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and

PROCEEDINGS OF THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

GEMMOLOGICAL ASSOCIATION
OF GREAT BRITAIN
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GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

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Committee of the National Association of Goldsmiths,
reconstituted in 1931 *as the Gemmological Association)*

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MODERN SYNTHETIC GEMSTONES

By ROBERT WEBSTER, F.G.A.

SINCE the end of the second world war there has been a spate of synthetic materials grown as crystals which have been produced either for gemstones in their own right, or as the result of experiments in the fields of electronics and space-age programmes. Some of these, too, have been found useful as material for gemstones for personal decoration, and some, still unused, have such a potential. Some of these crystals have no counterpart in nature.

The properties of many of these stones are known, but the literature is scattered throughout many different publications and this article is an attempt to correlate such information, and to incorporate some of the author's findings, so that the characteristics of these stones may be more readily available to the gemmologist.

There are many methods of growing single crystals, such as the well-known Verneuil flame-fusion method, the hydrothermal method, and those using various types of flux-fusion, one of which is the Czochralski "pulling" technique which is commonly used for the production of a number of these crystals at the present time. These methods will not be discussed at length in this article as this aspect has been well covered by Dr. Kurt Nassau of Bell Telephones of America, and by Dr. E. A. D. White of the General Electric Company and Imperial College, London; nor will the synthetic corundums and spinels produced before the war by the Verneuil process, which are well-known as jewellery stones, be covered in this survey, which will include only those stones manufactured since 1946. For ease of reference the stones will be referred to in alphabetical order, either by their chemical name or by their species name, whichever is the better known.

BARIUM TITANATE ($BaTiO_3$)

This titanate has been reported to have been grown as single crystals, but so far has not been met with as a gemstone, although from its properties there seems to be no reason why it should not be so used. Cubic in crystallization, the crystals probably have a hardness of about 6 to 6½ on Mohs' scale. The chemical composition is similar to that of strontium titanate—the well-known "fabulite"—in that the strontium is replaced by the heavier alkaline earth metal barium. The refractive index is, like "fabulite", quite near to that of diamond, and is 2·40, while the density of 5·90 is higher than that of "fabulite".

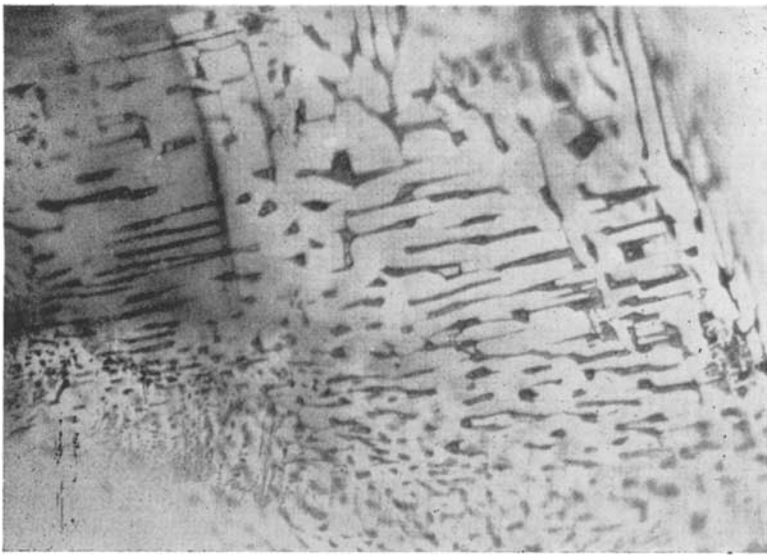
BERYL ($Be_3Al_2(SiO_3)_6$)

The synthesis of emerald was academically accomplished before 1939, but is was not until the end of the war that the synthesis of this valuable gemstone by Carroll F. Chatham of San Francisco, California, made the synthetic emerald a commercial proposition.

Aided by the investigations carried out on the pre-war synthetically produced crystals, particularly those grown by R. Nacken, and the production at I. G. Farbenindustrie by H. Espig and E. Jaeger at the chemical works at Bitterfeld, now in East Germany, it was found that the Chatham production conformed in character with the earlier syntheses and presented no great problem to the gemmologist.

The factors which gave this distinction from natural emeralds were their low density, and their low refractive indices and bi-refringence. These are illustrated in the table below, which gives the constants for the synthetic emeralds grown by Carroll Chatham and natural emeralds from various sources.

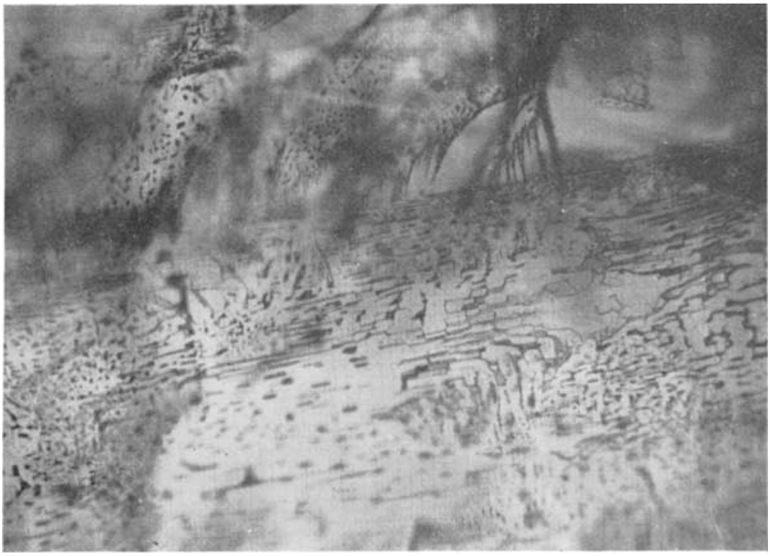
Locality	*R.I's*	*Biref.*	*Density*
Synthetic (Chatham)	1·564-1·561	0·003	2·65
Colombia (Muzo)	1·584-1·578	0·006	2·71
Colombia (Chivor)	1·577-1·571	0·006	2·69
Russia (Siberia)	1·588-1.581	0·007	2·74
South Africa	1·593-1·586	0·007	2·75
Brazil	1·571-1·566	0·005	2·69
India	1·590-1·583	0·007	2·74
Rhodesia (Sandawana)	1·593-1·586	0·007	2·76
Pakistan	1·600-1·593	0·007	2·76
Austria (Habachtal)	1·589-1·582	0·007	2·74
Norway (Eidsvold)	1·591-1·584	0·007	2·75



Structure of feathers in a Chatham synthetic emerald.

Typical feathers in a Chatham synthetic emerald.

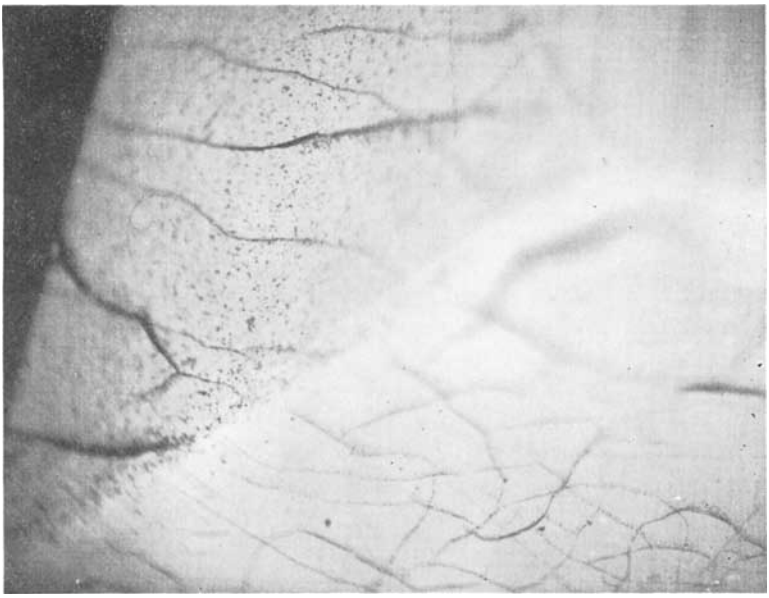
Feathers in a Chatham synthetic emerald.



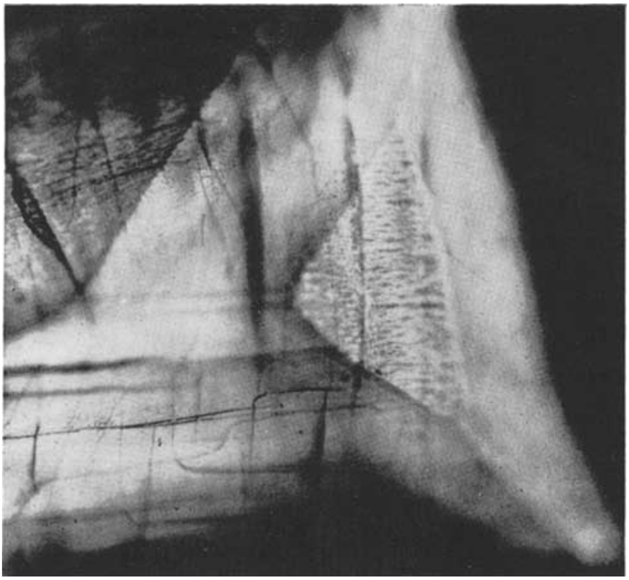
Feathers in a Chatham synthetic emerald.

Further confirmation is given by the strong red shown by the stones when they are viewed through a Chelsea colour filter, or by "crossed filters", and by the strength of the red glow under ultra-violet light. The absorption spectrum is usually more pronounced in the synthetic stones than in the natural, but what is most conclusive are the typical "veil-like" feathers, often two-phased, which are seen as inclusions in the stones. Synthetic emeralds are usually more transparent to ultra-violet light than are the natural emeralds. It is these criteria which identifies the synthetic emerald from those formed by nature. At least this was true up to 1968.

During 1960 there was marketed a new type of "synthetic emerald", the synthetic emerald-coated beryl produced by J. Lechleitner, of Innsbruck, Austria. These Lechleitner stones were first marketed under the name "emerita", but this was later changed to "symerald". They are produced by depositing, by means of a hydrothermal method using an autoclave, an overgrowth of synthetic emerald onto an already preformed (that is a cut stone) "seed" of pale emerald, or more usually pale aquamarine or pale yellow beryl. After a sufficiently thick deposit has been allowed to grow on to the cut stone "seed", the layer being less than half a millimeter in thick-



Crack-like reticulation of feathers in an emerald-coated beryl made by the firm of Lechleitner.



Synthetic emerald-coated beryl, showing an unpolished facet and the reticulation of crack-like feathers.

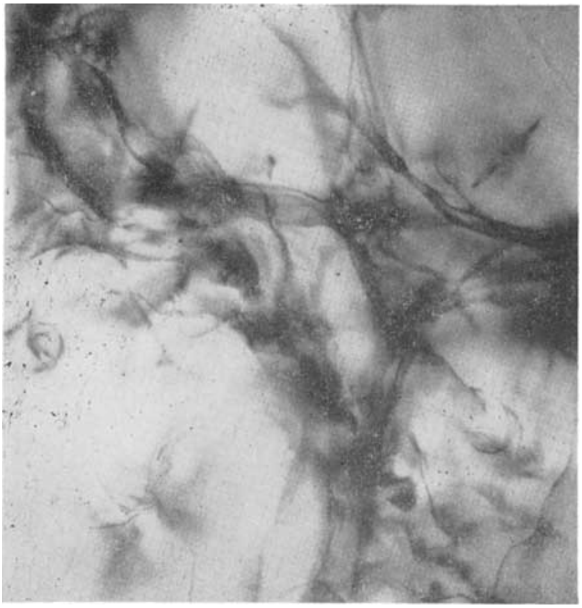
ness, the stone is removed from the autoclave and the facets finished by giving them a light polishing, although quite often one small facet at the back of the stone is left without a polish and this will assist in identifying the nature of the stone.

The density of these Lechleitner synthetic-emerald-coated beryls is about 2·7 and the refractive indices are near 1·581-1·575, values near to those for natural emeralds. Such coated beryls can be readily detected by the net of inclusions usually seen on the side facets; by the inclusions, which are usually those of aquamarine, such as "rain", and by the rim of red fluorescent light which may be seen when the stone is suitably irradiated, *i.e.* by "crossed filters" or by ultra-violet light In 1964 Lechleitner produced variations of this "synthetic-emerald-coated beryl". These stones were started from a seed plate of natural or synthetic colourless beryl upon which was grown a plating of synthetic emerald and the stone subsequently "enlarged" by growing on synthetic colourless beryl—presumably it is easier to grow synthetic colourless beryl than synthetic emerald. Cut stones of this make have not been examined by the writer, but Eppler states that the "sandwich" structure is only exhibited when the stones are viewed through the side and when immersed in a suitable liquid of similar refractive index.

This is not the end of the story of the Lechleitner beryls, for a multiple "sandwich" consisting of a central seed plate of synthetic emerald grown upon a suitable plate of natural (or synthetic) beryl has deposited upon it a number of layers of synthetic material produced hydrothermally. Seemingly the stone has to be placed in the autoclave a number of times before the final result is produced. No stones of this type have been examined, or, as far as the writer knows, have ever been seen in this country, although the simple single synthetic-emerald-coated beryls have been encountered mounted in jewellery.

During 1962 there was a report of another synthesis of emerald. This was a modified flux-fusion method using V_2O_3 as the flux, and a "seed" crystal to initiate the process. The writer has two specimens alleged to be of this type of synthesis, which was carried out by R. C. Linares and others. However, some doubt has been felt as to whether the specimens are synthetic or not and there is always the possibility that they are natural crystals which had by mischance become mixed in with the actual synthetic specimens. The method can have had no commercial success or it would have been continued.

The Chatham synthetic emeralds, which were at first called "cultured emeralds" until Carroll Chatham was stopped from using the name by the American Federal Trade Commission, who, however, allowed the name "created emeralds" to be used, held the market until 1964, when both Pierre Gilson of France and Zerfass of Germany produced and marketed their synthetic emeralds. These new synthetic emeralds, except for the earlier production of Gilson, which glowed with an orange and not a crimson light when bathed in ultra-violet rays, had similar characteristics to those of the Chatham synthesis. The earlier Gilson stones had a yellowish-green colour which was quite pleasing but later syntheses are more of a bluish-green colour and are as important commercially as the older established Chatham synthetic emeralds. It is the more recent Gilson production which is important, for certain changes in the synthesis have been made. These will be discussed later. The

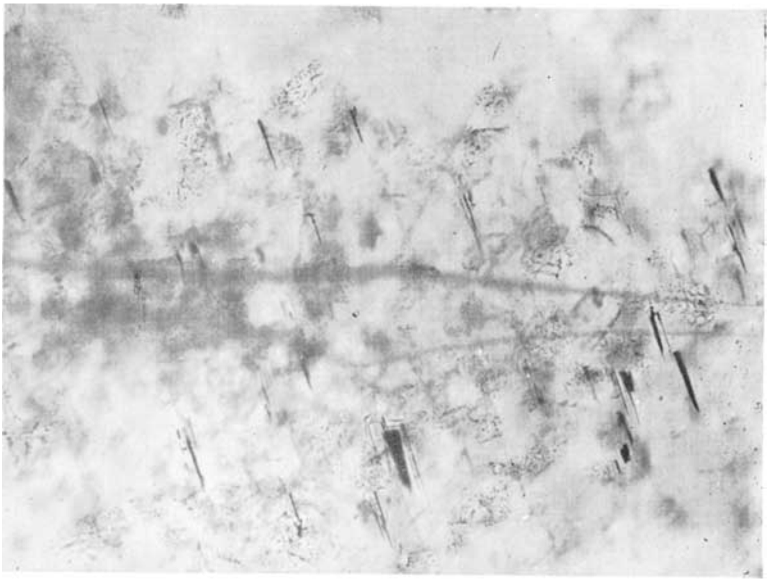


Feathers in a Gilson (French) synthetic emerald.

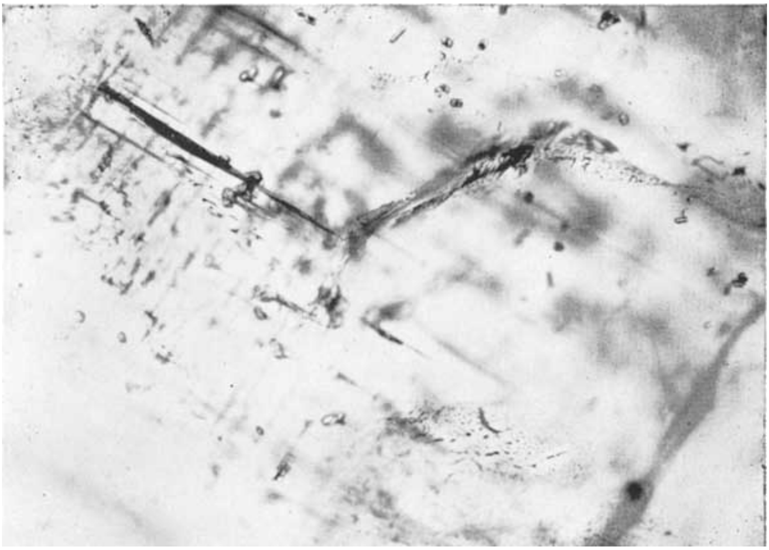
Feathers in a Zerfass (German) synthetic emerald.

Zerfass synthesis does not seem to be so important and few of the stones are seen on the market.

A year later, in 1965, the American firm Linde Air Products reported a new production of synthetic emerald, this time by a hydrothermal process, for the Chatham, Zerfass and Gilson are flux-melt syntheses, although Gilson was said to have started by using a hydrothermal system. The marketing of the Linde stones is confined to their own consortium, the stones not being sold to outside gem dealers but mounted into jewellery at their own factory in Southern California. Emeralds from this synthesis do not seem to have reached England and the few that have been seen in this country were some of the earlier experimental crystals and cut stones. The literature gives the constants for Linde synthetic emeralds as $\omega = 1{\cdot}572$, $\varepsilon = 1{\cdot}567$, with a birefringence of 0·005, and the density of the stones to be near 2·67 or even higher. The inclusions of Linde stones were seen to be veil-like inclusions, so commonly seen in other synthetic emeralds, and also nail-like cavities with the head of the "nail" formed by a single, or a group of, phenacite crystals. F. H.



Feathers and "nail-like" inclusions in a Linde hydrothermal synthetic emerald.



Early Linde synthetic emerald showing feathers and phenacite crystals.

Pough refers to "brush-like" stroke inclusions rather like fine parallel canals. What are, however, the most striking observations made on this type of synthetic material are the strong red light shown by the stone when it is bathed in a fairly intense beam of white light, and also the strong red fluorescence shown by the stone when viewed through a Chelsea colour-filter or "crossed filters" or under ultra-violet light.

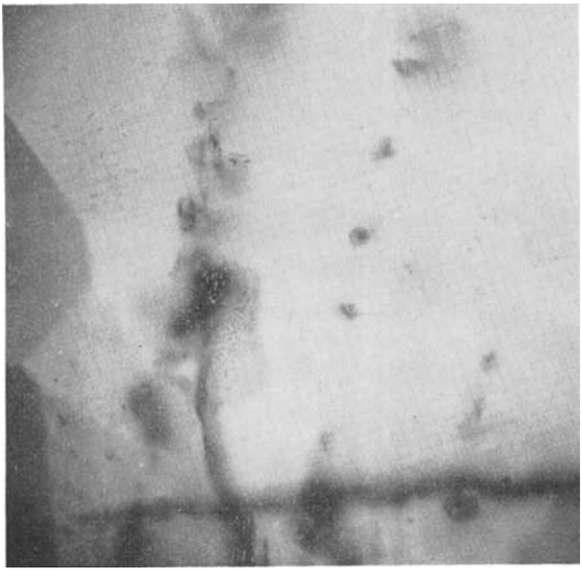
Some Linde hydrothermal emeralds examined recently by workers in the United States of America have refractive indices of $\omega = 1{\cdot}578$ and $\varepsilon = 1{\cdot}571$, with a birefringence of 0·007. The density was found to be 2·678. These stones showed much less fluorescence under ultra-violet light, although the red appearance when the stones were in a beam of white light was still a characteristic feature, and so were the nail-like cavities capped by phenacite crystals, as well as the veil-like feathers which are so common in synthetic emeralds.

Recently a few emeralds have been encountered which do not luminesce red under ultra-violet light and have densities and refractive indices similar to those of natural emeralds, but which, from their inclusions, are undoubtedly synthetic. Where these emeralds emanate from is not known for sure, but there are certainly other firms, and even individuals, growing synthetic emeralds. One stone recently examined had refractive indices of 1·575 and 1·570 giving a birefringence of 0·005, or perhaps 0·006. The stone sank in a mixture of bromoform and monobromonaphthalene, made up just to float rock crystal, and showed a red fluorescent colour when viewed under a Chelsea colour filter and when irradiated with ultra-violet light. The inclusions seen in the stone consisted of the typical veil-like feathers with a plane of oblong-shaped inclusions.

Gilson, too, has openly said that he has changed his formula to include iron in his synthetic emeralds. This inclusion of iron in the chemistry "poisons" the luminescence, hence the stones do not respond to ultra-violet light, nor to the "crossed filter" technique, and it may also produce iron line at 4270A in the deep blue of the absorption spectrum.

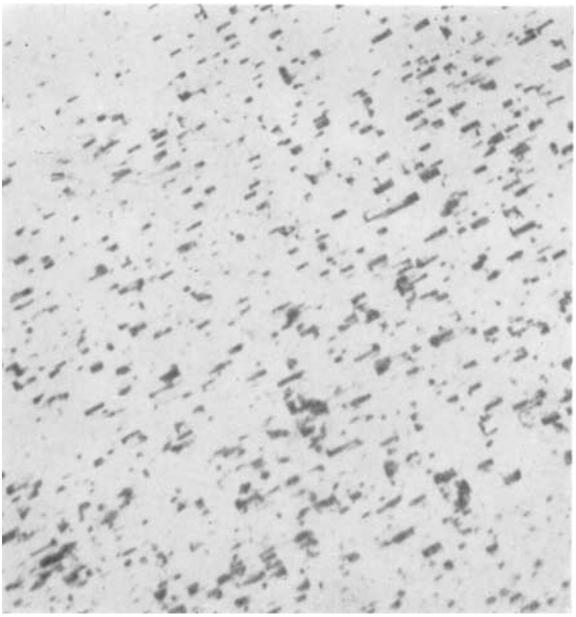
The detection of synthetic emeralds is tending to become more difficult, particularly as some of the "freak" emeralds encountered recently may well be from experiments in the production of crystals for solid state physics, and here it may be mentioned that synthetic emeralds have been produced by the Verneuil flame-fusion technique and also by high temperature/high pressure methods. These experiments do not appear to have borne fruit, but there is still the danger that some of these out-of-the-way crystal growths may come into the hands of the gemmologist, who perforce would know nothing about the characters of such stones.

The story of the synthetic beryls must not be concluded without mention being made of the synthetic beryls "doped" with trace elements other than chromium. Crystals have been grown, usually by a hydrothermal method, which have been doped with vanadium, producing green stones not far different from emerald itself, manganese giving a greyish-green, cobalt giving, not a blue, but a pinkish-brown colour, and nickel, which produces a pale green stone. These were first reported by Russian workers about 1964 and further experiments on these lines have been carried out in Australia, where it was found that iron produced a deep blue beryl and a light blue colour was produced by using copper. Specimens of these beryls have not as yet been made available for examination in this country.



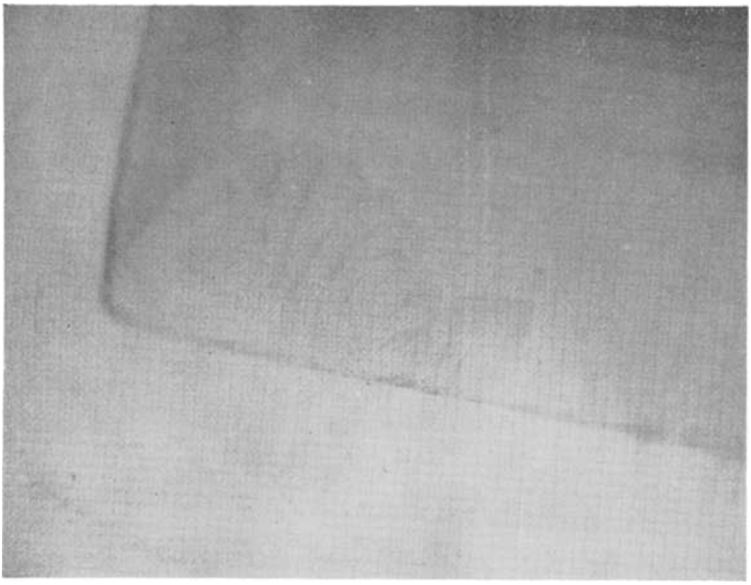
Inclusions seen in a synthetic emerald.
(Make unknown).

Feathers and rectangular-shaped inclusions seen in a synthetic emerald.
(Make unknown).

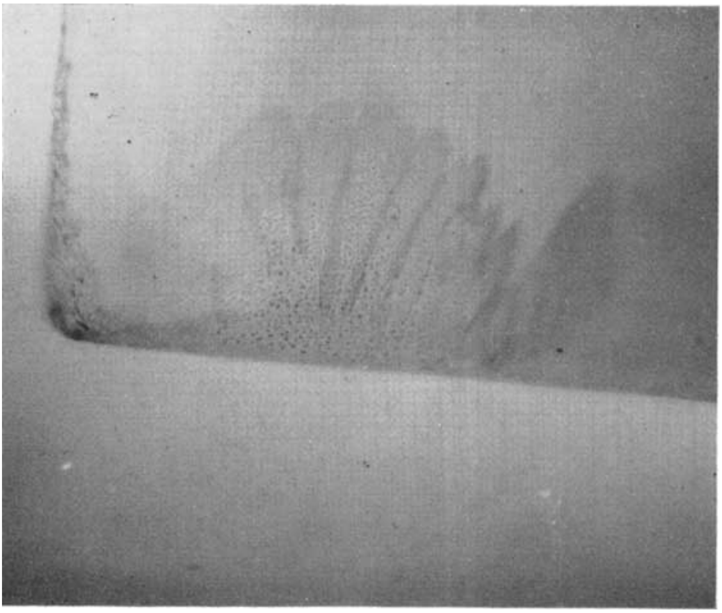


Block-like cavities in a synthetic emerald.
(Make unknown).

Unusual chain of inclusions and fine straight lines (canals?) seen in a recent synthetic emerald.
(Make unknown).



Fan-shaped feathers in low relief with straight zonal lines seen in a recent synthetic emerald.
(Make unknown).



Fan-shaped feathers in low relief seen in a recent synthetic emerald.
(Make unknown).

BORON CARBIDE (B_4C)

Like the silicon carbide better known as carborundum, boron carbide is also produced primarily as an abrasive and sells under the name "norbide". No single crystals of this material have been reported, but if such crystals could be grown, and there seems to be no reason why they could not, they would certainly be a potential gemstone. The density of the material is said to be 2·51.

BROMELLITE (BeO)

Colourless crystals of beryllia, a hexagonal mineral which in nature is called bromellite, have been reported to have been grown synthetically by a flux-diffusion method. With a hardness said to be 9 on Mohs' scale the stone has the qualification to enter the realm of synthetic gemstones. From details given by American gemmologists who have examined a specimen of the synthetic bromellite, the density approximates to 3·00 to 3·02, and the refractive indices appear to be $\omega = 1{\cdot}720$ and $\varepsilon = 1{\cdot}735$, the birefringence being 0·015 with positive optical sign. Under the long-wave ultra-violet lamp the specimen examined showed a faint orange glow. Against the advantages there is a positive disadvantage in that on grinding the stone during the fashioning process the pulverized dust produced is toxic. This may preclude the use of this material as a gemstone.

CALCIUM TITANATE ($CaTiO_3$)

Orthorhombic in crystallization, although near cubic, calcium titanate has been made synthetically. In chemical composition the material is similar to "fabulite", in which the calcium is replaced by strontium. It is another stone which may well take its place as a gemstone. The density is reported to be 4·05 and the mean refractive index 2·40. In hardness it is probably similar to "fabulite".

CHRYSOBERYL ($BeAL_2O_4$)

Small crystals of the alexandrite variety of the species chrysoberyl have been grown synthetically, but there is no report extant that they have been grown sufficiently large for gems to be cut from them.

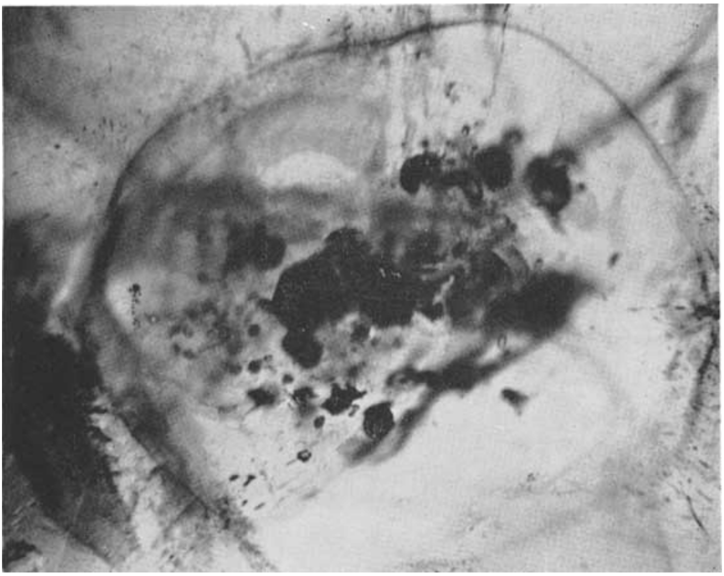
CORUNDUM (Al_2O_3)

Apart from the production by the Linde Company of synthetic star-corundums during 1947, there have been a number of syntheses of ruby both by flux-melt and by hydrothermal methods, but so-far these stones have not ousted the more conventional synthetic production by the Verneuil flame-fusion technique. This may well be due to the higher cost of production using these newer methods for very little gain in appearance. Such stones have, however, been marketed by Carroll F. Chatham, by the Bell Telephone Company (it is doubtful whether the production has been marketed as gems), and by Ardon Associates, who market their production as Kashan flux-grown rubies.

Admittedly the detection of these new types of synthetic rubies presents greater difficulty than is encountered with the Verneuil flame-fusion synthetics. In the hydrothermal types inspection of the internal features may show traces of the "seed" used to start the process, and the stones will certainly show rather typical feathers

Inclusions in an early hydrothermal synthetic ruby.

somewhat reminiscent of those seen in synthetic emerald; and in he flux-grown types similar feathers may often be seen. In the Kashan type of flux-fusion ruby there is seen a typical design of a dot-and-dash pattern of inclusions and these are sometimes like droplets. It has been verbally reported to the writer that the more recent production of Kashan rubies do not show these signs and any inclusions seen are natural-like needles. So far as is known none of these Kashan synthetic rubies have been seen in Britain. These newer synthetic rubies show a greater transparency to ultra-violet light, and if suitable apparatus is available the usually persistent phosphorescence after x-ray bombardment is indicative. In all cases the density and refractive indices are similar to those of natural stones of the corundum species. Finally, no striking advance seems to have been made in the synthesis of sapphires, although one American concern has experimented with the use of ground-up Montana sapphires for the feed powder for the blowpipe used in the Verneuil technique.



The "seed" crystal in a hydrothermal synthetic ruby.

DIAMOND (C)

The highlight of the period under review was the synthesis of diamond by the General Electric Company of America in 1955. Other firms in other countries produced similar diamonds about the same time or soon after. It was an academic and technological breakthrough but had no gem significance. Production did, however, become commercially important as the minute crystals produced had a use for industrial purposes and De Beers commenced industrial production both in South Africa and in Eire. So did other countries and it is believed that there is a production in the Soviet Union, but what goes on behind the Iron Curtain is to some extent a closed book. On the 28th of May 1970 The General Electric Company of the United States of America released the

Photo No. RDC-16, 183-9*;* 16, 183-2

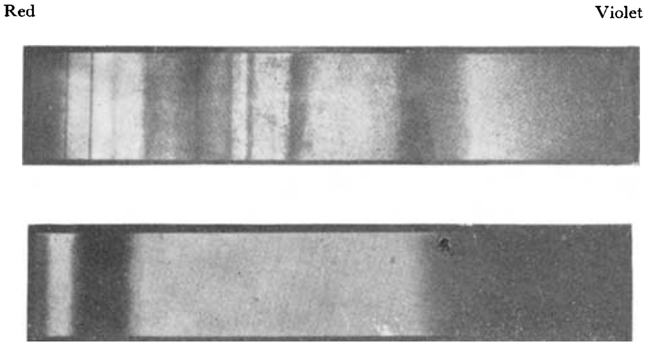
These gem diamonds were created by scientists at the General Electric Research and Development Center, Schenectady, New York. The larger crystals are approximately one carat in weight. Although these diamonds have undergone slight polishing, they have not been cut and retain the shape in which they were "grown" in a special apparatus for subjecting graphite (the pile of black powder) to extreme pressures and temperatures.

Photo: G.E.C. (U.S.A.)

information that they had produced gem diamonds of a carat or more in size. The report was careful to state, however, that the cost of producing such diamonds was much greater than the cost of similar sized mined diamonds. One cannot be complacent, for with the advances in science to-day there must surely come a time when synthetic gem diamonds become a commercial reality. The new materials can be produced in various colours and of those examined by the Gemological Institute of America, the near-colourless and blue stones were highly electrically conductive, highly fluorescent and phosphorescent. A yellow-coloured stone was not conductive. Further investigations are to be made by the G.I.A.

Fluorite (CaF_2)

Synthetic fluorite has been grown for scientific purposes, but the material with its low hardness and low indices of refraction is not a promising material for a gemstone. Some cut stones may have been cut experimentally and for collectors' items. Most of these fluorites are "doped" with various impurities which give, apart from physical and optical differences, such as luminescence, various attractive colours to the crystals. In 1963 a "boule" (?) of vivid green colour was identified as synthetic green fluorspar from its refractive index of 1·45. The density was given as 2·31, but this may well be a misprint for 3·21. The stone exhibited a bright blue



Spectra of synthetic fluorite.
Top. *Deep red colour.*
Bottom. *Green colour.*

fluorescence. However, a specimen of green fluorite examined by the writer gave an index of refraction of 1·435, a density of 3·186 and the stone showed an absorption spectrum with an absorption band in the deep red, a fine band at about 6900A and an an absorption from 6300A to 5800A, with further weak bands at about 5300A and 4900A. There was, in the case of this stone, no perceptible luminescence under either wavelengths of ultra-violet light and only a weak yellowish glow with no phosphorescence under x-ray bombardment. A colourless specimen examined had a refractive index of 1·44 and a density of 3·197. There was no significant absorption spectrum seen, but under ultra-violet light there was a green fluorescence which was more yellowish under the long-wave lamp. No phosphorescence was observed. Under x-rays the green fluorescence was brilliant and there was an exceptionally long phosphorescence of the same colour. Examination of the fluorescence spectrum, which was the same under all wavelengths, showed a discrete spectrum of strong bands in the red and orange and yellow and green with weaker fluorescent bands further into the green. It is suggested that the crystal may have been "doped" with indium. A red crystal with refractive index of 1·44 and a density of 3·181 showed a rare-earth spectrum which had a sharp line at 5650A and a range of nearly equally spaced lines of differing intensities from the yellow to the end of the green. No luminescence was observed in this crystal except for a weak mauve glow induced by x-rays. It may with some reason be suggested that uranium could be the, or one of the, "doping" elements here. Another pale pinkish crystal showed a typical "didymium spectrum" and was most probably "doped" with neodymium.

GAHNITE ($ZnAl_2O_4$)

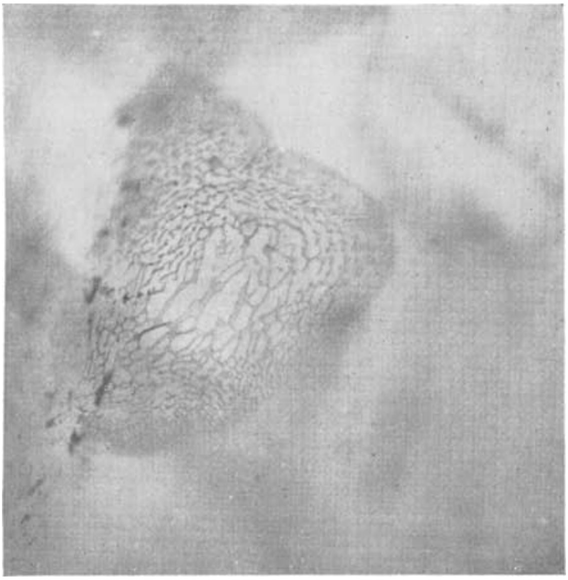
The cubic mineral gahnite is another crystal which has been successfully synthesized, but of its properties little has been so far reported. No specimen has been seen by the writer and the values quoted here have been taken from Dana's Textbook of Mineralogy for the natural gahnite and are as follows—a hardness of 7½ to 8, a refractive index of 1·82 and a density varying from 4·00 to 4·6; however, it may be presumed that the synthetic material would have been the higher values.

GARNET-TYPE SYNTHETIC STONES ($X_3Al_5O_{12}$)

The past decade has produced a number of artificially grown crystals which have a garnet-like structure, although they contain no silica. Such crystals are grown by the flux-melt method, or more often by the Czochralski "pulling" technique.

There are a number of these synthetic garnets all of which may be said to conform to the general formula $X_3Al_5O_{12}$, and a list of such crystals is given in the table below:—

Element	*Colour*	*Density*	*Ref. index*
Yttrium	colourless	4·57	1·832
Yttrium$^+$	green	4·60	1·834
Terbium	pale yellow	6·06	1·873
Dysprosium	yellow-green	6·20	1·85
Holmium	golden yellow	6·30	1·863
Erbium	yellow-pink	6·43	1·853
Thulium	pale green	6·48	1·854
Ytterbium	pale yellow	6·62	1·848
Lutecium	pale yellow	6·69	1·842



Feather in a flux-melt yttrium-aluminium garnet.

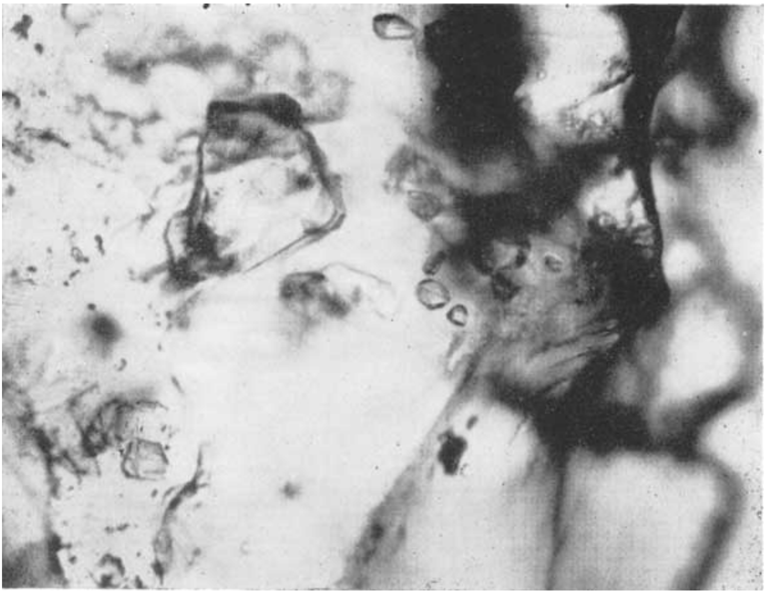
The crystallization is cubic, hence the stones are isotropic and their hardness is about 8 on Mohs' scale.

The most important of these from a gem point of view are the yttrium-aluminium garnets, which are usually known by the symbol YAG. The stones are colourless unless "doped", and it is the colourless stones which have the most interest as they are now being marketed as cut stones for the gem trade, where they are known under the name "diamonair". By the addition of trace elements various coloured crystals may be produced. Chromium will produce green-coloured stones, and some of these chromium-doped YAG's have masqueraded as demantoid garnets. Cobalt will give a blue colour, titanium a yellow and manganese a red colour to these garnets. Some yttrium-aluminium garnets are "doped" with praseodymium giving a pale green colour, or by neodymium which produces a lilac-coloured crystal.

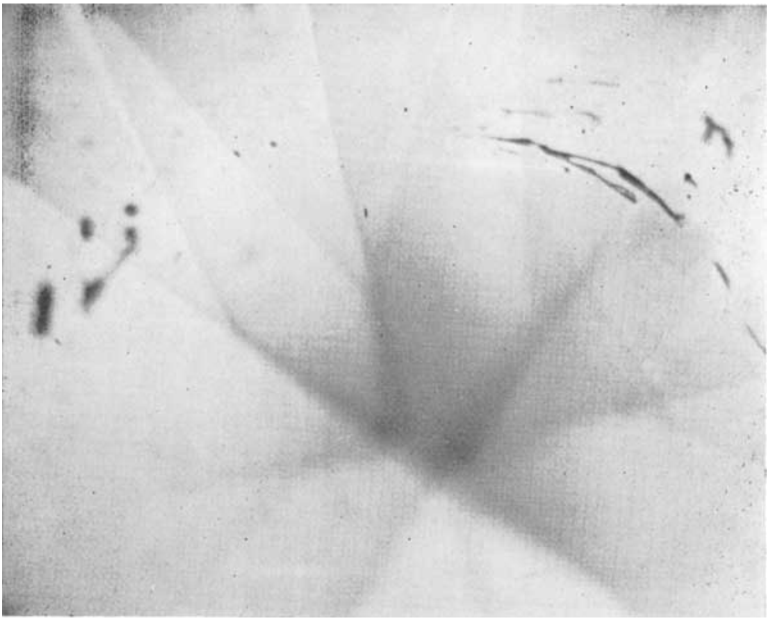
Examination of two colourless yttrium-aluminium garnets (sometimes called diamonair), one of American manufacture and one of English origin, showed the density to be 4·57. The American specimen showed a pronounced yellow fluorescence under long-wave ultra-violet light and a similar but weaker effect under the short-wave lamp. Under x-rays the glow was a bright mauve. The luminescent behaviour of the English stone, although similar, was much weaker. This luminescence, when examined with a hand-spectroscope, was found to be discrete with a strong band in the yellow. These diamonair stones do not have the "fire" of diamond, for the dispersion is only 0·028.

The green stones have been found to vary considerably in their absorption spectra. This may vary from a normal type of chromium spectrum to a composite one composed of the chromium lines in conjunction with the lines of a typical rare-earth spectrum; and one stone showed quite an anomalous spectrum. These green-coloured YAGs show a pronounced red under the Chelsea colour-filter or by "crossed filters", and this, with the obvious spectrum, distinguishes these stones from demantoid garnet.

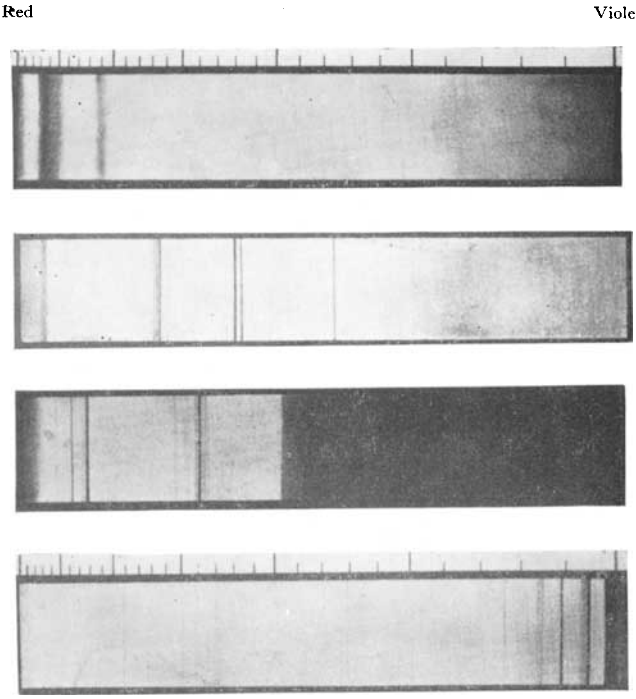
These inclusions observed in yttrium-aluminium garnets seem to vary with the method of growth. Those grown by the flux-melt



Crystal inclusions in an early flux-melt yttrium-aluminium garnet.



Extended bubble-like inclusions in circular arrangement seen in a "stone" cut from a "pulled" crystal of yttrium-aluminium garnet.



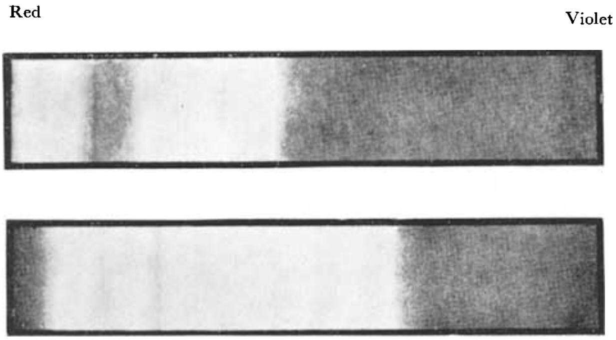
Absorption spectra of synthetic garnet-structured crystals.
TOP. *Light blue-green YAG.*
Green YAG.
Yellow europium garnet.
BOTTOM. *Light yellow YAG.*

method appear to contain natural-looking feathers and crystals, while those grown by the "pulling" technique often show twisted drop-like inclusions and sometimes angular black square or triangular crystals, or the black particles may show no regular shape. Some chrome-rich green stones may show "treacle".

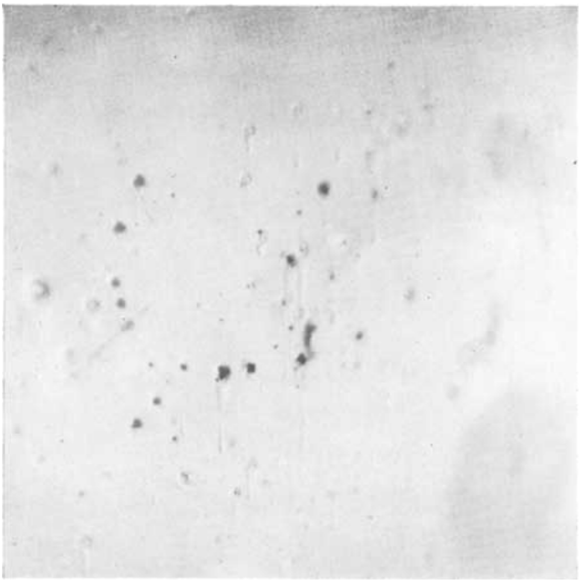
When the yttrium of the composition is replaced by other elements, the colours and particularly the physical and optical constants may vary greatly, as is shown in the table given earlier. In all cases where rare-earth elements are involved, either as a major constituent or as a "doping" agent, the absorption spectra are the most striking characteristics, which differ greatly with different rare-earths. Some of these spectra are depicted in the illustrations, which are taken mainly from those drawn by Robert Crowningshield of New York, but reversed left to right in accordance with British convention.

The gallium-aluminium and yttrium-gallium garnets are other types which have been made, but again these do not appear to have entered the gem field. However, a pink coloured sample of rough material examined in the United States of America showed the characteristically intense and striking absorption spectrum so common with rare-earth "doped" synthetic crystals.

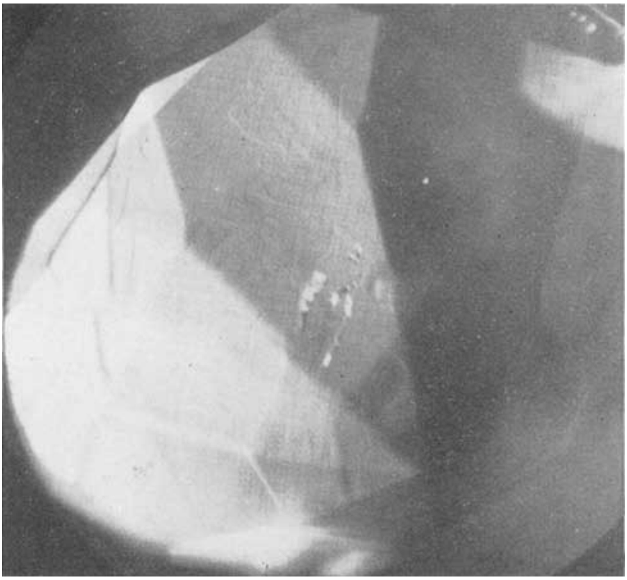
The so-called YIGs, the yttrium-iron garnets, which are black in colour and uninteresting as potential gemstones, are grown for the sake of their magnetic properties. Such stones are strongly magnetic but do not exhibit electro-conductivity. They have a density near 6. Recently there has come from Rhodesia a synthetic material with a metallic lustre, which in thin slivers is seen to have a deep red colour. The density of the pieces examined was found to be near 4·20 and the absorption spectrum to be that of almandine garnet, and this was confirmed by x-ray diffraction which showed the structure to be almandine garnet. The stones were found to be non-magnetic and do not conduct electricity. They may be said to be an extremely rich iron-aluminium garnet and have been called "hematite-garnet". Cabochon stones cut from this material are said to show an attractive iridescence, but no cut stones have yet been examined.



Differences in absorption spectra for green yttrium-aluminium garnets.
Top. *Intense green-coloured YAG showing an intense red through the Chelsea colour-filter.*
Bottom. *Lighter bluish-green coloured YAG which showed no red through the Chelsea colour filter.*



Inclusions in, probably, a "pulled" crystal of green yttrium-aluminium garnet.



Inclusions and "treacle" in a green yttrium-aluminium garnet.

GREENOCKITE (CdS)

The bright yellow cadmium-sulphide mineral was first described in 1840, presumably from material found at Bishopston in Renfrewshire, and received its name from Lord Greenock who later became the Earl of Cathcart. The natural mineral does not appear to have been cut as a gemstone, for the hardness of approximately 3½ on Mohs' scale is too low for such a use, except perhaps for the type impregnating smithsonite, which is found in Marion Co., Arkansas, U.S.A., and from which material cabochon stones could well be cut.

The constants for the mineral, which crystallizes as hemimorphic crystals of the hexagonal system, are approximately 4·9 for the density and the refractive indices are given as $\omega = 2{\cdot}505$ and $\varepsilon = 2{\cdot}529$, thus having a bi-refringence of 0·024 which is uniaxial and positive in sign. There is a distinct pyramidal cleavage and an imperfect basal one.

It is the synthetically produced greenockite which interests us in this survey, for greenockite is grown as single crystals, usually by the vapour-phase method, which can usually be of fair size, and these have been cut for collectors.

Two pieces of synthetic greenockite have been studied. No measurements of the refractive indices were carried out and it may be assumed that they would agree with those reported for natural greenockite. The density was found to be 4·825 and 4·829. There was no perceptible dichroism and the absorption spectrum showed a nearly complete absorption below 5250A, which appears to be the edge of a sharp band forming the beginning of the absorption. The luminescence shown by these specimens was under long-wave ultra-violet light a very weak orange glow, practically inert under the short-wave lamp, and a strong orange glow, but no phosphorescence, under x-rays. It must be remembered, however, that all synthetically produced crystals often have trace elements, as they are "doped" for special purposes for science and industry, and such "doping" may considerably alter the luminescence response. Both the specimens of greenockite examined exhibited electro-conductivity, with one specimen showing the effect much more strongly than the other.

KTN (niobium-doped potassium tantalate)

At a gemmological conference held in Barcelona a specimen of this colourless synthetic compound was exhibited and the suggestion was made that it would provide a satisfactory diamond simulant. So far KTN has not entered the realm of commercial gem synthetics, and whether it ever will is a moot point. The material is said to have a hardness a little greater than 6 on Mohs' scale, a refractive index of 2·27 and a density of 6·43. The writer has not as yet seen a specimen of KTN in order to examine in fuller detail this synthetic stone.

LITHIUM NIOBATE (Lithium metaniobate) ($LiNbO_3$)

Marketed under the name "linobate", this synthetic material has no counterpart in nature. It is grown as single crystals, usually by the "pulling" method, as colourless material, which, however, can be "doped" with trace elements to give other colours. The following table gives those credibly reported:—

Green	CrO_3
Red	Fe_2O_3 as $FeTiO_3$
Blue or Violet	Co_2O_3 as $CoTiO_3$
Yellow	MnO_2 as $MnTiO_3$
Yellow	NiO as $NiTiO_3$

According to literature lithium niobate crystallizes in the trigonal system, has a hardness of about $5\frac{1}{2}$ on Mohs' scale, a density of 4·64 and refractive indices of 2·21-2·30 giving a birefringence of 0·090, a double refraction which is sufficient to make the cut stones appear somewhat "muzzy". The dispersion for the B to G interval is 0·120, a value which is nearly three times that for diamond.

Examination of some specimens of lithium niobate gave the following results for density:—

Colourless	(0·6280 grams)	4·643
Colourless	(3·3969 grams)	4·644
Yellow	(4·1953 grams)	4·644
Brown	(2·8740 grams)	4·642

Coloured specimens showed distinct dichroism, but there was no characteristic absorption spectrum observed except for perhaps a very weak band in the blue part of the spectrum, nor was any luminescence observed under ultra-violet light, or under x-rays, to which radiation the stones, like zircon and strontium titanate, are opaque. There was no electroconductivity shown by the linobates.

MAGNETITE ($FeO.Fe_2O_3$)

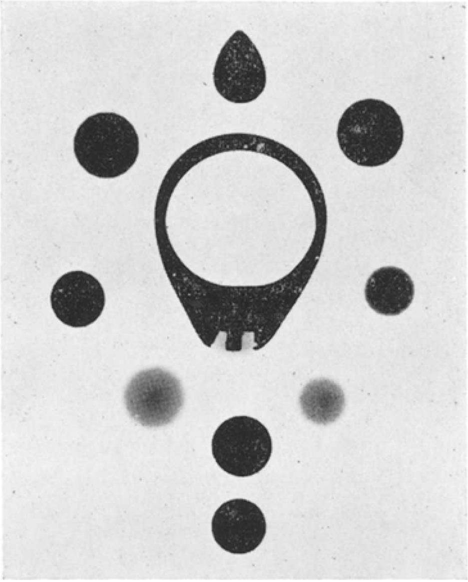
Included in this article solely for the sake of completeness, this mineral, a black oxide of iron, has been made artificially. No specimens of the synthetically produced material have been examined by the writer, but the literature gives for the natural mineral a density of 5·17, and the mineral is magnetic, hence the name.

MAGNETOPLUMBITE ($2RO.3R_2O_3$)

Another black mineral which has been synthetically produced is mentioned mainly because it has previously been mentioned in gem literature. Magnetoplumbite is an oxide of iron, manganese and lead and crystallizes in the hexagonal system. The density of the natural mineral is given as 5·517, but a determination made on a specimen of synthetically produced material was found to be 5·76. The streak is dark brown and the mineral is strongly magnetic.

PERICLASE (MgO)

The magnesium oxide mineral called periclase is another mineral which has been produced synthetically. The mineral, usually colourless, has cubic crystallization and from investigations by international workers the hardness has been shown to be about 5 on Mohs' scale, with a refractive index of 1·737 and a density of 3·55 to 3·60. Under long-wave ultra-violet light a specimen examined showed a weak whitish glow, which was, maybe, stronger under the short-wave lamp. X-rays produced a dull purplish-red fluorescence without any discernible phosphorescence. Unexpectedly there was a dull red colour seen when the specimen was viewed between "crossed-filters". Some Australian workers have observed weak absorption bands in periclase at 5400, 4850, 4670 and a cut-off at 4160A. The only specimen that the writer has examined seemed to show traces of such absorption bands, but they were too weak to have any great diagnostic value. American workers have mentioned observing square platelet inclusions in an American production of periclase. No electro-conductivity was found in the specimen tested. Periclase synthetically grown has been marketed as a gemstone under the name "lavernite".



RADIOGRAPH SHOWING THE TRANSPARENCY OF VARIOUS SYNTHETIC STONES TO X-RAYS.

Lithium niobate.

Yttrium-aluminium garnet.
Strontium titanate.

Diamond in ring.

Synthetic white spinel.
Natural white sapphire.

Synthetic scheelite.

Glass (Paste).

It will be readily seen that those stones whose constituents are elements of low atomic numbers are more transparent to x-rays than those containing elements of high atomic numbers. For example the spinel and corundum are near diamond in x-ray transparency. Rutile, too, shows some No. (22) of titanium.
translucency to the rays in keeping with the moderate atomic

PHENACITE (Be_2SiO_4)

Small green-coloured crystals of phenacite have been grown synthetically but not, so far, commercially. It is interesting to note that similar sized green crystals were grown by Hautefeuille and Perrey during the latter half of the nineteenth century and samples of such crystals are shown in the galleries of the Musee de l'Histoire Naturelle in the Jardin des Plantes in Paris. It seems that there has been little advance over the past eighty years, probably because of its scant use in modern science. However, it is said that larger crystals can be grown. The synthetic phenacite crystal in the possession of the writer is too small to carry out satisfactory tests, but it may be assumed that the constants would be the same as the natural stones, such as a density near 3·00, refractive indices of 1·654-1·670 and a hardness of 7½ on Mohs' scale. Examination of the small crystal showed it to contain many liquid-filled inclusions, but the crystal was too small for any convincing absorption spectrum to be seen. The crystal did not luminesce under either range of ultra-violet light, or under x-rays. Distinct dichroism was observed, the twin colours being green and pale yellowish-green.

QUARTZ (SiO_2)

Rock crystal has been grown synthetically by a hydrothermal technique for a number of years—primarily for its use in certain scientific applications—but the synthetic rock crystal is not likely to enter the gem market as the cost of production is probably greater than the price of the natural mineral. Some cut stones of synthetic rock crystal are extant but they are in the hands of collectors, usually after having been cut for exhibition purposes. It is the coloured synthetic quartz which has more importance in gemmology and synthetic quartz can be "doped" with a number of "impurities" to give colour. Only two colours have so far been met with as commercial gemstones; these are a green, resembling tourmaline green, which is probably induced by a trace of iron, and a bright blue, which may be called a "French-blue", a colour which is undoubtedly due to cobalt.

The green stones have been found to show rather different inclusions to what one would expect to find in quartz, but some other stones of English manufacture, including one in the writer's collection, are perfectly clean and show no signs of the synthetic nature of the stone except for the unnatural colour. The blue stones are comparatively easy to detect as the tell-tale cobalt absorption spectrum is seen in these stones. There is some reason to believe that these coloured quartzes have emanated from the Soviet Union.

Brown and other colours of synthetic quartz have been reported to have been made, but it does not appear that they have yet come into the jewel market, and this applies to the prized violet and purple stone—the amethyst—of which it is doubtful whether any production has truly been made. The constants for these synthetic quartzes are the same as for the natural stones of this species and it is only by colour and colour phenomena that they can be identified.

RUTILE (TiO_2)

The synthetic rutile, sometimes called "titania", entered the market during 1948. Although grown in other colours, such as brown, red, orange, yellow and blue, the most important at the time was a near colourless variety, which was marred by the fact that it always showed an unpleasant yellowish tinge which precluded the stone from being a successful imitation of diamond. Synthetic rutile, even in its coloured varieties, does not seem to have had much acceptance in the jewellery trade, although there have been some reports that the Japanese have manufactured coloured material for gem purposes in recent years.

Rutile is grown on a modified Verneuil furnace, for titanium minerals (and this includes strontium titanate and other titanates) appear to lose oxygen when near melting point, so that the conventional Verneuil furnace is equipped with a surrounding annular tube supplying an outer envelope of oxygen to the normal oxy-hydrogen flame. The boules are black when taken from the furnace and need to be annealed before they become transparent and suitable for cutting.

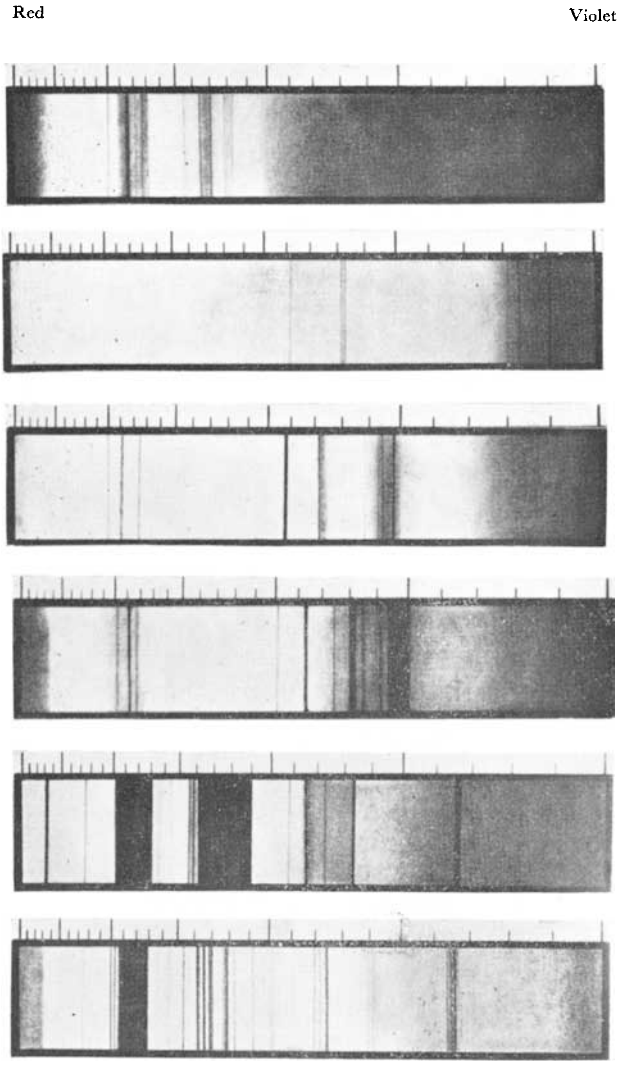
Rutile has a hardness of about 6½ on Mohs' scale, a density of 4·25 and refractive indices of 2·62 for the ordinary ray and 2·90 for the extraordinary ray. The crystallization is tetragonal and hence the stones are uniaxial. The birefringence is large, having a value of 0·287 and is positive in sign. The dispersion ("fire") is about six times that of diamond, and this, with the pronounced double refraction, makes the lighter coloured stones look rather garish. The stones do not show any perceptible luminescence but are usually slightly electroconductive and this may have a directional effect, being stronger along the optic axis than across it. The blue coloured stones are however strongly electroconductive and match the natural blue diamonds in this.

SCHEELITE ($CaWO_4$)

As a gemstone the calcium tungstate mineral called scheelite has little importance, except for those who collect unusual stones. Scheelite has, however, been produced synthetically mainly for certain of its properties which have an importance in modern science and industry. Single crystals of scheelite, reported to have been grown by the Verneuil technique by the firm of Linde Air Products during 1963, were reported upon by American gemmologists. One of these was a yellow colour and the other a lavender colour; the latter was "doped" with neodymium and the specimen showed strongly the rare-earth lines in the spectrum ascribed to this element. Currently the synthetical production of scheelite, which is used for laser production of coherent light, is carried out by the Czochralski "pulling" method of growth from a flux-fusion.

Synthetic scheelite is colourless, but the crystals may be "doped" for various scientific purposes and this "doping" gives various colours to the stones. Colourless scheelite has been cut, and so have the brown and yellow coloured material, and it is these latter stones which have posed problems in identification, for brown and yellow colours are common to natural scheelites. The synthetic stones, however, usually exhibit a stronger didymium spectrum than those of natural origin.

The hardness of scheelite is about 5 on Mohs' scale and the density about 6, there being some justification for suggesting that the density of the synthetic material may be slightly higher, at about 6·1, as against the 5·95 to 6·00 for the natural scheelite. Dana's *System of Mineralogy* gives the indices of refraction for natural scheelite as $\varepsilon = 1{\cdot}9365$ and $\omega = 1{\cdot}9208$, which gives for this tetragonal mineral a positive uniaxial birefringence of 0·0157. These figures are of little use to the gemmologist for they are outside the range of the refractometer.



SPECTRA OF SYNTHETIC SCHEELITE

TOP. *Rich red-brown scheelite.*
Pale yellow scheelite.
Pale green scheelite.
Pale green scheelite.
Rich purple scheelite.
Pale purple scheelite.

In common with the natural mineral, synthetic scheelite exhibits no, or very little, fluorescence under the long-wave ultra-violet lamp, but the stones glow strongly with a blue glow when irradiated with short-wave (2537A) ultra-violet light; but there are exceptions. Two pieces of synthetic scheelite of yellow colour, which exhibited rare-earth lines in the green and blue, glowed with a strong orange light under both radiations of ultra-violet light, and under x-rays a pink glow was produced. The density of these pieces was found to be 6·16. There is a report of a synthetic scheelite of a peridot-green colour, which had no recognizable absorption spectrum, and which fluoresced a dull brick or orange-red in only one half of the specimen when under ultra-violet light. Unfortunately no information was given as to the wavelength of the ultra-violet light employed.

SILICON CARBIDE (SiC)

Better known under the trade name "carborundum" and for its use as an abrasive, silicon carbide is formed by the fusion of 70% sand (quartz) and 30% coke (carbon), although crystals may have been produced by other methods. The reason for the inclusion for this material in this article is that a few stones have been cut from suitable crystals, which are normally thin and tabular. These platy crystals are of hexagonal symmetry and are usually bluish-green in colour, and the cut stones in appearance may resemble some "bombarded" diamonds.

The hardness of silicon carbide is about 9¼ on Mohs' scale and the density is 3·17. The refractive indices are 2·65 for the ordinary ray and 2·69 for the extraordinary ray and the positive birefringence is 0·043. The material has about twice the dispersion ("fire") of diamond, from which it may be identified by the double refraction, distinct dichroism and mustard-yellow fluorescence under long-wave ultra-violet light.

The above refers to the so-called "alpha" type of silicon carbide, but there is a cubic modification—the "beta" type—which is colourless and from its characters could be a possible diamond simulant. However, as far as the writer knows nothing has materialized in this direction.

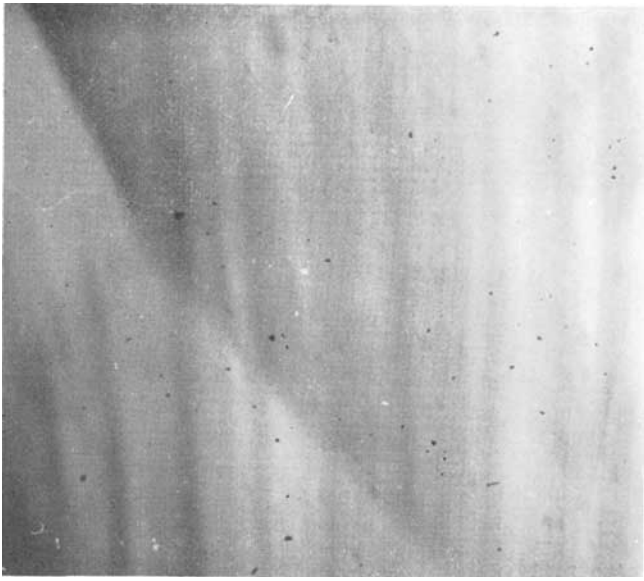
SPINEL ($MgAl_2O_4$)

The synthetic spinels which have been grown by the Verneuil process since, one might say, 1907 are too well known to need description and this section will deal only with stones of this species which have been produced since 1946.

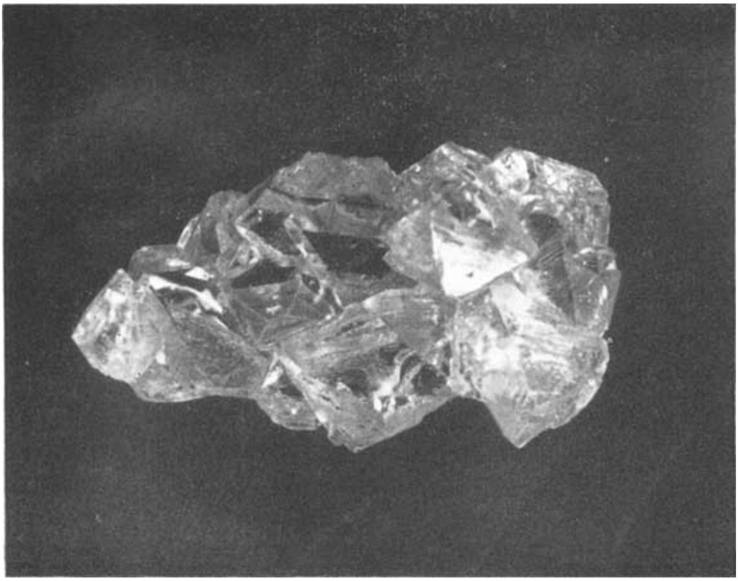
During 1954 a cobalt-rich sintered synthetic spinel was made to imitate lapis-lazuli. In a few cases small specks of gold were included in the sintered mass in order to simulate the iron pyrite which is so common an inclusion in lapis-lazuli itself, instances of where the imitation is of greater value than the real thing. Detection of these stones is easy, for apart from the strong cobalt absorption spectrum which can be seen by scattered light, the density, which is lower than for the normal spinels, of 3·52 will indicate the nature of the stone. The lapis-lazuli-coloured sintered synthetic spinels do not seem to have entered the British gemstone trade to any extent.

Three years later the schillerized synthetic white spinel came on the market. The schillerization produces a moonstone-effect and presumably the cabochon cut stones are intended to represent the moonstone variety of feldspar. Detection is again easy here for under the short-wave ultra-violet lamp these simulants of moonstone glow with the characteristic strong blue glow, in contradistinction to the true moonstone which glows with a yellowish light under similar excitation. Further, the other simulant of moonstone, the schillerized rock crystal, is inert under these ultra-violet rays.

The one colour of synthetic spinel which had not been made as a commercial production before 1946 was the red synthetic spinel. This was apparently due to the fact that chromium, which gives the red to ruby and the green to emerald, when introduced into the commercial type of boule which contains an excess of alumina, being, usually, $MgO2\frac{1}{2}Al_2O_3$, gives a "tourmaline green" colour. It is only in equimolecular boules, *i.e.* $MgO.Al_2O_3$, that a red colour is produced, and such boules are said to crack so badly that only small stones could be cut from them. However, about 1960 a number of small red synthetic spinels came on the market. These stones, which were only about a tenth of a carat in weight, were used for eternity rings. They do not seem to be prominent in the gem trade to-day. During 1968, whilst in the United States of



Curved bands of colour seen in an American synthetic red spinel.



A group of crystals of synthetic spinel grown by the flux-melt method.

America, the writer found that synthetic red spinels grown by the Verneuil process, were available in fairly large sizes, certainly greater than one or two carats.

The smaller stones of the earlier type were found to have an index of refraction of 1·722 and a density of approximately 3·60. The stones varied considerably in their internal structures and often showed pronounced curved colour bands, and/or lines, and included gas bubbles. The larger American stones have a refractive index of 1·720 and densities, taken on two samples in possession of the writer, of 3·580 and 3·594. The structures showed rather broad curved bands somewhat reminescent of the bands in synthetic blue sapphires. In all these stones, both the earlier small ones and the larger American production, the absorption spectra, and particularly the fluorescence spectra, resemble those of ruby in that only one strong fluorescent line is present, the rest being weak, and the whole effect is dissimilar to the "organ-pipe" spectrum seen in natural red spinels. The fluorescence is crimson under both ranges of ultra-violet light and under x-rays, in the latter case there being pronounced phosphorescence.

A more modern type of synthetic spinel is that grown by the flux-fusion method. Primarily intended for scientific purposes the crystals grow as octahedra or groups of octahedra, the latter having the greater gem significance as these groups have been used in the modern concept of jewellery design where uncut crystals form the central motif. Such spinel groups are grown in many colours by "doping" with trace elements, such as red by chromium and blue by cobalt, and there are seen groups with a yellow or pale blue-green colour, the "doping" agent being unknown in these cases.

The characters shown by specimens of these synthetic spinel groups, all of English manufacture, showed two specimens of red colour to have densities of 3·592 and 3·598 both showing a fluorescence spectrum having a single strong line at 6855A and traces of others. This fluorescence spectrum is similar to that shown by the Verneuil flame-fusion synthetic red spinels. Under ultra-violet light of both ranges the glow was crimson and under x-rays the fluorescence was more of a purplish-red and there was a persistent phosphorescence.

The blue-coloured group had a density of 3·600 and showed the typical cobalt absorption spectrum of three bands. Under the Chelsea colour-filter the group showed a bright red, but the group did not show the differential response to ultra-violet light as seen in the Verneuil-type blue synthetic spinels which show red under the long-wave ultra-violet lamp and a greenish- or bluish-white under the short-wave ultra-violet lamp. Indeed in the group examined there was very little luminescence under ultra-violet light or x-rays, except for a possible dull red glow when irradiated with the short-wave lamp. It is always problematical whether such a glow is not reflected from the light passed by the lamp.

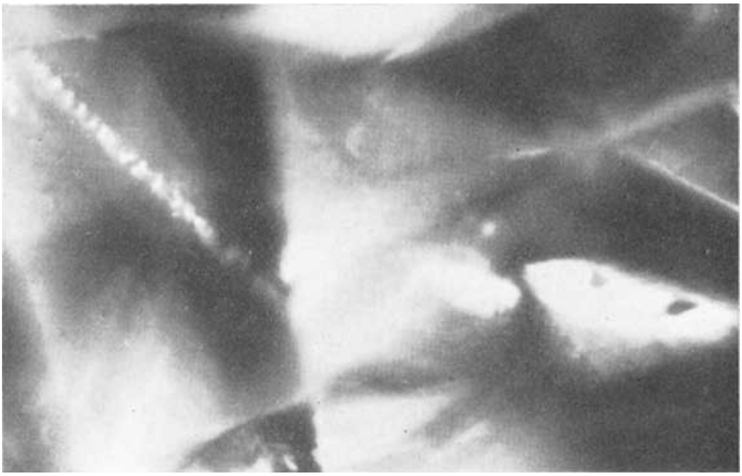
The yellow-coloured specimen was found to have a density of 3·609, showed no distinctive absorption spectrum, but exhibited a green fluorescence under long-wave ultra-violet light, practically inert or with a slight dull yellow glow under the short-wave lamp, but under x-rays the glow was a vivid green, there being no phosphorescence. The pale green specimens having densities of 3·601 and 3·589, again showed no characteristic absorption spectrum and only slight luminescent response of indeterminate colour under ultra-violet light, but a dull green glow under x-rays.

Two unusual specimens of similar habit and of a pale bluish-green colour were found to have unusual characters, for the density was about 5·7, and the absorption spectrum showed a fine line in the red and indeterminate lines in the yellow, which may be traces of the didymium series. The luminescence under ultra-violet light and x-rays was a strong yellow. The exact nature of these crystals is not known, but such objects may be mounted in their uncut state, as are the known flux-melt synthetic spinels.

As a footnote to the spinels, although they are unlikely to have any importance in jewellery—until someone wants an unusual black stone—is the flux-grown lithium-iron spinel. A specimen of this material was found to have a density of 4·58 and to be strongly magnetic.

STRONTIUM TITANATE ($SrTiO_3$)

A stone which is unknown to nature, strontium titanate, first came on to the market during 1953. Earlier known as "starilian" the stone is now better known as "fabulite". Despite its low hard-



"Ladder" in a strontium titanate.

ness, about 6 on Mohs' scale, this stone has outshone the synthetic rutile as a diamond simulant, for it is whiter in colour and has less "fire" than rutile. However, by its excessive "fire"—some four times that of diamond—it may be distinguished from diamond. The stone can be tricky when viewed in a half-light, but if attention be paid to the facet edges, which usually appear "rolled" (this is generally, but not always, a feature of strontium titanate) no deception need occur. Indeed it is these features, "fire" and "rolled edges", which must be looked for in a mounted stone, as the refractive index of 2·40 is near to that of diamond and is too high to measure on a refractometer. When the stone is unset the problem is easy for the density is 5·13, nearly half as much again as for diamond, hence if such a stone is gauged on a diamond gauge and then weighed, the "error" will be strikingly shown. Further, this difference must be taken into account if an estimate be needed to replace a diamond with a "fabulite".

Unlike diamond, strontium titanate does not fluoresce under ultra-violet light, and "fabulites" are comparatively opaque to x-rays in contradistinction to diamond, which is relatively transparent.

"Fabulites" are generally clean and do not show much in the way of inclusions, but "ladder-like" structures have been seen.

A. E. Farn has pointed out that the "ladders" are surface faults and can be induced by a needle used as a hardness point—a test not to be recommended unless great care be taken. In the same context it must be mentioned that "fabulites" are brittle and are easily damaged, and they have been known to become flawed all over after treatment in an ultrasonic cleaning bath. There should certainly be no difficulty in identifying these stones, but it must be realized that "fabulite" is one of the more convincing simulants of diamond.

YTTRIUM OXIDE (Y_2O_3)

There has been reported from America that crystals of yttrium oxide may provide another diamond simulant. The mineral is cubic in crystallization and has been reported as having a refractive index of 1·92 with a dispersion of 0·050. The hardness is said to be between 7½ and 8 on Mohs' scale, and a density of 4·84 has been mentioned.

ZINCITE (ZnO)

Another mineral which has been grown as synthetic crystals, by vapour-phase and by hydrothermal methods, is the zinc oxide called zincite. The only specimens of this product seen by the writer are small yellow crystals, but presumably larger ones could be grown.

The hardness and density of the natural mineral are given as 4½ on Mohs' scale and 5·43 to 5·7 respectively. The red to orange-yellow colour of the natural mineral may well be due to manganese oxide, and the refractive indices of zincite, which has hexagonal crystallization, are given as $\omega = 2{\cdot}013$ and $\varepsilon = 2{\cdot}029$.

The small specimens of synthetic zincite examined showed a dull to bright yellow fluorescence under ultra-violet light and a strong yellow or green under x-rays. There was no apparent dichroism nor was there any distinctive absorption spectrum.

ZIRCON ($ZrSiO_4$)

Zircon is another stone which has been grown synthetically as single crystals. This is not new for there is on show at the Musée de l'Histoire Naturelle in Paris a small crystal which was grown by

Hautefeuille and Perrey about 1890. A crystal of similar size is in the writer's collection, having been given to him by Dr. Kurt Nassau. It was probably grown by Bell Telephone Laboratories. This crystal, approximately 3mm by 2mm has a purple colour and a good tetragonal form consisting of prism and pyramids. Too small for much work to be carried out on it, some observations were, however, carried out of the absorption spectrum and on the dichroism. The absorption spectrum was seen to be dissimilar to that shown by natural zircons, but on such a small stone all that could be seen was a distinctive broad band absorbing the yellow region of the spectrum. There was no apparent fluorescence when the crystal was irradiated by either wave-band of ultra-violet light or under x-rays. What was most striking was the dichroism shown by the crystal. This was exceptionally strong, the "twin colours" being purple and yellow. Presumably the stone is "doped", but what with is not known. It has been mentioned that there is no reason, except perhaps because there is no demand, why larger crystals should not be grown.

This article has been written to record what has occurred in the way of manufacturing synthetic stones since about 1945, and it is hoped that it will serve as a guide to the problems which may well beset the gemmologist in the future.

The writer is indebted to Dr. Kurt Nassau of New Jersey, U.S.A., Mr. Jerry Call of the New York Laboratory of the Gemological Institute of America, and Mr. Grant Waite of Toronto, Canada, for the gift of many of the specimens examined. To Mr. B. W. Anderson and the Officers of the Gemmological Association of Great Britain, thanks are also due for the loan of specimens from their collections. Without the help of these friends this compilation could not have been completed.

TABLE OF CONSTANTS OF SYNTHETIC CRYSTALS

The more important stones are shown in heavy type

	H.	S.G.	R.I.	Bi-ref.
Barium titanate	6-6½	5·90	2·40	Isotropic
Beryl				
Emerald (Chatham)	**7½**	**2·65**	**1·562**	**0·003**
Emerald (Zerfass)	**7½**	**2·66**	**1·562**	**0·003**
Emerald (Gilson)	**7½**	**2·65**	**1·562**	**0·003**
(Gilson recent)	**7½**	**2·69**	**1·572**	**0·005**
Emerald (Linde)	**7½**	**2·71**	**1·575**	**0·005**
"coated" beryl	**7½**	**2·70**	**1·570**	**0·005**
Beryl (other colours)	7½	2·68	1·570	0·005
Boron carbide	9½	2·51	?	?
Bromellite	9	3·01	1·728	0·015
Calcium titanate	6	4·05	2·40	?
Chrysoberyl	8½	3·71	1·745	0·009
Corundum	**9**	**3·99**	**1·764**	**0·008**
Diamond	10	3·52	2·42	Isotropic
Fluorite	4	3·18 +	1·45	Isotropic
Gahnite	7½-8	4·6	1·82	Isotropic
Garnet types:—				
YAG	**8**	**4·57**	**1·832**	**Isotropic**
Terbium	7 +	6·06	1·873	Isotropic
Dysprosium	7 +	6·20	1·85	Isotropic
Holmium	7 +	6·30	1·863	Isotropic
Erbium	7 +	6·43	1·853	Isotropic
Thulium	7 +	6·48	1·854	Isotropic
Ytterbium	7 +	6·62	1·848	Isotropic
Lutecium	7 +	6·69	1·842	Isotropic
YIG	7 +	5·99	?	Isotropic
Hematite garnet	7 +	4·20	?	Isotropic

	H.	S.G.	R.I.	Bi-ref.
Greenockite	3½	4·85	2·51	0·023
KTN	6½	6·43	2·27	?
Lithium niobate	**5½**	**4·64**	**2·25**	**0·090**
Magnetite	6	5·17	?	Isotropic
Magneto-plumbite	?	5·52	?	?
Periclase	**5**	**3·57**	**1·74**	**Isotropic**
Quartz	**7**	**2·65**	**1·55**	**0·009**
Rutile	**6½**	**4·25**	**2·75**	**0·287**
Scheelite	**5**	**6·1**	**1·925**	**0·016**
Silicon carbide	9¼	3·17	2·67	0·043
Spinel	**8**	**3·61**	**1·72**	**Isotropic**
Strontium titanate	**6**	**5·13**	**2·40**	**Isotropic**
Yttrium oxide	8	4·84	1·92	Isotropic
Zincite	4½	5·55	2·02	0·016
Zircon	7½	4·68	1·95	0·059

The values given are taken from literature and checked where possible by personal determinations. Some of the values given are those from the literature on natural minerals where it can be assumed that the synthetic crystals would not depart from them.

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ASSOCIATION NOTICES

GIFTS TO THE ASSOCIATION

The association is indebted to Scandinavian Jewellers' Associations for a bound copy of the first edition (1970) of the Scandinavian diamond nomenclature and grading standards.

The Association is also grateful for a gift of star-stones and cats-eyes from the executors of the late Nigel Kennedy (Cheshire) and for a cut ekanite from Mrs. C. Mendis (Ceylon).

A collection of Indonesian cabochon agates, cut and polished in Indonesia, has kindly been donated by Mr. Tampubolon, Ir. L. C., Djakarta.

GEMS AND GEMOLOGY

Copies of the Spring 1967 and Winter 1968-1969 issues of *Gems and Gemology* are required.

BRANCH MEETINGS

For their 1970 summer outing, members of the Scottish Branch of the Association visited Edinburgh Castle. A private viewing of the Scottish Regalia was arranged, allowing close examination of exhibits which is not possible when the general public are admitted. The Crown Jewels were of special interest. After lunch members visited the Royal Scottish Museum which contains an excellent collection of minerals and gemstones.

The Annual General Meeting of the Midlands Branch of the Association was held on the 12th June, 1970, at the Auctioneers Institute, Birmingham. Mr. P. Spacey presided and in his report recalled the meetings held during the past year. The following

Officers were elected: Chairman, Mr. P. Spacey; Vice-Chairman, Mrs. S. Hiscox and Secretary, Mr. P. West. Messrs. P. Alabaster, J. Marshall, D. Jones and G. Porter were elected to the Committee.

EXAMINATION RESULTS

The results of the 1970 examinations in gemmology will be published in the January 1971 issue of the *Journal.*

SUBSCRIPTIONS 1971

As announced in the July 1970 issue of the *Journal of Gemmology,* Vol. 12, No. 3, the annual subscription for Fellowship and ordinary membership will be £3 0s. 0d. as from 1st January, 1971. The annual subscription for the *Journal of Gemmology* for non-members has been increased to £4 0s. 0d.

EXAMINATIONS 1971

The 1971 Examinations in Gemmology will be held on the following dates:

Preliminary: Tuesday, 15th June, 1971.

Diploma Theory: Wednesday, 16th June, 1971.

Diploma Practical: Thursday, 17th and Friday, 18th June, 1971, London.

Provincial and overseas centres by arrangement.

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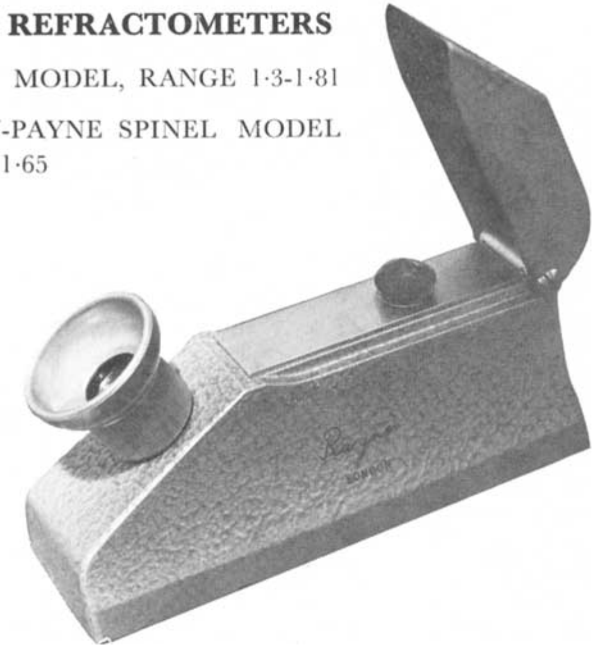
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