C.V.O., for an extremely interesting talk on the " Structure of Quartz," which was given at the Medical Society of London's Hall on Thursday, April 21st, 1949. Subsequently Sir James presented to the Association the models that he had used to illustrate his talk.

On Saturday, May 14th, the Association's Vice-Chairman, Dr. G. F. Claringbull, showed a party of members some interesting features of the mineral department of the British Museum (Natural History).

MEMBERSHIP

The following were elected to membership on May 4th, 1949:—

Fellow:
  M. B. Wade, London.

Ordinary Members:
  C. H. Bond, Virginia, U.S.A.
  A. R. Harid, Colombo, Ceylon.

Probationary:
  J. Best, Hereford.
  M. J. C. Brocklehurst, Chorley Wood.
  M. L. Butterfield, Leeds.
  R. F. Cassidy, Worcester.
  Miss M. Hutchings, Perth, W. Australia.
  D. B. Mackay, Glasgow.
  L. Penn, Birmingham.
  V. S. Talbot, London.
  D. F. Byrne, Chessington.
  J. E. Campion, Plymouth.
  C. Robson, Manchester.

GIFTS TO ASSOCIATION

The Council of the Association is indebted to T. Harding, 22, Gt. Pulteney Street, London, W.1., Messrs. Drewell & Bradshaw, Ltd., 25, Hatton Garden, London, E.C.1, for gifts of gemstones, and to Sir James Walton for a gift of models of quartz crystal structure.

AMERICA

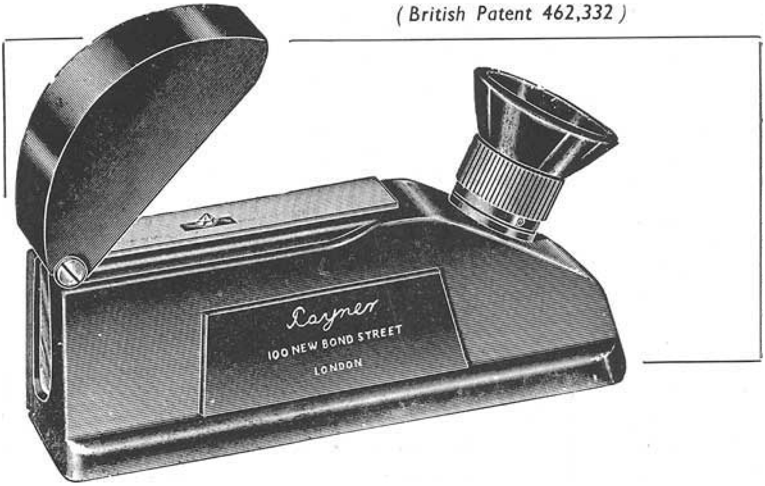
At a meeting of the Board of Governors of the Gemological Institute of America in April, Edward H. Kraus, Dean Emeritus of the College of Literature, Science and the Arts of the University of Michigan, was elected for his fourth term as President of the Institute. At the same time, Fred J. Cannon, Vice-President of Koke-Slaudt & Co., Los Angeles, who served previously as a member of the Operating Committee, was elected Secretary-Treasurer of the G.I.A. to succeed C. I. Josephson, Certified Gemologist, of Moline, Illinois. Robert M. Shipley continues as Director of the Institute, which is located in Los Angeles, California, with Eastern Headquarters in New York City.

Elected to the Chairmanship of the Board for the second term was Paul H. Juergens, Certified Gemologist, Juergens & Andersen, Chicago. J. Lovell Baker, Certified Gemologist, J Henry Birks & Sons, Ltd., Montreal, will again serve as Vice-Chairman of the Board.

Members of the Board of Governors of the Gemological Institute of America are elected from the Sustaining Members of the Institute, numbering 89 at the present time. In a broadening programme to parallel the widely increasing demand for gemmological knowledge among jewellers and their customers, and in order to increase the number of eligibles from whom such officers may be elected, thus giving greater representation among progressive jewellers of the country, the Board voted to increase its Sustaining Membership by approximately 50 each year in the future.

PRESIDENT HONOURED

Dr. G. F. Herbert Smith, President of the Association, has been awarded the C.B.E. in the June, 1949, Honours List. It is a well-merited recognition of his services in connection with the preservation of the flora and fauna of the British Isles. Dr. Herbert Smith has for many years been Honorary Secretary of the Society for the Promotion of Nature Reserves as well as maintaining an active interest in the Gemmological Association, of which he was made President in 1942.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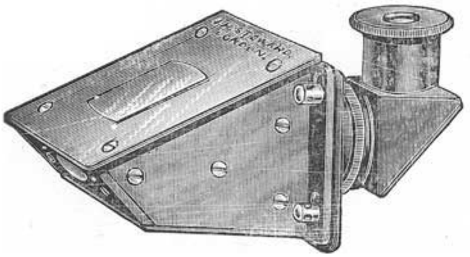
J. H. STEWARD, LONDON.

Vol. II
No. 3
July, 1949

CONTENTS

ASSOCIATION NOTICES :—

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