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IDENTIFICATION OF DIAMONDS BY THEIR FLUORESCENCE

by W. F. COTTY

FLUORESCENCE is a property of diamonds which has been studied scientifically by a number of research workers but, so far, it has received little attention from the diamond trade itself. This is rather surprising, because fluorescence offers the dealer an invaluable tool for identifying his diamonds, especially if the stones in question have a distinctive colour of fluorescence. If he knew the fluorescent properties of his stones he could, at any time, recognize them instantly, or conversely he would be warned immediately of the loss of any of them.

Experiments have shown that the majority of gem diamonds fluoresce to some degree under the rays from an ultra-violet lamp fitted with a Wood's filter. The apparatus required to view this phenomenon is a specially prepared black box in which the ultra-violet lamp is mounted. (Such equipment is available commercially for the outlay of a few pounds.) In general, diamonds fluoresce in many colours, notably blue, green and yellow, while those of white and bright yellow are sometimes found. On the other hand, there are diamonds which do not fluoresce at all and are almost invisible in ultra-violet light. As a matter of interest to the scientifically minded readers, diamonds which fluoresce belong to the group which scientists call Type I, while the rare Type II specimens are found among the non-fluorescent diamonds.

From the results of the academic work done in laboratories we know that fluorescence in diamonds is due to the internal structure of the crystal. In the author's experience 80–90% of all gem diamonds show some sort of fluorescence, and, because this property depends on the crystal's structure, many shades of the different fluorescent colours can be distinguished.

If, for example, we took a parcel of rough and uncut melee (Fig. 1) and sorted it in the normal way into, say, two qualities of good colour and a lot of yellow stones, he would be a clever man indeed who could select a number of diamonds from each group, then return them to their original groups and later pick out the same diamonds with any degree of accuracy. If, instead of the rough melee, we used well matched cut stones the task would be infinitely more difficult. Therefore, we may say that by using ordinary methods we reach the limit of identification for any diamond after we have recorded its physical properties of shape, quality, colour and weight. And any of these, except the colour, may be changed subsequently by cutting and polishing.

Now if we examined the same parcel under ultra-violet light (Fig. 2) an entirely new field is open to us. Since the fluorescence is determined by the internal structure of the diamond and as no two individual diamonds—as distinct from pieces of the same stone —have an identical number of chemical impurities or lattice defects, what may appear to be a perfectly matched pair of diamonds in ordinary light, may well show very different fluorescent characteristics. It needs but little practice to grade a parcel of diamonds into the three common fluorescent colours of blue, green and yellow, and, as one gains experience, to subdivide each of these colours into three shades, say, pale, medium and bright. This gives us a choice of nine fluorescent colours. If we took a photograph in colour of the diamonds fluorescing we would have a permanent record of them. Add to this the stones' physical properties and we have as good an identity card as one is likely to get—a diamond passport as it were.

If necessary, we could go one step further and add the diamond's " finger prints " to its passport by including a graph of its absorption properties in the ultra-violet or infra-red regions of

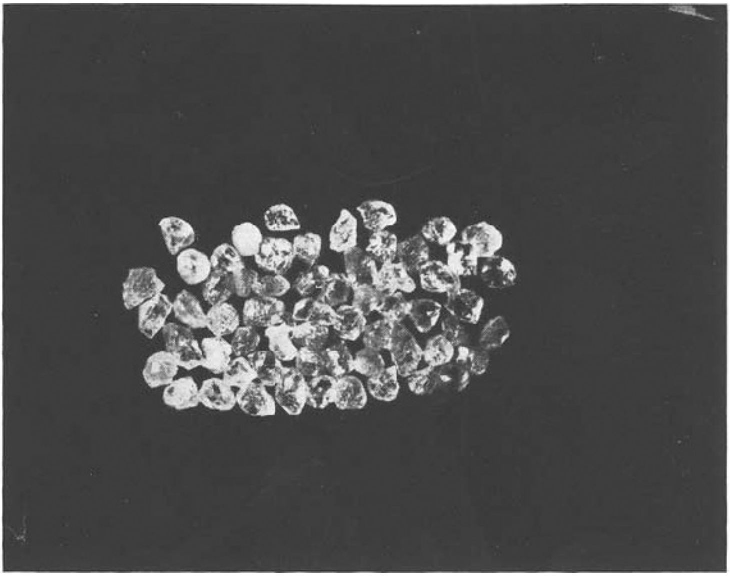

Fig. 1

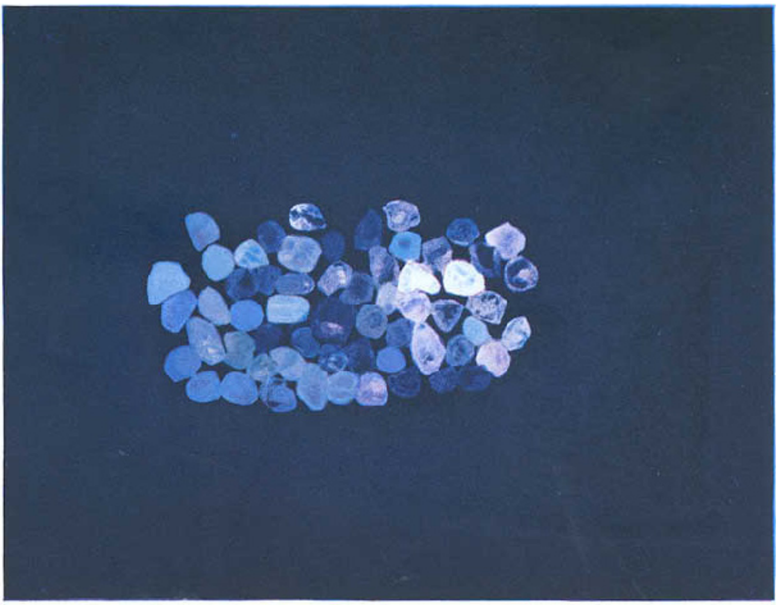

Fig. 2

the spectrum. The graph actually records the variations in the structure of the crystal so one would expect every diamond to give a different trace. Experiments have confirmed this. To illustrate the wide variations which sometimes occur we have included Fig. 3, which shows the graphs traced out in the infra-red region of the spectrum by (*a*) Type I diamond and (*b*) Type II.

In the discussion so far we have dealt only with loose diamonds, but the fluorescent method may be equally useful for identifying pieces of diamond jewellery. In all probability the diamonds in a cluster would fluoresce different colours and if the jewellery were photographed in colour while fluorescing we could record the details permanently. Should the jewellery ever get lost, identification on recovery would be helped considerably by a picture such as this. We believe that this photographic record used in conjunction with those specifications already in common use would make most pieces of diamond jewellery practically unique for purposes of identification.

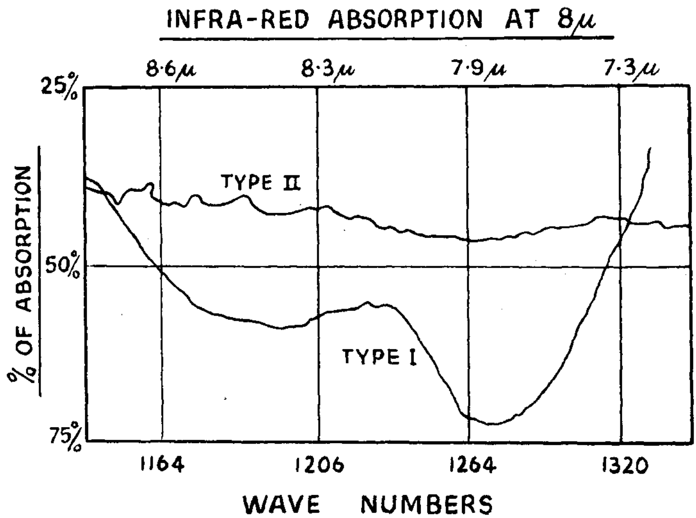

Fig. 3

EMERALD FROM HABACHTAL

by E. J. GÜBELIN, Ph.D., C.G., F.G.A.

THE emerald deposit of Habachtal, in Austria, is discussed in some detail in this paper not only because it is the only source of emeralds on the continent of Europe and among the oldest known to man but because to date practically no authoritative literature on the deposit exists in the English language. [10, 11] The initial aim of this study, however, was to discover whether the emeralds from the relatively unknown but nevertheless very interesting deposit in the Habachtal area differed by any local characteristics from emeralds from other sources.

History

The occurrence of emeralds in the Salzburg Alps was already known to the Romans who did not actually exploit the mine but found emeralds among the rocks and gravel in the Habach Valley while prospecting for ores. There is evidence that the Archbishop of Salzburg had the mine worked for emeralds, from which old Salzburg families still retain cut specimens, in the Middle Ages. But the fate of the mine was subject to frequent changes throughout the centuries ; legal as well as illegal prospectors challenged their luck ; but at no time did the " Mountain of Green Jewels," as it was called by the native mountaineers, yield its treasures generously. In a Mining Chronicle published in 1727 the emerald of Habachtal is mentioned among " ores, rocks and stones " of the Duchy of Bavaria, to which the area belonged in the 18th century. The Empress Maria Theresa owned an ink-pot, the size of a big man's fist and sculptured from a Habach emerald, which is now exhibited at the Museum of Art in Vienna. J. Frischholz[1] described the emerald deposit thoroughly in 1821. But there was no organized exploitation until a jeweller from Vienna started regular mining in 1860, yet with no profitable success. At the beginning of this century an English Company was founded which intensified the operations. Although no statistics are available, the locality is credited with having yielded good returns. In 1906 the operation was ceased ; the mine fell into decay and was not repaired until after World War I, when Austrian

Fig. 1
Col. Hans Zieger and one of his miners sorting " emerald-rock " before the entrance to the mine.
(Photo H. Zieger)

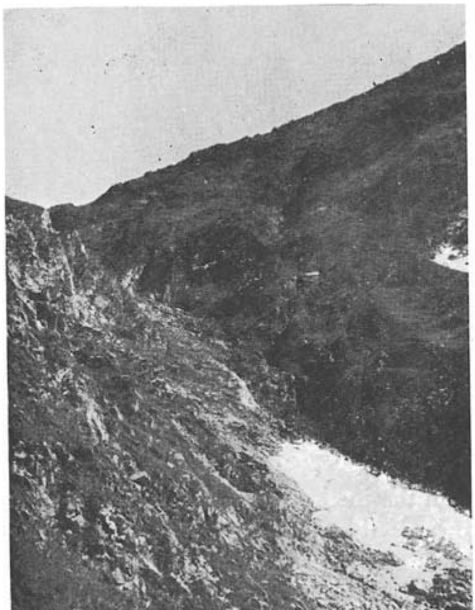

Fig. 2.
The couloir of the Legbach with the entrance to the mine in its northern slope (on the left side of the picture at an altitude of 2,100 m.).
(Photo H. Zieger)

prospectors resumed mining. In 1936, after the mine had been lying idle for many years, a Swiss company (Schaffhauser Smaragd A.G.) bought it and promoted the exploitation with great energy and generosity. A fifth gallery was driven 110 yards into the mountain. All of these five drifts lay in the emerald-bearing layers. That period is said to be one of the most prosperous —and, among others, one find was made that was valued at 20,000 gold crowns. The Nazis hindered further operations of the Swiss company but continued themselves until the mine was confiscated as German property by the Allies after World War II. It was later released as property of the Salzkammergut, the Government of which let it out on lease to an old prospector, Col. Hans Zieger, who worked the deposit on a small private basis (Fig. 1) with a few employees until his recent death. The cold and rainy summers of the last three years did not favour exploitation. One reason for the continued failures may be due to the fact that the source lies at an altitude of 2,100 m. in the inhospitable area of the Gross Venediger, where for three-quarters of each year there is severe wintry weather. Frequent rock-slides, thunderstorms, avalanches, etc., render approach and access to the mine extremely hazardous (Fig. 2), and life in the simple rest camp is most primitive. At present the deposit is worked chiefly by a few solitary prospectors who hold licences. They are adventurers who attempt to make their fortune at the price of hard labour and privation. The output is not rich, although recently a few respectably large specimens have been recovered (Nos. 1 to 5 of Table 1). Further and systematic prospecting may yield gratifying results to a company with sufficient resources and a generous licence to enable them to undertake the extensive mining necessary to investigate the occurrence.

Locality

The Habachtal—the name is a distortion of " Valley of the Hay Brook "—is the most picturesque of several valleys descending from the main ridge of the Gross Venediger in the Hohen Tauern towards the north-west. The Hay Brook (Habach) is the outlet of the Habach Glacier and one of the southern tributaries of the Salzbach, which it joins near the hamlet of Habach (a local stop of the Pinzgau train). Pinzgau itself may be reached by train from Salzburg via Zell-am-See (Fig. 3). The Habach Valley

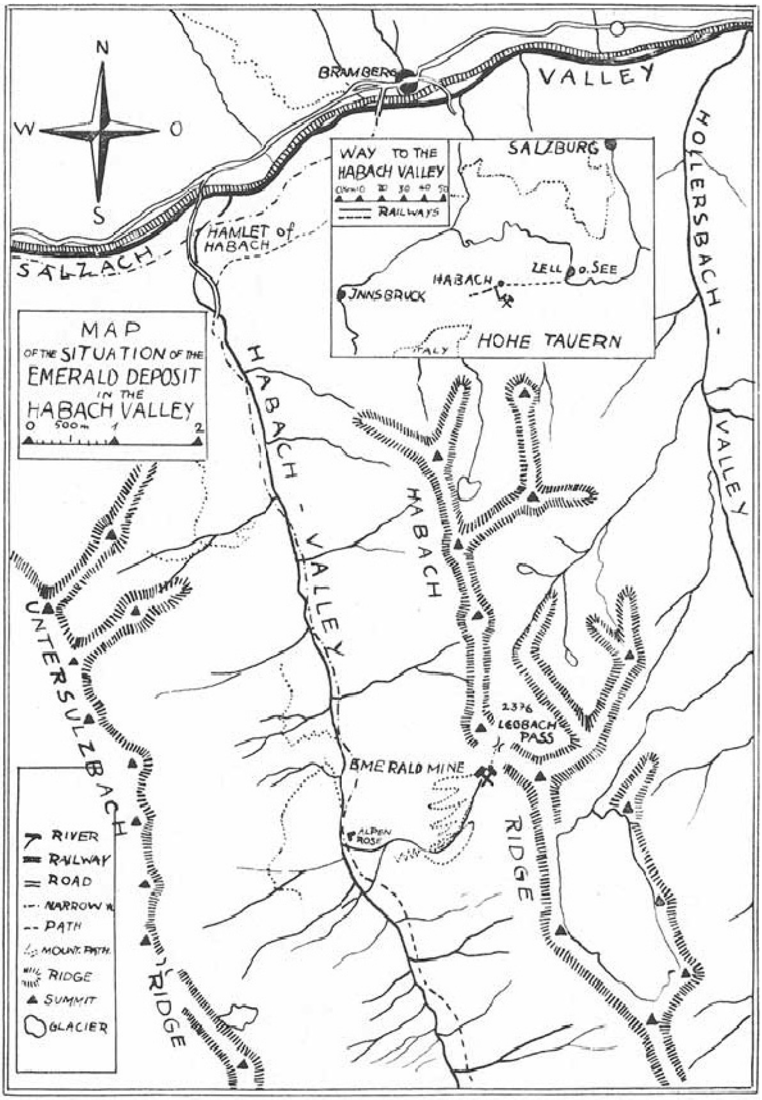

Fig. 3. Map showing the situation of the Habach Valley and the emerald deposit in the Legbach couloir. (R. Bolsche (Lit. 7).)

has the characteristic shape of a former bed of a long glacier nose. After the first ascent which leads through a narrow V-shaped gorge, cut through the rocks by the melted waters of the glacier, the valley opens, revealing a U-shaped profile, and presenting a beautiful view of the majestic scenery of the snow-capped peaks of the Hohen Tauern. After seven hours of rigorous hiking one reaches the mine which is situated on the western slope of the Habach ridge that forms the side of the Habach Valley on the east. A narrow stony pass called Legbach Scharte (2,375 m.) (Fig. 4) leads into the neighbouring valley to the east—the Höllersbachtal. The emerald deposit is situated a little below this pass in the topmost part of the Legbachrinne. (Fig. 5.)

Geology

This couloir, which is a geotechnical depression, is situated in the actual contact-zone of the two main bodies of rock forming the Hohen Tauern—the central gneiss on the northern side and the schists on the southern side. Originally this contact was an injection-contact, and the emerald deposit owes its formation to the intrusion of residual solutions from the granitic magma of the central gneiss.

The local geological conditions are such a classical example of the alteration of old neighbouring rocks by the intrusion of eruptive (igneous) rocks—so-called contact metamorphosis—that it may be instructive to give a more detailed description of this deposit.

The gneiss originated from granite which solidified from molten masses in the depths of the earth. In the course of, and through the formation of the mountains it was mauled and assumed a schistous character and thus turned into so-called gneiss. Its colour is pale grey-white and its composition of grains of quartz, feldspar and mica may be seen with the naked eye. The disintegration of this gneiss is already quite remarkable.

The amphibolite on the southern side is a schistous dark rock which, contrary to the gneiss, consists of such tiny mineral-components that even with a loupe they cannot be distinguished. Under the microscope thin sections disclose hornblende (amphibole)—the main component besides feldspar, zoisite, epidote and

Fig. 4.
Topmost part of the Legbach couloir and Legbach Pass.
(Photo R. Bölsche)

Fig. 5.
Col. H. Zieger and one of his miners before the entrance to the mine.
(Photo H. Zieger)

others. The hornblende is responsible for the dark-green hue of the amphibolite-schist. This amphibolite is a so-called crystalline schist which was re-formed in the depth of the earth's crust out of some other rocks as a result of pressure and high temperature. Later this amphibolite happened to get in contact with the molten masses, out of which the granite (gneiss) was formed through the process of cooling off and solidifying. The couloir of the Legbachrinne is one section of the zone where contact took place. Along this contact-zone the glowing hot molten mass of granite affected the amphibolite and, through the reaction of these two rocks, new rocks and minerals were formed. The contact-rocks and contact-minerals of this schist pod are of various kinds. The emerald mother-rocks and the emerald itself—being the most precious product of this contact-metamorphosis—belong to them.

One interesting species of rock is the " migmatite " (mixed rock) which clearly shows some effect of the intrusion process. It was formed by an intermixture of the molten mass of granite with the amphibolite. The migmatites form layers—dark amphibolite layers interchanging with layers of light-coloured granite. The fact that these layers are often bent and folded is evidence that during the intrusion of the granite into the amphibolite the mountains went through a phase of formation. Another most conspicuous kind of rock is a bright, white talc schist which appears above the emerald mine. This rock is soft and greasy to the touch and in many places it is interspersed with glittering specks of brass-yellow cubes of pyrite. The same pyrite inclusions may also be found interstratified in a further altered rock of this intrusion zone—the aplite, which is almost white and consists of minute grains. This is a gangue which was formed by the molten mass of granite penetrating into clefts of the adjacent rock. The most beautiful rock of this contact metamorphosis is a sort of tremolite-rock, bearing long, slender, bright dark green tremolite crystals in a white ground-mass. The serpentine rock belongs to the gabbro group and owes its formation to a metamorphosis from peridotite.

In connexion with the present study, still another altered rock of this contact zone is of eminent interest—it is the strongly schistose, dark brownish to brownish-green biotite schist which is the actual emerald-bearing bed of the whole complicated metamorphic schist pod and the mother-rock of the Habach emerald. The biotite appears in all colours from deepest black and green through brown to almost colourless transparent plates. The biotite schists often form veins within the amphiboles, yet emeralds and white translucent beryls may occur only in a few places and only within hanging aplites or where strongly dispersed with aplitic veins. The best specimens, clear and with few or no cracks, are found in the softest, talc-like parts of the biotite schist where the emerald crystals could develop undisturbed. Also in tremolite schists, talc schists, and very rarely in actinolite schists, have emeralds been found, but only in closest relationship to biotite schists.

Microscopic and chemical examination revealed that the distribution of rock, the variety of minerals, and the transportation of material during the formation of the deposit show greatest similarity to those larger and richer emerald mines in the eastern Siberian Urals. In the Habach Valley the central gneiss must have brought all the minerals. Free silica and potash must have reacted with ingredients of the melanocrate basic rock pods, MgO, FeO and CaO forming great masses of biotite schists along with tremolite, actinolite and chlorite. It is interesting to note that here in the Habach Valley below the Legbach Pass the same arrangement and succession of mixture-rocks may be observed as described by Fersmann for the emerald deposits in the region of the Tokowaya in the Urals, namely :

(*a*) Aplite (present in Ural pegmatite)

(*b*) Biotite schists

(*c*) Tremolite, actinolite and chlorite schists

(*d*) Talc.

According to Fersmann these are the rocks of the emerald series and all four of them are in close contact with each other.[3, 4, 5]

Colour

The majority of beryls (which never occur as massive pieces, but always as well-developed euhedral crystals) are green, while only a small part shows true emerald green colour. Most are pale sea-green, grey-green, and sometimes parti-coloured—white and green. White and yellowish varieties are rather rare. The green hue of well-coloured emeralds from the Habach Valley is extremely beautiful. Some jewellers consider it the finest velvety emeral green that exists. Indeed, the highly-prized green of the fine emeralds occurs more often in the Habach emeralds than i emeralds from Muzo, El Chivor, Tokowaya, Transvaal or Indi: Same as in all emeralds, the green hue is caused by an intermol cular impurity of chromium oxide, of which H. Leitmeier in h chemical analysis found ·12 per cent to be present in pale an ·16 per cent in deep green emeralds. This again substantiat the contention that the percentage of the chromium content responsible for the shade of the emerald-green hue. Howeve the greatest number of these stones are unfortunately marred b numerous inclusions, hence the appearance and value of th otherwise beautiful Habach emerald are completely impaired.

Crystallization

The local influence as exerted on the development of th crystal habit is very obvious with emeralds from this source. A varieties of beryl in this Habach deposit developed the sam habit. The emerald from the Habach Valley has poorer cryst

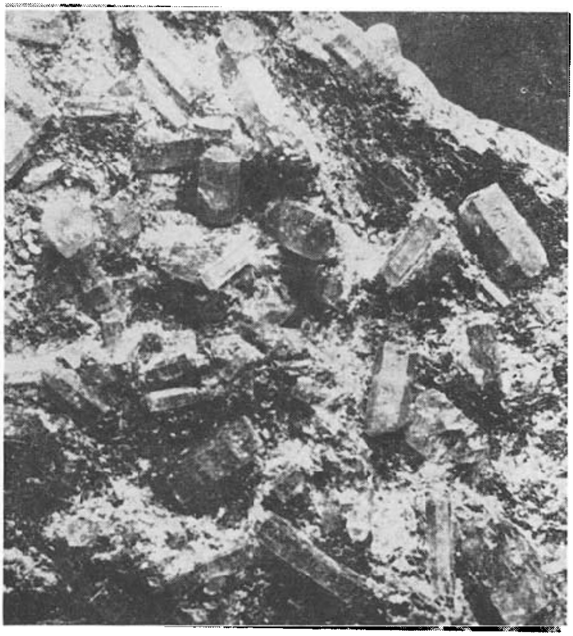

Fig. 6.
Habach emeralds i situ.
(*Photo R. Bölsche*

faces than the emeralds from all the other sources. Without exception only the prism face (1010) and the base (0001) are developed, though the latter is usually absent. In the biotite schist the emeralds lie partly parallel, and partly oblique to the schist plane (Fig. 6). In the latter case they are often developed as tablets in that two opposite prism faces dominate, although they may sometimes recede so that the crystals assume a rhombic habit.

Chemical Composition

H. Leitmeier carried out numerous analyses with abundant material, the purest of which gave the following values :

	per cent
BeO	12·28
MgO	1·82
CaO	·71
Al_2O_3, Fe_2O_3, Cr_2O_3	18·20
SiO_2	63·24
H_2O	3·03
	99·28 per cent

If when considering theories of crystal structures the calculation was based upon RO only for the value of BeO, and R_2O_3 only for Al_2O_3, the chemical analysis would concur well with the formula, which would allow one to assume that by far the majority of the other elements do not act as atomic replacements. One would obtain :

$$R_2O_3 : 3{\cdot}1\ RO : 6{\cdot}2\ SiO_2\ (1\ H_2O) = Al_2O_3.\ 3BeO{\cdot}6SiO_2 = Be_3Al_2Si_6O_{18}$$

The chemical composition, just the same as the particular geological circumstances of the deposit, offers instructive information on the formation of the emerald. Beryllium, which occurs in the composition as BeO, is a chemical element which originates from the granite ; the amphibolites do not carry any beryllium. The colour pigment chromium, present as Cr_2O_3, was offered by the serpentine rock, which as a member of the gabbro-group brought that valuable element into the process of contact metamorphosis.

Physical Properties

The determination of the specific gravity was carried out by the hydrostatic method with a semi-automatic Mettler balance with immersion of the stones in ethylenedibromide. It proved rather difficult to obtain constant density values for all the material tested, the reason for this being partly the enormous quantity of impurities which are so densely enclosed by almost all Habach emeralds. However, this variation in values should be attributed to the variation in chemical composition rather than to mere inclusions and due mainly to the impurity of ferric iron (Fe_2O_3), which forms a structural impurity by isomorphous replacement. The density was found to vary from 2·72 to 2·76 with an average value of 2·74.

All the refractive indices given were measured with an Abbé-Pulfrich refractometer and, despite small facets on the smaller stones, reliable values could be read in all directions. It was interesting to observe that dark specimens showed higher indices while the birefringence remained quite constant for all stones tested. Chromium content seems to have a greater influence on this variation than the amount of iron. The following average values may be established :

$$\omega = 1{\cdot}591 \quad \varepsilon = 1{\cdot}584 \quad \Delta = 0{\cdot}007$$

No optical anomalies were observed.

Keen gemmologists may be interested in receiving more detailed information on the findings with individual specimens (vide special Table No. 1).

The average data from Table No. 1 may be compared with indications published by other authors.

In order to reveal how individual and of what local importance these values of the Habach Emerald are, especially with a view to clearly recognizing them and distinguishing them from emeralds of other localities, the data become particularly instructive when compared with the average constants of emeralds from other sources.

The dichroic colours vary slightly according to the specimen's body colour but may generally be described as yellow-green for ω and bluish green for ε in dark stones. The dichroism is never strong.

Table No. 1

Habachtal Emerald		Refractive Indices			Specific Gravity	Dichroism	Absorption	Chelsea Filter	Fluorescence			Inclusions
		ω	ε	Δ					Stokes' Fluoroscope	U-V long 3650A	U-V short 2537A	
15·35 ct	No. 1	1·59505	1·5880	·00705	2·7470	yellowish green blue green	normal: 6830, 6800, 6620, 6460, 6370, 6300–5800	red	distinct, pale red	inert	inert	Tremolites
11·79 ct	No. 2	1·5925	1·5856	·0069	2·7395	yellowish green bluish green	normal	red	distinct, red	inert	inert	Biotite, Microlites & Secondary liquid Inclusions
10·82 ct	No. 3	1·5901	1·5831	·0070	2·7536	greenish yellow bluish green	normal	red	distinct, red	inert	inert	Tremolites
6·06 ct	No. 4	1·5922	1·5853	·0069	2·7522	yellow green bluish green	normal	red	distinct, red	inert	inert	Numerous Inclusions, parallel fine fissures
4·77 ct	No. 5	1·5970	1·5901	·0069	2·7460	yellow green bluish green	normal	red	distinct, pale red	inert	inert	Numerous Inclusions, polysynthetic layers parallel to basis
·69 ct	No. 6	1·5919	1·58466	·00724	2·7670	yellowish green bluish blue green	very strong, all lines are broad bands	red	weak, red	inert	weak, red along girdle	Tremolites
·26 ct	No. 7	1·5901	1·5831	·0070	2·7401	yellowish green bluish blue green	normal	pink	strong, red	inert	inert	All of them contain many Inclusions, especially Biotite, Fissures, Tremolites, Apatites, other Microlites and secondary Inclusions (Nos. 7–11)
·60 ct	No. 8	1·5880	1·58094	·00706	2·7309	yellowish green bluish blue green	normal	pink	strong, red	inert	inert	
·44 ct	No. 9	1·58514	1·57815	·00699	2·7203	yellowish green bluish blue green	normal	pink	strong red	strong, red	inert	
·54 ct	No. 10	1·5871	1·58002	·00708	2·7266	yellowish green bluish blue green	normal	pink	strong red	strong, red	inert	
·62 ct	No. 11	1·5892	1·5821	·0071	2·7337	yellowish green bluish blue green	normal	pink	strong red	inert	inert	

TABLE No. 2

Authors		Refractive Indices			Spec. Gravity
		ω	ε	Δ	
H. Leitmeier	No. 5	1·5819	1·5769	·005	2·703 Lit. 2
,,	No. 7	1·5790	1·5740	·005	2·704
R. Böse	No. 30	1·5907	1·5839	·00681	2·740 Lit. 9
W. F. Eppler		1·5907	1·5839	·00681	2·740 Lit. 8
R. Webster		1·591	1·584	·0068	2·740 Lit. 10
E. Gübelin		1·591	1·584	·007	2·740

The absorption spectrum appears to be normal with slight changes in the strength and width of the absorption lines and bands, and all of the following were observed :—6830, 6800, 6620, 6460 and 6370A.

Through the Chelsea Filter the Habach emeralds appear pink—a very pale pink in transmitted light but pronounced pink in reflected light.

The high iron content in the majority of the Habach emeralds acts as a strong inhibitor of fluorescence in ultra-violet light (both long and short waves). Only along the girdles of some thin slabs

TABLE No. 3

Locality	Refractive Indices			Spec. Gravity
	ω	ε	Δ	
1. Transvaal	1·595	1·585	·007	2·72 —2·78
2. Indian	1·595	1·585	·007	2·725—2·745
3. Habachtal	1·591	1·584	·007	2·72 —2·76
4. Eidsvold	1·5908	1·5838	·007	2·759
5. Siberian	1·588	1·579	·006/·007	2·72 —2·74
6. Columbian	1·584	1·569	·005/·006	2·69 —2·71
7. Brazilian	1·582	1·565	·004/·006	2·67 —2·70
8. Synthetic	1·566	1·563	·003/·004	2·645—2·665

or stones of low specific gravity can reddish fluorescence be observed. On the other hand, the fluorescence is quite distinct between the crossed filters of Stokes' Fluoroscope and varies from red for dark stones to pink for paler ones.

Inhomogeneities and Inclusions

The dense cloudiness of the interior which makes most Habach emeralds so turbid to the naked eye reveals itself to be a multitude of fascinating inclusions which are very characteristic of this locality. Cleavage parallel to the base is quite remarkable. Specimens without any cleavage cracks, or indications thereof, are quite rare. As a matter of fact this easy cleavage is perhaps the most serious drawback of Habach emeralds in that the crystals very often not only break readily under the slightest pressure (even when carefully removed from their mother-rocks), but also frequently contain a succession of numerous cleavage cracks. Open cleavage cracks, into which biotite has intruded, appear quite often. In addition, numerous fissures and fracture cracks may occur which usually traverse the crystals with striking regularity and at angles deviating from 10° to 20° from the basal plane. Together with the cleavage cracks they often form a lozenge-shaped grill pattern. As long as the crystal still lies in its mother-rock it may be observed that many of these cracks run parallel to the exfoliation of the surrounding schists.

Apart from these cleavage and fracture cracks which still persist, the stones show proof of successful healing activity during their growth, since they are often densely interspersed with healed fissures. This proves that in the course of crystal formation we may conclude that some mechanical forces must have caused fractures, and while the beryl formation continued the cracks filled with healing substance out of the mother liquor. Very often this healing liquid lacks pigment, resulting in a thin colourless layer within the otherwise green emerald. This observation may allow the assumption that the Cr_2O_3 was exhausted during the early phase of beryl formation which resulted in emerald, whereas in a later phase only colourless beryls were able to grow. These healing fissures are the cause of the numerous liquid feathers which form irregular, wavy, conchoidal planes traversing the crystals in all directions.

Fig. 7. Liquid and solid inclusions. 75 ×.

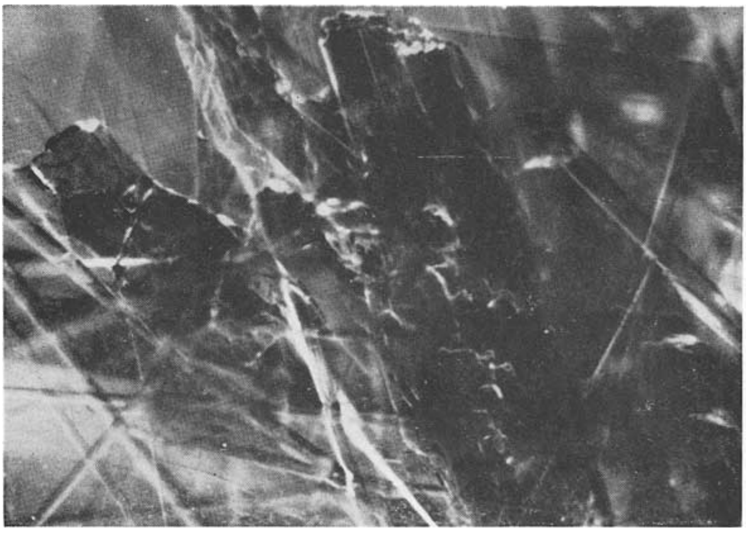

Fig. 8. Long and stout stalks of apatite enclosed among slender tremolite rods. 80 ×.

Since most of the minerals of the rocks in the " emerald series " were formed almost simultaneously we may expect to encounter most of the externally paragenetic minerals again in the internal endogenesis of the Habach emeralds. Thus we find biotite, tremolite, tourmaline, apatite, epidote, sphene and rutile in evidence (Figs. 7 and 8). Biotite is by far the most frequent mineral inclusion, often penetrating the emerald through its surface, i.e. from the mother-rock extending through the host—partly irregular and partly along cracks. Sometimes these cracks, accompanied by biotites, run parallel to the exfoliation of the former matrix through the emerald—oblique according to the relative position of the crystal in the schistose rock (Fig. 9). In many emeralds there are clusters of biotite " books " which are nothing else but tiny enclosures of the mica component of the mother-rock. Then again, biotite laminae are strewn singly throughout the crystal (Fig. 10) or filed into parallel or irregular rows. This biotite is either brown (in all shades) or completely colourless in thin leaves or, again, sometimes light to dark green in accordance with the rock in which the host emerald was formed. Also, the biotite is not always fresh and well-preserved but quite often surrounded by a brown coating of hydrate of iron oxide or strongly resorbed. Sometimes biotite seems to have disappeared so that only the residual ferrite substance may be seen. The biotite inclusions are almost always accompanied by liquid inclusions—either irregular cavities or negative crystals very often forming two-phase inclusions and frequently so tiny and so numerous as to form feathers. They are the type which is most common in beryls and they are mainly responsible for the turbid appearance—hence the mediocre quality of the Habach emeralds of the biotite schist. Very few have the deep rich green transparency so highly valued by jewellers.

The emeralds from the tremolite rocks are considerably clearer and most beautiful, although their colour may not be as fine but rather a cold bluish-green. They are, on the other hand, less frequently and less densely marred with cracks and yet they are normally teeming with thin tremolite needles (Fig. 11) or broad blades. They may either traverse the entire host crystal (Fig. 12) or end within its body with broken stumps (Fig. 13) or with euhedral heads. They are usually evenly distributed through the emerald or congregate in clusters and bundles and are not always straight but often bent (though rarely crushed) (Fig.

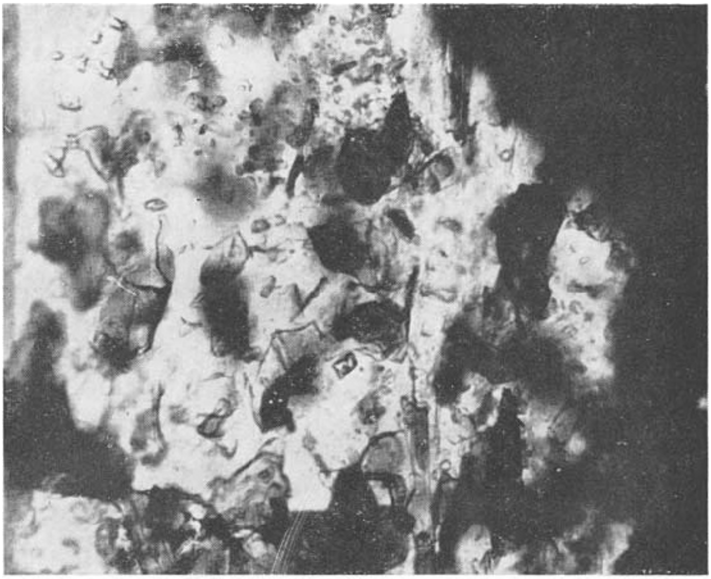

Fig. 9. Broken or resorbed biotite platelets. 75 ×.

Fig. 10. Individual flakes of biotite. 80 ×.

14). Their colour is always green but varies from pale to dark shades. The phenomenological picture of these tremolite inclusions is absolutely unique and most characteristic for Habach emeralds, particularly to the jeweller since most cut specimens originate from the tremolite rocks which produce the clearer emeralds. This type of inclusion cannot be easily confused with those in emeralds from other sources, not even with Ural emeralds although these are characterized by actinolite inclusions which admittedly show some resemblance to tremolite. Rutile inclusions are quite rare, but sometimes occur in dense masses within a single crystal. The clearest of all are the bluish emeralds from the baryte-mica rocks. They contain none of the above-described mineral inclusions and usually have very few cracks.

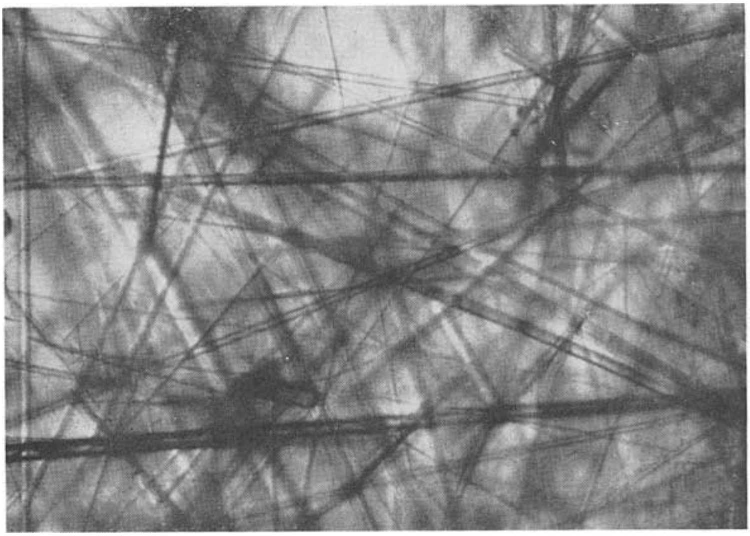

Fig. 11. Long slender needles of tremolite. 75 ×.

SUMMARY

Detailed investigation of the deposit demonstrated it to be a classical example of emerald for formation in biotite schist and revealed close relationship to the deposits in Siberia, India and Transvaal. As regards physical properties, the emerald from Habachtal ranks well with emeralds of similar occurrence and even excels by its phenomenological physiognomy of internal paragenesis.

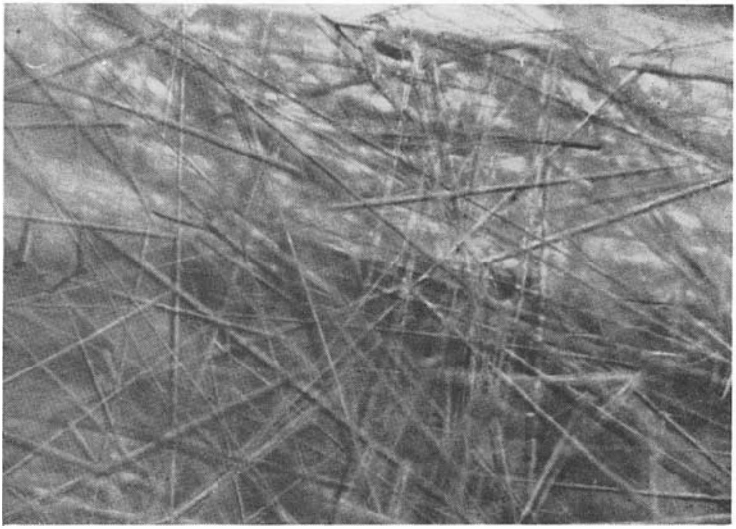

Fig. 12. Habach emerald dense with tremolite needles. 40 ×.

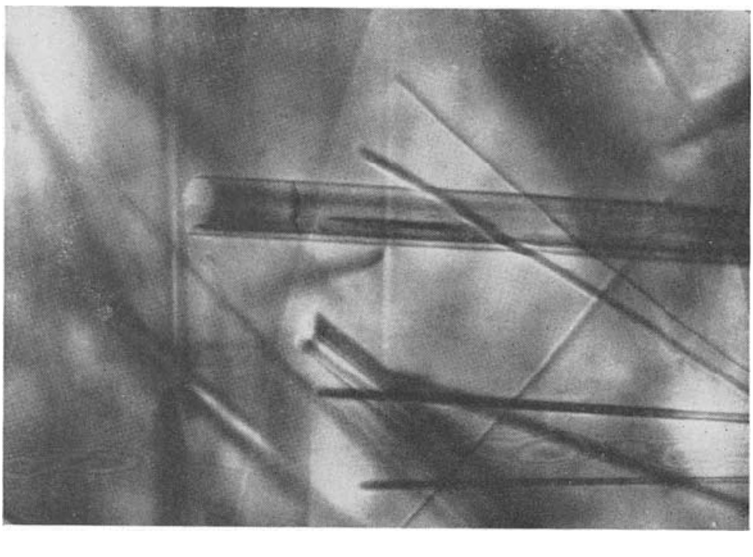

Fig. 13. Tremolite rods partly with euhedral partly with broken ends. 125 ×.

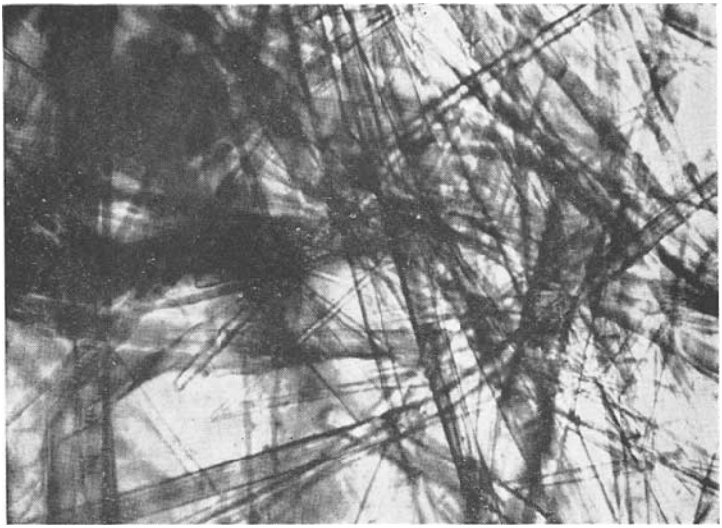

Fig. 14. Some of the tremolite needles were bent or broken as they were embedded by the growing emerald. 75 ×.

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OBSERVATIONS ON THE ORIGIN OF OPAL FIELDS

by G. F. LEECHMAN, F.G.A.

THE importance of some knowledge of geology and mineralogy to the student of gemmology is perhaps not always sufficiently appreciated. Gemmology is undeniably a particular section of the study of minerals and some knowledge of it is more than merely advisable for those who would claim to be specialists. Further, a knowledge of the foundations renders the subject of still greater interest. For instance, gem quality corundum occurs as isolated crystals in crystalline limestone, while other corundum occurs in igneous rocks. If we find this contrast rather intriguing, in order to read it up satisfactorily we should be able to realize what is implied by crystalline limestones and what by an igneous rock. Geology is an absorbing subject which, like our museums, has for too long been wrongly suspected of a musty dusty atmosphere of fossils and skeletons. The student who visits the Scottish Highlands, the Cornish cliffs or any field between them will find in fact that it is far from dull. During a recent trip into the centre of Australia the writer was deeply impressed by the advantages of following such a policy. The feeling was that, having some knowledge of the geological history and formation of each area, and some appreciation of the normal origin of the various minerals observed to be " out of their natural surroundings," some activity must have taken place in the past which had been associated with the formation of precious opal, some unusual activity which had not been thoroughly investigated, so far as was known.

The route from Adelaide was by train to Port Augusta and on to Pimba, thence to Andamooka by lorry and then back via Pimba and Kingoonya (both on the Transcontinental Railway) in a jeep to Coober Pedy ; thence by car to Alice Springs and returning by air to Adelaide. Thus we flew back over much of the country which had been traversed by road and so were able to correlate observations made on the surface with views over larger tracts of the terrain from the air.

Once a week from Pimba the lorry carrying goods and the mail and perhaps a passenger or two in the cab or on the back makes its way over the 70 miles of soft sandy cart-track to Arcoona and Andamooka sheep stations and 30 miles north to Andamooka opal fields. The road is impossible if wet. We left at 9 a.m. with three and a half tons and five passengers aboard and arrived nine hours later, just before dark—we got bogged nine times and dug ourselves out eight. The last time a jeep from Andamooka station came and pulled us out. They had been worried by our lateness and came to see where we were. During all those descents to solid ground there was ample opportunity to note that all the surface stones (gibbers they call them, with the " g " soft) were of coarse angular greyish sandstone quartzite, obviously derived from the weathering of the bare rock immediately underneath them. (This is very ancient, Cambrian or older, has almost no soil and very sparse vegetation. The erosion is almost entirely aeolian—it very seldom rains. But as we approached Andamooka opal field gibbers were partly replaced by different materials, rounded quartzites of fine grained purple sandstones, pieces of milky quartz, chalcedonic veinstones, agates, limonite and even some silicified siderite—iron carbonate. These were definitely out of place and unexpected, and the question naturally arose how did they get there and why had the agency which brought them to Andamooka not deposited them equally over the plain ? They were not artifically dumped for road making (there is none on that route) and they were too water-worn to be glacial erratics. Some explanation was called for. Another point was that driving over the very extensive peneplain extending all the way from the railway line no valleys or water courses were seen—merely slight undulations and occasional groups of sand hills which slowly creep about over the almost flat surface, driven by the prevailing winds : but a few miles south of the opal field we found ourselves close to a steep and deep dry gully, exceptionally large in view of the very limited basin it drained. At Andamooka a number of these well-developed valleys ran together to form Opal Creek. This and the one previously mentioned both run into Tea Tree Creek which leads to Lake Torrens about eight miles to the east. There is, of course, seldom any water in these creeks or indeed in the lake, which is a dry flat of saline deposits some hundred and twelve feet above sea level. Andamooka draws its drinking water from three wells sunk in the bed of the creek.

The little village has perhaps a hundred inhabitants, not including a large number of aboriginals who have a permanent camp a mile or two away. There are some fifty to sixty dwellings, some very nicely built of wood and white clay, others entirely of earth and stone. There is a wireless telephone, post office, store and school with five pupils. About twenty to thirty men are gouging regularly, but the production of opal, especially of good quality, is very low. The shafts are sunk in the hill sides down some twenty to forty feet through sandstones and thick beds of white gypsite, a mixture of sand, clay and gypsum. Thick seams of gypsum are often found, also, usually 6 to 8 inches across, filled with shining fibrous crystals of pure satin spar. Below the gypsum we usually find the opal level (although sometimes opal occurs in and through the crystals). It consists of a thick seam (12 inches to 18 inches) of siliceous mud in which are the so-called painted boulders. These are of the same material as the fine grained purple sandstone quartzite pebbles previously described, but they frequently carry precious opal either in cracks which penetrate them or as a coating perhaps $\frac{1}{8}$ inch thick which partially surrounds them. Precious opal is also occasionally found in separate nodules and in seams in the clay or even in the country rock; a great deal of useless inferior opal (potch) also occurs, as well as ferruginous veins and staining and quantities of iron hydroxides either as muds or nodules.

It seems that one should not simply accept these deposits without any thought as to how they came to accumulate there. The usual explanation is that they are derived from the decomposition by weathering of the superlatant strata. However, in those areas in which opal fields are found these upper strata are invariably sandstones from Cretaceous beds. Being sand they have already suffered very extensive weathering and decomposition and one would hardly expect them to produce large amounts of calcium sulphate, ferruginous muds or soluble silica (the sand, being a marine deposit, is obviously insoluble under surface conditions). The deposits could perhaps be fluvial, in which case they should occur in many old river beds and estuaries, or alternatively they might be derived from deep-seated hydrothermal activity.

Two miles south of Andamooka is an extensive fault, running east and west for at least ten miles. The crush zones associated with faults frequently form reservoirs or aquifers which, on pressure, supply springs and these are normally mineralized as the waters, superheated under the great pressure at depth, dissolve or carry in suspension various constituents of the rocks. Studying the creeks in the area it was noted that they each became suddenly deeper and wider approximately on the fault line. If springs were responsible the coincidence in the positions of the watercourses and their large width and scour would be explained, as also would the type of minerals found and the waterworn pebbles first noted among the typical gibbers.

We went on to Coober Pedy by jeep—it was an ancient jeep with no speedometer, which made navigation a thing of guess and gain, no oil gauge, no brakes (except switching off the engine) and particularly no springs. The distance is about 370 miles with some 6,000 corrugations to each. We went via Pimba and Kingoonya.

Coober Pedy is several degrees more primitive than Andamooka. There are only three houses or buildings and the other habitations are dug-outs which reminded me of the trenches in 1916, the year in which the field was opened. There is a post office and store, but no school. There are perhaps twenty-five miners and production is far from large. The water supply is held in a large circular concrete reservoir, the result of communal effort years ago ; it is over 100 feet in diameter and more than 10 deep and when full it is said to contain enough water to last ten years. It is covered to lessen evaporation and wire-netted to prevent kangaroos, dingoes or other livestock from getting drowned in it.

The road from the south over which we travelled is marked on the maps as " very rough and hazardous. Travellers to Alice Springs are advised to rail their cars." It runs across an endless peneplain, an extension of the Nullabor (Treeless) Plain very similar to that south of Andamooka, but of Cretaceous Age, with much loose sand, less gibbers and practically no vegetation. Approaching Coober Pedy we see two buildings, nothing else. One is the post-office with its store ; across the road is the boarding-house and its store. Here the road takes a hair-pin bend round the post office to avoid going over the cliff—and then continues on to Alice Springs. The cliff is the steep edge of the peneplain. To the east the flat

" low level " spreads out 150 miles towards Lake Eyre, which is 39 feet below sea level—the scarp between the two levels stretches roughly north and south from the junction of the Todd and Hale Rivers in 25 degrees south latitude to Lake Torrens in 31 degrees south—a distance of over 350 miles.

The scenery at Coober Pedy, typical of that all along the scarp, which parallels a major continental fault, is most impressive. Standing on the low level flats and facing north, on the left and behind is the steep slope while in front and on the right are a number of isolated conical hills and flat-topped ridges and mesas of a particular form, their sides being always of a gradient of nearly 30 degrees, similar to that of the scarp, and their height being constant at about 80 feet. Thus the individual hills are invariably strictly conical, the ridges appearing to be a sequence of such conical hills close together. These outlines are seen over many miles. They have admittedly been formerly part of the peneplain whose elevation they equal, the constant (aerial) erosion having attacked the formation from the side and driven back the talus slope while the mesas and buttes emerged.

One of these hills was particularly striking and known to the aboriginals as the " Sacred Mount," probably because they held corroborees there. It is a perfect cone, its peak pure white against the blue sky and its lower flanks a light sandy shade. At its foot on one side is a dry water course with a number of small green trees and bushes, the only ones in sight. Their roots were evidently in touch with some deep source of moisture. On its southern slope we found quantities of stone artifacts and many discarded fragments of spear heads and scrapers. It was evidently the site of an ancient armament factory. Further up specimens of jasper were found, some roughly worked—white (porcelanite), yellow (siderite silicified), brown (kidney ore), bright red (haematite) and dark purplish brown (manganese)—all of which appeared to be silicified muds. In addition there was a small seam outcrop of limonite and many crystals of gypsum—a collection sufficient to make anyone pause and ponder. Most interesting, however, was the material from which most of the artifacts were worked—a homogeneous fine-grained light grey quartzite. It gave out a pleasant musical clink, and could be flaked to a smooth fine finish with hard and sharp edges and point. What mineral was this and where did it come from ? The answer was found on the top of the hill, on the tops of the ridges and, but only in patches, on the original peneplain—large rounded water-worn and wind-eroded boulders of grey mudstone quartzite, commonly known as Grey Billy, a name probably given by the old Cornish miners to whom a " billy " or " bully " is a large smooth stone. Here and there, accumulated on the flat surface, are groups of these boulders, sometimes bound into a conglomerate by a bond of friable brown mud which is easily, and often has been, washed away by what little rain does fall. These form a siliceous capping which may partly protect the surface from pluvial erosion, but not the sides, which are exposed to the strong desert winds. Thus the escarpment is steadily cut back until here and there the outlines of more resistant masses appear. In time the cliff becomes embayed as the harder parts emerge and stand out like headlands on a sea coast. Steadily the process continues until they become peninsulars and eventually isolated conical island peaks standing apart out on the low level desert plain.

Sometimes the upper beds of the Cretaceous sandstone, the surface of the peneplain, are heavily cemented by soluble silica, forming an almost impenetrable cap-rock (but even that gets undermined over the less resistant sectors). Thus wherever the rises show patches of white gypsite, whether protected above only by grey billy boulders or by extensive indurated sandstone slabs, there the peninsulars which ultimately become outlying conical hills seem to develop. Completely unprotected from the wind they endure its attack over very long periods while in the same amount of time the slope with its talus has retreated perhaps two or three miles, sometimes more. Obviously these hills are much more resistant, better equipped to withstand erosion and an explanation must be sought which will conform with this feature. It seems that any explanation which treats the peneplain as a homogeneous formation will be unable to account for such local variations but if we suggest that concealed in it are extinct springs, their sites hardened by silicification yet marked only by a group of boulders, a scree of pebbles different from the normal gibbers, or gullies unusually large, we are able to explain the embayment of the scarp and the subsequent development of the promontories and isolated peaks. Where a line of springs marked a fault, there we might suggest a ridge or small plateau would take shape. Such an explanation seems to meet satisfactorily every question advanced.

The underground workings at Coober Pedy are similar to those at Andamooka and the typical heavy deposits of gypsum are seen, the beds of siliceous earths and the quartzite pebbles and jaspers. Ferric compounds are perhaps not so plentiful but there is more manganese. In general, the area has all the appearance of a hydro-thermal region, which has become extinct probably on account of a decrease in the rainfall.

For most of the journey to Alice Springs the countryside was much the same as it had been south of Coober Pedy—the same undulating stony tableland covered with sparse vegetation and loose iron-stained sand a few inches deep. For miles and miles there was almost nothing to be seen, not even trees. The track runs across bare open country unfenced and without a dwelling of any kind. On the run we saw only four houses in three hundred miles. However there were often hills in the far distance and we drove across a number of wadis, their beds strewn with waterworn pebbles of various kinds and stained white in places from the gypsum in the surface sand. Here and there we passed likely looking opal country marked by patches of white earth in contrast to the usual grey or reddish sand, and often in their vicinity a light covering of nodular limonite or martite spread over the hill side. Several such places were carefully noted and subsequent enquiries have verified the existence of potch or opal having been found there.

A hundred miles south of Alice Springs the country begins to get much more interesting. The wide Fincke River bed lined with splendid trees was crossed and the finger post—" a thousand miles to Darwin and 1,000 miles to Adelaide "—passed. Hills and mountains converge on the track until the scenery is awe-inspiring and beautiful. Henbury cattle station, famous for its meteorite craters, was seen, also the road out to Hermannsburg mission in the McDonald Ranges, while the great Ayers Rock lay off to the West of our route.

We were now completely out of the opal country, which is away to the East, over the great artesian basin which lies beneath the massive sandstones deposited in the inland seas of Cretaceous times. Subsequently these strata rose as an unbroken shield over

1,000 miles across. This uplift was associated with faulting, especially on the western and southern edges where the opal fields of White Cliffs, Andamooka and Coober Pedy are found. Lightning Ridge is not precisely on the edge, but some 50 miles north of it, while the Queensland fields lie in a belt down the centre of the dome as if a line of weakness were there. This faulting and consequent pressure resulted, presumably, in hydro thermal springs, which, rising towards the surface, found themselves blanketed by substantial beds of lightly consolidated sand and shales. Through this they were able to penetrate with three results. Firstly, the superheated waters would be able to enlarge their channels by removing the sandstone lining them, thus scouring out considerable cavities. Secondly, the mineralized waters would seep horizontally into the beds surrounding the springs and thus produce an enriched cemented mass. Thirdly, the siliceous waters emerging on the surface of the peneplain would, to some extent, spread out over it, depositing siliceous sinter and mineral muds and permeating the upper strata, resulting in a highly silicified indurated capping and later carving gullies in the otherwise almost level country. Such springs might flow for many centuries depositing at different times volumes of gypsum, soluble silica, ferric and similar hydroxides derived from decomposition of the deeper rocks.

In many cases, when after a long period a spring commences to recede, and while the temperature is still high at depth, intermittent ejection in the form of geysers may take place when siliceous grey mud-stones and boulders, vein-quartz fragments and various quartzites may be ejected to accumulate around the orifice. As activity decreases further the vent is likely to become choked since ejected material falls back and is cemented together into a concrete-like mass (found in the opal workings) forming an immovable plug. Under pressure, still spasmodically exerted from below, the saturated waters seek a new outlet but the sandstone above is already silicified into an impermeable capping. The waters are thus forcibly injected along the lines of least resistance, through the shaley bedding planes between the massive blocks, where further deposition will take place. The spring continues to die away, the deposits slowly consolidate, silica gel forms from the sol and in time hardens to opal in various forms, as found lying in the different levels.

This appears to be the " unusual activity " referred to earlier in these notes. Stated thus, as briefly as was possible, it will be seen to account for the phenomena observed, the minerals seen, the resistant isolated hills and ridges, the enlarged gullies and the harder masses in the cretaceous beds revealed as they emerge from the retreating scarp. The heavily cemented plug would prove extremely durable and maintain the altitude of the conical hills.

Much of the evidence available has not been included. A number of very pertinent mineral specimens were collected and many photos taken of relevant topography.

We reached " The Alice " in bright sunlight and found it really delightful. It is prosperous, well organized and attractive. The water supply is unlimited, being derived from springs beneath the well-timbered alluvial flat which the river has formed among the outstanding McDonald Ranges of ancient well-weathered and craggy rocks.

We flew back to Adelaide over some likely looking country and dry Lake Eyre, touching down at Oodnadatta. *En route* white-topped hills were noted here and there and carefully recorded, especially those with dark aureoles, presumably of ferruginous nodules. Just North of Oodnadatta one particularly favourable spot was seen. It appeared to have all the brand marks of an opaliferous area. Weeks later, back in Sydney, the writer, visiting the technical museum, saw a deeply glowing opal—from Oodnadatta.

Gemmological Abstracts

CHUDOBA (K. F.). *Zur Synthese und Bezeichnung der " Chatham" Smaragde.* (On the synthesis and name of the Chatham emeralds.) Deutsche Goldschmiedezeitung, Vol. 54, 1956, No. 2, p. 64.

D. E. Mayers has stated his opinion (Gemmologist 290, 1955) that Chatham emeralds were not synthetic, and suggested the name " cultured emerald," as they were not produced by the Verneuil process, but a hydrothermal method. Chudoba disagrees and objects to a hydrothermally produced stone being called anything but synthetic.

E.S.

SCHLOSSMACHER (K.). *Das Einschlussbild der Edelsteine.* (Picture of inclusions in gems.) Deutsche Goldschmiedezeitung, Vol. 54, 1956, No. 3, p. 106.

This article deals with the " picture of inclusions " by which the author means the appearance of the whole field of view, not just of individual inclusions. He draws a comparison between a flower (corresponding to the inclusion) and the impression of the whole garden (being the picture). Examples are Burma rubies, where the rutile needles, intersecting at 60 degrees, give a picture of the stone. Ceylon rubies and Ceylon sapphires also have rutile needles, but these present a completely different " picture," as the long, thick, straight needles are more loosely arranged. Zircon is a characteristic inclusion material in many Ceylon stones. Ceylon corundums often contain veils of liquid inclusions. These are also seen in Siam sapphires, which often contain " flying saucers," black hexagonal minerals resting on a thin, flat, round " saucer."

E.S.

STOKES (R. B.). *The Australian Opal Fields.* Mineralogist (Oregon) May, 1956, p. 231.

A brief restatement of the occurrence, mining of opal and types of opal by a mining engineer who has visited the Australian opal fields.

S.P.

Baier (E.). *Benennung und Wertung in Wissenschaft und Prax* Terminology and value in science and practice. Zeitschr d. Deutsch. Ges. f. Edelsteinkunde, No. 15, 1956, pp. 7-12.

This valuable contribution by Prof. Baier illuminates tl difficulties which arise in the " applied science " of gemmolog In scientific definitions there is no room for valuations li " precious " or " semi-precious." Gemmologists, however, mu adapt their terminology to the demand of industry and trade.

In chemistry, synthesis is the formation of a compound fro its elements or simpler compounds. It does not seem justifie therefore, to use the word " synthesis " for the preparation of crystallized material from a suitable melt. In spite of this, it h become usual in mineralogy to call a laboratory-made miner " synthetic " if it corresponds to the natural mineral in compositi and crystal structure. The gemmologist must not be blamed f following this lead, although the genetic " artificial " would ha been at least as clear.

Gemmology is trying to bridge two attitudes. On one si there are producers, manufacturers and buyers of gems with the sense of the beautiful, durable, genuine and their ideas of prop ganda, presentation and value, and on the other side the scienti whose object it is to devise a classification comprising all materi of the earth's crust, without expressing any opinion on value. It useful to illuminate these different attitudes in order to facilita fruitful discussion. W.

Wild (K. E.). *Die Anfänge der Schmucksteinschleiferei im Mittelalt* The beginnings of the gem cutting industry in medieval tim Zeitschr. d. Deutsch. Ges. f. Edelsteinkunde, No. 15, 195 pp. 12-19.

An interesting contribution to the history of gem cuttir The author reports that the first lapidary shops in the Idar-Ob stein district were mentioned in the 16th century and thus contr dicts the theory that they are of Roman origin. Bibliography 19 items. W.

Plate (W.). *Edelsteinkunde als Unterrichtsfach.* Gemmology as subject for teaching. Deutsche Goldschmiedezeitung, V 54, 1956, No. 5, pp. 209-210.

The Technical College of the Precious Metal Trade Schwäbisch Gmünd is a compulsory school for goldsmiths' a setters' apprentices. Two hours weekly are devoted to gemmology. So long as there were fewer than 12 pupils, one hour was spent on theory and one hour on the practical use of instruments. Now, with about 60-70 pupils, the weekly hour devoted to theory has been maintained, but the practical exercises are limited to two-day courses each for 12 pupils at the end of the term.

W.S.

CHUDOBA (K. F.). *Künstlich " grüne Diamanten " durch Elementarteilchen-Beschuss.* Green diamonds through atomic particle bombardment. Deutsche Goldschmiedezeitung, Vol. 54, 1956, No. 4, pp. 152-153.

A review of the present state of knowledge. Diamonds can be artificially coloured by exposing them to a bombardment of atomic particles which have been charged in a cyclotron with several million electron-volts. Diamonds coloured in this fashion show a clear demarcation line between the green outer layer and the undisturbed core, if deuterons or alpha particles are applied. The demarcation line can be observed easily when the stone is immersed in a liquid of high refractive index, for instance methylene iodide. If the diamonds are subjected to a neutron bombardment, the whole stone may be uniformly coloured green. A reliable method of differentiation between natural green and artificially coloured diamonds has not yet been established. It is relevant that the American Atomic Energy Commission stipulates that diamonds coloured in their reactors may be sold only as artificially coloured diamonds.

W.S.

ANON. *The opal deposits of Queensland to-day.* Gemmologist. Vol. XXV, Nos. 226-7, pp. 57-8 and 75-6. March-April, 1956.

A factual write-up of the appearance of the Queensland opal fields to-day by a prospector who first visited them in 1899. The writer tells of the country west of Hughenden and beyond the rail station of Winton into the opal country. Visits were paid to the Fermoy opal field, the Don field and the field at Opalton and those about the Moyne river. The opal surrounded by ironstone nodules known as " Yowah " nuts is mentioned. Gypsum is a common associate in the opal-bearing ground. Notes and anecdotes on the flora and fauna of the district enliven the article.

2 illus. R.W.

Sinkankas (J.). *Some freaks and rarities among gemstones.* Gems and Gemology. Vol. VIII, No. 8, pp. 237-241 and 254. Winter, 1955-56.

The second instalment of this article describes the transparent rhodonite from the John Reed mine at Alicante, Lake Co., Colorado. The tourmalines from Maine and California are said to suffer from spontaneous rupture and fissuring, especially in the case of the parti-coloured crystals in which the colour is parallel to the length of the crystal. Some conjectural reasons for this are expounded. A cat's-eye nephrite from the Kobuk river (Alaska) is mentioned as well as the brownish-yellow idocrase from Laurel, Quebec, Canada. A light olive-green diopside from near Richvilla, De Kalb Township, St. Lawrence Co., New York ; leucite from the Alban Hills, Italy, and the transparent datolite from Westfield, Massachusetts, and from the New Jersey Quarries are mentioned. The kyanite from Sultan Hamed, Kenya, and from Brazil, and the green kyanite crystals from Yancey Co., North Carolina, are also discussed. The article closes with a description of the co-called " Television stone," which is a fibrous massive ulexite (a monoclinic hydrous borate of sodium and calcium) found in California. It was found that when a thick section of the material was cut at right angles to the fibres, these were so straight and reflective that newsprint placed against one polished face appeared like magic on the other, even with an intervening distance of an inch of material. The fibrous mineral is ordinarily used, despite its softness (1 on Mohs's scale) for the production of cat's-eyes. It is suggested that a similar " television effect " might be possible with the gypsum satinspar found in England. R.W.

Webster (R.). *Fire pearl.* Gemmologist. Vol. XXV, No. 298, pp. 88-92, May, 1956.

Billitonites, glassy pebbles ascribed to a meteoric origin, have long been known. This article tells the story of attempts to popularize stones cut from such pebbles through the medium of sensational journalese. The physical and optical data obtained from two specimens of this material are recorded. The density was found to be 2·455 and 2·442 and the refractive index 1·51. The pebbles are round to oval in shape, of a dark greenish-black colour, and have a wrinkled exterior surface. A composition of billitonite (taken from literature) is given and the internal structure is reported as containing round bubbles typical of bottle glass. The structure is unlike moldavite. The origin is said to be problematical.

1 illus. P.B.

ANDERSON (B. W.) : PAYNE (C. J.). *The spectroscope and its applications to gemmology.* Gemmologist. Vol. XXV, Nos. 296-7-8, pp. 41-43, 61-66, 81-84. March-April-May, 1956.

The absorption spectra due to copper are discussed. Copper in the divalent state gives a blue colour, while with monovalent copper the medium coloured is most often red. The absorption spectrum of cuprite (ruby copper) shows a continuous absorption from the orange at 6300A to the ultra-violet, producing a " colour filter " passing the red only. It is suggested that the deep " copper ruby " glasses owe their colour to minute crystals of elementary copper. Cuprous copper compounds on the other hand effectively absorb the red and pass the blue and violet, e.g. copper sulphate. Azurite and malachite are said to owe their different colours to a variation in the content of hydroxyl ions. These two copper carbonate minerals are too opaque to transmit enough light for spectrum observations to be made, and by reflected light no bands have been observed. Turquoise alone exhibits bands due to copper which are of a diagnostic nature. There are three bands in turquoise, a vague band centred at 4600A, a sharper and more prominent band at 4320A, and another, which is too far into the obscurity of the violet to be visible except by photographic methods, at 4200A. The 4600 and 4320A bands are visible by scattered light and these are important as turqouise is simulated by so many natural and artificial substances. The absorption spectrum of zircon is fully discussed. The history of its first observance by Church in 1866, and Sorby's similar discovery of the bands which he inferred as due to a new element which he named *jargonium* (this he later realized was incorrect and that the lines were due to uranous oxide) is interestingly told. The absorption spectrum of zircon consists of a number of dark lines throughout the spectrum and full tables of these are given. The most important is the strong and persistent line at 6535A. In Ceylon zircons about 14 bands may be seen ; in Burma zircons as many as 41 lines have been counted in one stone. The brown crystals from Indo-China show scarcely anything but the heat-treated material derived from them, the colourless, blue and orange zircons used in jewellery, always show the 6535A line and other lines, particularly one at 6605A.

Red-coloured zircons are usually devoid of absorption lines. Low-type zircons, the type broken down by radio-activity (called metamict zircons) exhibit only a woolly band centered at 6535A. Two rare variations of the zircon spectrum are reported, both of which are metamict types of zircon. One of these shows three broad strong bands in the red and centred at 6535, 6690 and 6865A, and these three bands are present in conjunction with many other bands similar to normal type zircon spectra. The refractive index and density of one such stone was found to be 1·792-1·796 and 3·965 and the colour was a dull green. Another variation in the spectrum of a low-type zircon was shown by three cases where bands at 6550 (vague), a strong band at 5200A and another at 4560A were seen. In each of these three stones the refractive index and density was 1·82 and 3·98 respectively. No birefringence was seen. The writers then deal with spectra due to rare earths. There are three groups of rare earths, the cerium group, the terbium group and the yttrium group. The compounds of these rare earths are so similar chemically that they are difficult to separate from one another. The reason for this has been found to be due to the difference in the electronic distribution of such elements from that of the elements more commonly known. In the case of the rare earths the electronic difference from one element to the next in the series involves the " filling-up " of a deeper lying electron shell, the N shell, and not to the " filling-up " of the outer shell of electrons as is normal. To this is also due the sharpness of the absorption lines, and the fluorescence lines, in the spectrum of such elements. The wavelengths of the lines are very little affected by the host crystal as these deeper electrons are screened by the shells of outer electrons, and thus electron shifts in the N orbits are relatively undisturbed. The spectrum due to didymium is described as not being that of a single element but a combination of two elements—neodymium and praseodymium—which are always in association with each other and thus give a combined spectrum which is always referred to as the didymium spectrum. This didymium spectrum consists of a group of closely spaced fine lines in the yellow at 5975, 5855, 5825, 5772 and 5742A, with another group in the green at 5335, 5295, 5265, 5250 and 5210A. This is the absorption spectrum seen so strongly in the yellow apatite, and it is seen, albeit very weakly, in other minerals having calcium in their make-up, such as danburite, sphene, fluorspar, idocrase, calcite and scheelite. Warning is given that many Crooke's glass spectacles show a vague didymium spectrum and this should be taken into account if such spectacles are worn during the examination of the absorption spectrum of any stone. The observance of a didymium spectrum in emerald which contains an inclusion of the rare mineral parisite is noted.

8 illus. R.W.

Brose (H. W.). *Civilizations and Gems of America* (Part Two). Lapidary Journal, Vol. IX, No. 5, p. 456, December, 1955.

While the first part of this article (*Journ. Gemmology Abs.*, Vol. V, No. 5, 1956) covered the title ground more or less generally, part two deals with the particular. The author shatters the illusion —if indeed it still is an illusion—that the early American colonies were largely made up of British people. Here again a new country was being traded for beads, and the Island of Manhattan, on which New York now stands, cost the Dutch $24.00—in beads. The early story of any new country is a story of survival—agriculture, fishing, hunting, home industries, begetting children, primary education, and so on. An interest in jewellery, and therefore gemstones, is a much later trend. Ornamentation means at least some leisure—not only to create it but to wear it. Yet in a country of such virility as the U.S.A. this developed with surprising rapidity. Not much later than a hundred years after the first settlers, there were already goldsmiths and silversmiths, and the famous revolutionary leader, Paul Revere, was a first class goldsmith. This, however, was merely the eastern side of the U.S.A. Those who went west, and the trek seems to have been continual, with appalling hardships, were still confronted with the primal urges. They had to hunt for food and later grow it. The gold rush, comprising people of all nationalities and classes, was still later. Somewhere out of this medley, Mr. Brose tells us, the prospector developed, and drawing largely on his own experience the author gives us a thumb-nail sketch of many unusual characters. There was the cook, or chef, who, with two fat ponies, headed for the mountains every spring. For diversion he read geology and "polished an enormous garnet, larger than a hen's egg." There was the man who first discovered and operated a sapphire mine. There was the engineer who found a magnificent opal (one-third matrix) weighing almost ten ounces. There was the Shakespearean scholar who "hunted opals in Mexico, topaz in Texas, diamonds in Arkansas, sapphires in Montana, and beryl in Colorado." There was the man who had worked in the Chivor mines and owned an exceptionally beautiful emerald crystal. And so on and on. The gemstones of Brazil alone must be a very long story, too long to condense into a short article. Later, the author deals, almost affectionately, with the gemstones in each of the States ; not the spectacular variety of South America but those that must interest every gemmologist. Nature seems to have a strange way with gemstones. She is either prolific or she yields sparingly, almost grudgingly. We are reminded by the author that he writes of the south-west some forty-years ago though with renewed acquaintance between the years of 1948 and 1952. Prospectors are a vanishing breed. Without question they were colourful. And the author's nostalgic note is understandable. E.R.

PAYNE (C. J.). *An alexandrite crystal from Burma.* Gemmologist. Vol. XXV, No. 296, pp. 39-40. March, 1956.

The report of an alexandrite crystal which was found in the Mogok Stone Tract of Upper Burma, a locality not considered as a usual source of alexandrite. The crystallography and physical data are given. The refractive indices were found to be : for the gamma ray 1·7548, for beta 1·7484 and for alpha 1·7463 giving a birefringence of 0·0085 and biaxial positive in sign. The density proved to be 3·706 and the pleochroic colours : gamma (z) blue-green, beta (y) green and alpha (x) purple, the latter deeper in colour when viewed with artificial light and weak when in daylight. A full list of the absorption bands is given and the inclusions were found to be reminiscent of those seen in Burma ruby. 3 illus. R.W.

VERMA (R. K.) : SIRKAR (G. N.) : CHATTERJEE (S.). *An automatic Verneuil furnace.* Gemmologist. Vol. XXV, No. 296, pp. 52-56. March, 1956. Extracted from Journ. Sci. and Industrial Research (India), Vol. 13, No. 11, November, 1954.

Describes a Verneuil inverted oxy-hydrogen furnace of usual construction except for the addition of an automatic drive to control the height of the boule in the flame, and the gas and powder feeds. The apparatus was primarily designed to produce rod-type boules of various synthetic minerals, such as the tungstates of calcium and cadmium, used for the detection of nuclear radiations. Synthetic gemstone production may also be carried out on such apparatus (which is covered by patents). The gas supply is controlled by needle valves and capillary tubes, and the powder supply by a relaxation oscillator (10, 20, 30 and 40 times per minute) operating an electro-magnetic relay on the tapping hammer. The raising or lowering of the boule support is by an electric motor through reduction gearing and this is controlled by a photo-electric cell, which " sees " the luminous tip of the boule and keeps it in the hottest part of the flame.

5 illus. R.W.

MITCHELL (K.). *Some unusual inclusions.* Gemmologist, Vol. XXV, No. 297, pp. 59-60. April, 1956.

The article describes a pink synthetic spinel with " hose " type inclusions and tells of the sale of the stone as a natural pink sapphire. The note closes with the report of a dark grey scapolite cat's-eye. The refractive indices of this stone were measured as 1·548-1·568, and the density to be 2·638.

3 illus. R.W.

LEA (I.). *Further notes on " inclusions " in gemstones, etc.* Gems and Gemmology. Vol. VIII, pp. 231-236 and 254. Winter, 1955/56.

A further verbatim reprint of one of three papers written in 1869 (*see Abstracts Journ. Gemmology.* Vol. V, No. 6, p. 320). The inclusions noted and drawn by this nineteenth century worker are reported—in particular the two- and three-phase inclusions seen in emerald and quartz. The inclusions, or lack of them, observed in calcite, fluorite, apatite, the feldspars, tourmaline, cyanite, quartz, topaz, beryl, garnet, zircon, chrysoberyl, iolite, peridot, spinel, turquoise, opal, lapis lazuli, and corundum are discussed.

1 illus. R.W.

SLAWSON (C. B.) : BASTOS (F. M.). *The gemstones of Minas Gerais, Brazil.* Gems and Gemology. Vol. VIII, No. 8, pp. 227-229 and 253-254. Winter, 1955-56.

An account of the gemstone industry of the State of Minas Gerais, Brazil. Few cutters were employed prior to the second World War, but, during the hostilities, owing to the virtual closing down of the European cutting of gemstones, a cutting industry grew up in Belo Horizonte, Teofilo Ontoni and Rio, some 450 cutters being employed in these three places. The dyeing and cutting of black onyx, which was shipped north from near Soledade, Rio Grande do Sul, was mainly carried out at Belo Horizonte, but this activity practically ceased after the war ended. Refugee cutters from Europe aided this expansion, although their value was more as middlemen on the commercial side than actual cutting. After the war came the demand for strategic minerals to be found in the pegmatites and alluvials, such as industrial diamonds, rock crystal quartz, high quality sheet mica, cassiterite, scheelite and industrial beryl, and these endeavours opened up new sources of gem minerals. The Marta Roche aquamarine, weighing 74·8 lbs. was found in 1954 in alluvial diggings whilst searching for rock crystal for the electronics industry. The crystal, named after a young Brazilian woman who had obtained second place in an international beauty competition of that year, yielded 60 to 70 per cent of cuttable material of extremely good colour. The Brazilian cutting is good, but does not equal pre-war Idar-Oberstein standards. The cut is often for weight to the detriment of brilliancy. The cutting is done on laps of tin and lead solder with carborundum as an abrasive, and polishing is with tripoli on a lead coated cast iron lap. The laps are often allowed to become slightly concave resulting in the facets being to some extent convex, which is again somewhat detrimental to the make of the stone. Comparison is made of the attitude of customers in the United States and those in Brazil, the latter appreciating fine colour the better. This is specially so in the case of aquamarines. 1 table. R.W.

HEGEL (O.), SCHLOSSMACHER (K.). *Das Einschlussbild der Edeltopase.* Inclusions in precious topaz. Zeitschr. d. Deutsch. Ges. f. Edelsteinkunde, No. 14, 1955/56, pp. 12–16.

Many stones were examined and the pink variety was found to have most inclusions. E. Gübelin mentions that topaz has many liquid inclusions, frequently containing two liquids which do not mix. This was found to be so. These inclusions can be very small, can form feathers ; there are also large inclusions, irregularly bound, always flat. E.S.

GÜBELIN (E.). *Einteilung der farbigen Edelsteine nach Ursache der Farbe.* Sub-dividing coloured precious stones according to the cause of their colour. Zeitschr. d. Deutsch. Ges. f. Edelsteinkunde, No. 13, 1955, pp. 7–8.

Short survey of idiochromatic and allochromatic stones. Allochromatic stones can be subdivided into those stones where the colour is caused by a "colouring" molecule, for inst. Cr_2O_3 in Al_2O_3, and those where the colour is caused by colloidal or otherwise microscopically fine particles, which are either regularly arranged in the stones, or can be irregular or arranged in zones.

E.S.

GÜBELIN (E.). *Absorptionsspektren von Edelsteinen.* Absorption spectra of precious stones. Zeitschr. d. Deutsch. Ges. f. Edelsteinkunde, No. 13, 1955, pp. 9–13.

This table deals with the absorption spectra of (*a*) zircon, (*b*) gems coloured with Cr_2O_3, (*c*) gems coloured with iron, (*d*) caused by manganese, (*e*) caused by other pigments, (*f*) structurally caused spectra, (*g*) didymium lines, (*h*) synthetic stones and (*i*) glasses.

SCHLOSSMACHER (K.). *Die Einschluesse.* Inclusions. Zeitschr. d. Deutsch. Ges. f. Edelsteinkunde, No. 13, 1955, pp. 13–17.

A short survey covering nimeral inclusions as well as gas bubbles feathers, etc. E.S.

BOOK REVIEW

CHUDOBA (K. F.) ; GÜBELIN (E. J.). *Echt oder Synthetisch ?* Grundlagen und Methoden zur Unterscheidung natürlicher Edelsteine von synthetischen Steinen. (Genuine or synthetic ? Basic theory and methods of differentiating between natural precious stones and synthetic stones.) 156 pp., 117 illustrations, 11 tables, 1 colour plate. Rühle-Diebener Verlag K. G., Stuttgart, 1956.

The reader who expects a most valuable contribution by two top-ranking gemmologists will not be disappointed. Much has been written before on the synthetic gem-stones and their determination, but a concise compilation of facts had been missing so far. The authors have succeeded admirably in showing how a century of scientific work formed the basis of modern methods of gem-material production. The Verneuil process and hydrothermal methods are dealt with adequately. The history of diamond synthesis, given in nine pages, shows how another method has been added, namely direct transformation of one modification (graphite) into another (diamond) at high temperatures and extremely high pressure.

It may perhaps be suggested that in future editions of the book not only the names of previous workers are given, but that their papers are listed in the bibliography at the end of the book. On page 26 credit for the development of a lapis-lazuli coloured synthetic spinel is given to a Dr. Jaeger, whereas at Idar-Oberstein the synthetic is called " Grasmück lapis " after its inventor, a local dentist.

Roughly half of the book is devoted to the differentiation between genuine and synthetic stones, and all known scientific methods are described meticulously. The initiated will welcome in particular the tables listing the characteristics of genuine and synthetic stones and their behaviour when examined in different ways, for instance under filters, U.V. light, X-rays, etc. Dr. Gübelin's competence in pointing out the difference revealed in microscopic inspection of inclusions in synthetic and genuine stones is well known. His photomicrographs are a source of joy, even if reproduced in black and white. It is inherent in the method, that inclusions reveal frequently not only the genuineness of a stone, but also the locality where it comes from. An exact determination of this kind is highly satisfying. It should not be overlooked, however, that those who deal in gems are frequently in a position to see the " occurrence " at the first glance. Among the hints given, the colour of synthetic and precious stones in ordinary daylight should not be forgotten. For instance, the difference in appearance between a Burma and a Siam ruby may be due to inclusions, but iron containing feathers in Siam rubies may give them also the less desirable brownish hue which the " connoisseur " spots at once.

The authors considered natural and cultured pearls outside the scope of their book. Although the methods of determination are completely different from those relating to synthetic stones, it is to be hoped that the title of the book does not stand in the authors' way, should they feel that the book could be usefully enlarged in this direction.

The book is a most useful and enjoyable help to the gemmologist in a field which is perhaps the most important in practice.

W.S.

ASSOCIATION NOTICES

VICE-PRESIDENCY

Dr. Edward H. Kraus, President of the Gemological Institute of America and Dean Emeritus of the College of Literature, Science and the Arts of the University of Michigan, has honoured the Association by accepting the Council's invitation to become Vice-President of the Association. Recently Dr. Kraus was re-elected as President of the Gemological Institute of America for the eleventh year. Over the years he has done much to further the cause of gemmology, and is a co-author of *Gems and gem materials*, firstly with Dr. E. F. Holden, and subsequently with Dr. C. B. Slawson.

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to Mr. R. Webster for a copy of Tutton's " Crystals " and various specimens of gem material which have been polished by " tumbling."

The Council is also grateful to Dr. E. Gübelin for a copy of " Echt oder Synthetisch ? " by K. Chudoba and E. Gübelin.

GEMOLOGICAL INSTITUTE OF AMERICA

New Building

A combined dedication of its new building in the Brentwood area of Los Angeles and the 26th annual meeting of the Board of Governors made 27th February a significant day for the Gemological Institute of America.

The ceremony was held in the spacious new classrooms, with Jerome B. Wiss, Chairman of the Board, introducing H. Paul Juergens of Chicago as Master of Ceremonies. The programme took its keynote from the rededication of plaques in recognition of Beatrice and Robert M. Shipley, founders of the Institute in 1931 ; the late Godfrey Eacret, sponsor of the Institute's first laboratory facilities ; and Edward Wigglesworth, Ph.D., Director of the G.I.A. Eastern Laboratory in Boston until his death in 1945.

A crucifix carved from wood from the Mount of Olives, with a figure made from early American silver, was presented to the Institute by Mr. Loud as a symbol of the faith in ideals which is reflected in the sound growth of the Institute. Mr. Loud felt that the wood from Jerusalem, the Holy City to Catholic, Protestant and Jew alike, represented religious faith, and the early American silver from various times of crisis in our past represented faith in the democratic way of life ; that together they made an appropriate symbol of faith by which to guide the future of the Institute.

Richard T. Liddicoat, Jr., Executive Director, rededicated the aims of the Institute to the principles on which it was founded ; viz., the training of personnel for the jewellery profession and the maintenance of high standards for all phases of the industry, through knowledge. He outlined some of the projects which are now nearing completion, including the two new courses to be announced within the next few months, as well as the future objectives contemplated by the G.I.A. staff.

Dr. Edward H. Kraus, Dean Emeritus of the College of Literature, Science and the Arts of the University of Michigan, was re-elected President of the Institute for the eleventh consecutive year.

Diamonds for Institute

In 1955 G.I.A. announced the generous gift of over 1,500 carats of rough diamonds made to the Institute by the Diamond Corporation, through the generosity of Sir Ernest Oppenheimer. This important acquisition, the Sir Ernest Oppenheimer Student Collection, contained many crystals in a range of qualities which if cut would provide for the Institute an excellent group of stones for Diamond Evaluation and other Resident classes.

Upon learning of the acquisition of the stones, the firm of Lazare Kaplan & Sons, New York City, immediately offered to cut a large number of these stones for the Institute without charge. The Kaplan firm, which has already cut about fifty stones, followed to the letter the G.I.A. request to cut the stones in a manner which would yield a cross section of the types of makes and finishes commonly encountered in the industry to-day. Thus the generosity of the Kaplan firm, following that of the Diamond Corporation and Sir Ernest Oppenheimer, has provided the jewellery industry of America with a large number of stones which are ideally suited to the diamond evaluation instruction offered to the trade by the Gemological Institute.

TALKS BY MEMBERS

Blythe, G. A. : "Gemstones," Ladies' Circle, Southend-on-Sea, 18th May.

Ewing, D. J. : "Gemmology as applied to Police inquiries," Police Training College, Edinburgh, 9th April.

Gale, H. C. : "Modern Jewellery Design," Chapelfields Townswomen's Guild, Coventry, 15th September, 1955 ; St. Mary Magdelen's Young Women's Guild, Coventry, 23rd November, 1955 ; Stoke Heath Townswomen's Guild, Coventry, 21st January, 1956.

Melrose, R. A. : "Gemstones," Heaton Rotary Club, Northumberland, 24th April, 1956.

COUNCIL MEETING

A meeting of the Council of the Association was held at Saint Dunstan's House, Carey Lane, London, E.C.2, on Tuesday, 8th May, 1956. Mr. F. H. Knowles-Brown, Chairman, presided.

The Council decided to invite Dr. Edward H. Kraus, President of the Gemological Institute of America, to become Vice-President of the Association.

The following were elected to membership :—

Fellowship

Hartland, Edward, London D.1949

Spittle, Theresa R. (Miss), Birmingham D.1955

PROBATIONARY

Blignaut, Adi (Mrs.), Johannesburg, S. Africa

McCann, Brian J., Whitecraigs

Sherrard, Julian S., London

ORDINARY

Asscher, Joseph (Jr.), Amsterdam, Holland

Baily, Hugh G., Sutton Coldfield

Flapper, Jan, Arnhem, Holland

Hewlett, Jack W., London

Inglis, Alexander, Dunfermline

Lawrie, William H., Killin

MacLeod, Hector M., Glasgow

Marks, Percy G., Sydney, Australia

Padbury, Edna P. (Miss), Birmingham

Thirlwell, Arthur P., Great Malvern

Walsh, Harvey L., Arlington, U.S.A.

Arrangements were made for the presentation of the awards gained in the 1956 examinations to be presented by Mr. B. W. Anderson at Goldsmiths' Hall, London, on Wednesday, 3rd October, and for a Conversazione to be held at the same place on 28th November.

Bye-law 5 (*e*) was amended so as to read: " The President, Vice-Presidents and Honorary Fellows shall not be called upon to pay an annual subscription."

The Council also decided to acknowledge as being competent the gemmological examinations and title of the Swiss Gemmological Association.

HERBERT SMITH LECTURE

The growing shortage in the world of real gemstones might well cause British jewellers to take an increasing interest in synthetic stones and this factor might lead to a " realistic attitude " being taken towards them. This was a belief expressed by Dr. Frederick Pough, when he gave the annual Herbert Smith Memorial Lecture before the Gemmological Association of Great Britain on 28th March.

Dr. Pough, who received a most enthusiastic welcome, was lately curator of minerals at the U.S. Museum of Natural History and is also the author of the extremely popular book, " A Field Guide to Rocks and Minerals."

Earlier in his talk, Dr. Pough referred to the remarkable ability of oxygen to bring about changes in a synthetic gemstone boule. In the production of synthetic titania the work started with the production of a boule which was almost black in colour. Yet, during a period of only about eight hours, the gas could penetrate this boule and give it an off-white colour ; this meant that the oxygen succeeded in penetrating, during this short time, about half an inch of solid material.

The speaker also gave an interesting commentary upon preferences in stones. Long ago, those who had the handling of them were unable to cut them and so produce sparkling gems. Preference, therefore, ran to the most opaque stones (a factor which is easily confirmed by the reader who cares to examine the gems in museums). This aspect of the subject was illustrated by lantern slides of outstanding character, as were the later parts of the lecture. Of course, the glass imitations of jewels made with comparative ease in days gone by were by no means durable, but obviously the jeweller's main requirement to-day was durability of high order. Early in the development of the craft there had been attempts made to melt aluminium oxide, but it was found extremely difficult to achieve the temperatures and pressures necessary. The achievement of glass-like synthetics was made possible only in the last century with the development of the Verneuil process.

It had never been practicable to melt down either ruby or sapphire material in order to produce a number of inexpensive gems. Those rubies and sapphires produced from boules, however, were the same as natural stones save in respect of the inclusions, which could be observed with a magnifying glass. Even to-day, there were great difficulties met with in the production of these stones and great quantities of rejected material might still be found at manufacturers' premises, due to upsetting factors which had obtruded themselves during the growth of the boules. All these failures, or " accidents," increased production costs.

There was no doubt that the synthetic industry in the United States had grown up of necessity during the war years, when the U.S. was cut off from European supplies. By the time supplies were resumed, the manufacturers had made considerable progress and were producing types of stones not made in Europe. The rod-shaped sapphire, which was free from wastage, was a good example. This formation resulted from a supersaturation of the boule with titanium oxide. The boule is heat-treated at just below the melting point of titanium oxide. Of the star forms, rubies were larger and generally more successful than sapphires. The American Museum of Natural History possessed the largest example of such stones which the speaker had seen. This, dubbed the " Turkey Egg," weighed 109 carats. There was a hint for those whose tasks included the separation of synthetics from real star stones. If one observed the back of a synthetic, one found that it was smooth and partly polished.

There had also been star stones made in Germany, but in the U.S. this achievement ran up against patent difficulies. The patent specification granted was such that even if a different technique were used the final product must not be the same. The German stones were, in the experience of the speaker, more milky than the American, and the star formation was not so distinct.

Another German achievement was that of a dentist who had synthesized a lapis lazuli type of gem from sintered spinel. The appearance was assisted by the making of little pits in the stone and filling these with gold.

In the U.S. there had been very great progress made in the past 17 or so years. The speaker instanced a West Coast producer who, before World War Two, was synthesizing emeralds. At that time this particular producer was managing to bring his stones up to the order of about one-tenth ct. Shortly after the war he had managed to bring the size of stone up from four to five carats ; but so far he had not been able to exceed this limit significantly while still producing clean stones. All these stones were started as crystals. There was no patent on the process, but the secret had been well kept. The lecturer gave the view that these stones were probably started from seed crystals in a high temperature, high pressure " bomb," with a growing time which might be as long as between six and 36 months. The largest stones so far produced were little more than " stunt " pieces ; they were rather liable to break down.

Another process using the high temperature, high pressure " bomb " was rather off the jewellery line—the production of quartz for the radio industry. This process started with slices of natural quartz, and American workers had soon found out the importance of proper orientation of the quartz slices, a factor which had been overlooked in the past by German scientists on a similar line of country. Effective rate of growth of quartz crystal was stated to be in the region of 1 lb. per diem. Synthetically produced quartz had a small crystalline formation and research workers were still unable to find the factor which, in nature, led to large-diameter crystals. There was also a considerable amount of work done in connection with the growth of the so-called " rose-quartz "—a substance which came under fire at the recent panel session of the Gemmological Association. So far, attempts to synthesize this material resulted in non-transparent samples. Amethyst production had met with a similar fate. Synthetic mica had been produced and this material had a higher temperature tolerance than did the natural substance.

Dr. Pough turned his attention to some of the raw materials used in synthesis and after a discussion of halogen compounds dealt with silicon carbide. He stated that stones made from this material were extremely attractive with an appearance similar to that of cyclotroned diamonds. This material, like titania, would seem to have great possibilities in the realms of synthetic gem production. Using titania (found in nature as black rutile), stones of many attractive colours had been made, and some large sizes achieved. Indeed, stones weighing up to 200 ct. had been manufactured. Most trade interest centred upon white stones produced from this material, but gold, blue, red, and purple were among the colours achieved.

Finally—and, doubtless, as many of his hearers hoped—Dr. Pough referred to the synthetic diamonds which had been produced by the General Electric Co., in U.S.A. These were not, he asserted, of gem quality. They were at first manufactured in pressures of 1,500,000 p.s.i., but this had now been stepped-up to 2,500,000 p.s.i. at temperatures around 5,000 deg. F. So far, the largest synthetic diamond made was of about one-hundredth of a carat. The press was about two storeys high, yet the actual chamber in which the stone was formed was about the size of an india-rubber. He understood that success was now being achieved consistently, with about 80 per cent of the raw material used being converted into diamond material. Production had now emerged from the experimental orbit and had been taken over by a manufacturing department. No one had so far seen one of the end-products outside the G.E.C. organization so that he was not aware of the differences between the synthetic and natural diamonds. (This report, with slight revision, is reprinted with permission from the *Jeweller and Metalworker.*)