SOME UNUSUAL GEMSTONES IN THE COLLECTION OF THE RIJKSMUSEUM VAN GEOLOGIE EN MINERALOGIE OF LEIDEN

by

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Introduction

Our Museum can take pride in a very valuable gem collection for, besides the numerous specimens which were gathered by King William I of the Netherlands, a great many of the more unusual stones are to be found in it. Especially since World War II the Museum has acquired many interesting and important stones by gifts and purchases. This enlargement is especially due to the efforts of Professor Dr. B. G. ESCHER, who was continually aimed at the acquisition of rare and unusual stones for the gem collection, bringing it gradually up to modern standards.

As in so many gem collections, one finds stones which are not suitable for wearing, because they are soft or easily cleavable. It is surprising to see the variety of minerals that have been cut in recent years and which are scarcely suitable as gems for this reason. They are collectors' stones only.

In this paper ten stones, belonging to our collection, will be described. This description has been based on the newest methods of investigation and special attention has been paid to the spectroscopic examination.

The figure that accompanies the paper is an immersion contact photograph, a technique to measure approximately the refractive indices of cut stones. This method was introduced by ANDERSON in 1952. Of these ten stones, alexandrite and spinel are more rare than unusual.

Alexandrite is a well-known stone but fine specimens are very rare. Our specimen shows a good colour change in daylight and in artificial light, which cannot be said of most alexandrites.

The spinel in this group is larger than usual and of a colour which is rarely seen.

The remaining stones are very unusual and hardly ever occur on the market.

Spessartite is a rare garnet which is characterized by the typical inclusions and the absorption spectrum.

The new mineral sinhalite is still comparatively rare.

The inclusions of diopside (No. 5) are of great importance, as I have not yet found any description of them in the literature on the stone.

Bronzite (No. 6) has a very rearkable pleochroism and an exceptional absorption spectrum; these properties are important to distinguish this stone from kornerupine which has about the same physical properties as bronzite.

The andalusite shows a particularly strong pleochroism and nice liquid inclusions can be seen.

The cut apatite specimens from Mexico are not yet widely distributed, our sample shows special inclusions.

Finally a very lovely little specimen of gem scapolite adorns the collection; the rutile inclusions are very interesting.

Acknowledgements. I am indebted to Mr. R. K. MITCHELL, F. G. A. of London, who was so kind as to correct the English manuscript.

Further I want to thank Mr. B. F. M. COLLET, who made the figures and Miss J. A. A. VAN WERKHOVEN, who typed the manuscript.

Methods of determination

The specific gravity of the stones was measured with the aid of a hydrostatic balance; for that purpose they were immersed in distilled water and hung in a coil of silver wire.

For each stone a number of measurements was made and the mean value for the specific gravity was taken.

The refractive indices were measured by means of a RAYNER refractometer, using sodium light. The stones were put on it with the table on the glass of the refractometer.

The largest possible distance between the shadow edges was obtained by mounting a FIELD Rotagem on the refractometer.

Mr. A. C. TOBI was so kind as to measure the refractive indices of a rough bronzite specimen with the aid of a Double Variation Equipment after EMMONS. The absorption spectra of the stones were examined as far as possible with a HARTRIDGE Reversion Spectroscope. The accuracy of this instrument is not very great for broad bands; in such cases readings may be incorrect to 10 Ångström units. The pleochroism was observed with a dichroscope when this was necessary.

Use was made of a Chelsea colour filter for some stones when necessary for determination.

Description of the gems

No. 1: *Spessartite from Pecos Caballos, Brazil*

This orange-red garnet is trap-cut and it weighs 2.36 carats. The size is 9.1 × 6.8 × 3.2 millimeters. The stone is completely transparent but contains many inclusions which can be observed with the naked eye.

Microscopically one sees typical liquid inclusions (fig. 1) which are described by ANDERSON (1951, p. 185) as follows:

"These are difficult to describe, but appear rather like shreds of a black mantilla shawl which has been torn to pieces and scattered at random through the stone".

CHUDOBA and GÜBELIN (1953) even state such inclusions do not occur in other garnets. The stone has an anomalous double refraction; its refractive index N = 1.802; the specific gravity is 4.155. These values are somewhat higher than those of spessartite from Ceylon that generally have N = 1.795 and S. G. = 4.12.

The absorption spectrum is very characteristic; it has strong bands in the blue and violet and weak bands in the green. In the green part of the spectrum a broad band can be observed centred at 5698 Å, a band at 5304 Å and a sharp band at 5045 Å.

Two further strong lines are seen at 4875 Å and 4605 Å in the blue; finally a strong band at 4316 Å is present in the violet. The two bands in the green at 5698 Å and 5304 Å are weak almandine bands which are evidently present in this spessartite; ANDERSON (1951) considers this to be a normal phenomenon. We can explain these almandine bands because almandine and spessartite belong to an isomorphous series. Although the stone has no

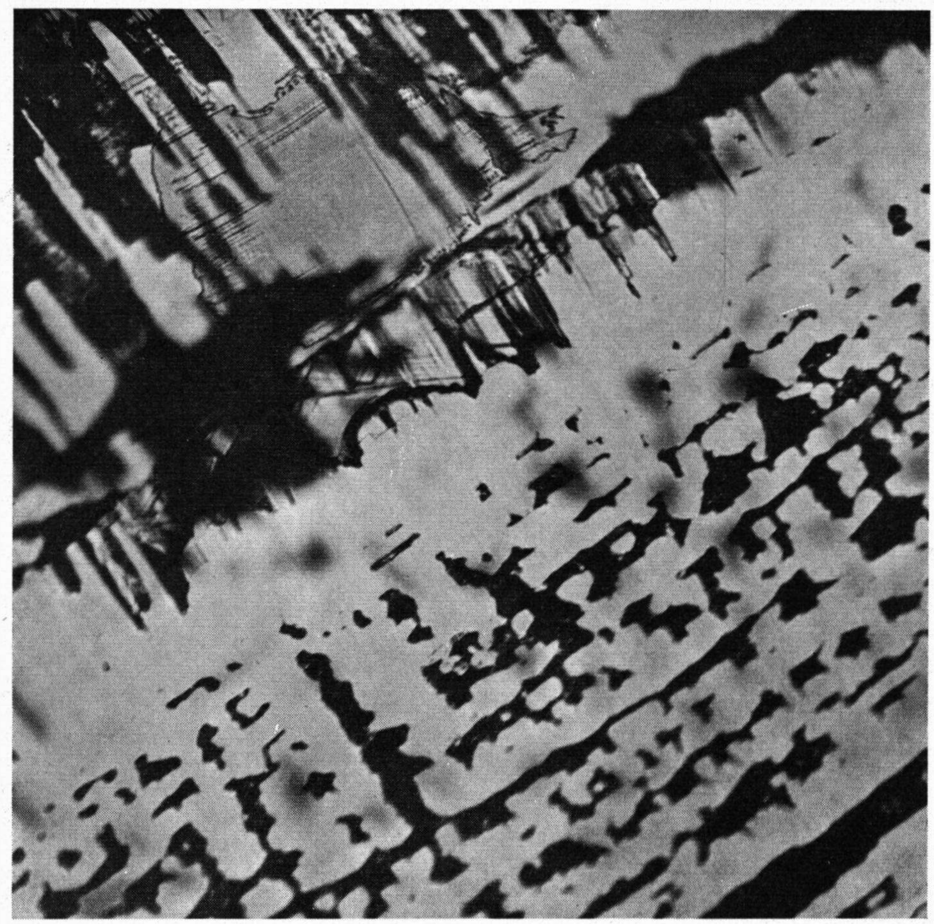

Fig. 1. Liquid inclusions in spessartite (No. 1). × 100.

great aesthetic value because of the numerous inclusions, it is a precious possession by reason of its rarity.

No. 2: *Alexandrite from Ceylon*

This mixed-cut stone is watery green coloured in daylight with orange-red flashes. In artificial light it has a watery red colour. It is a transparent stone and the weight is 2.89 carats.

The size is 10.1 × 9.8 × 2.9 millimeters.

The specific gravity is 3.710.

The refractive indices were measured $N_z' = 1.753$ and $N_x' = 1.745$. The stone is strongly pleochroic: Z = bluish green, Y = pale yellow and X = red.

Under the Chelsea colour filter the stone has a bright red colour. The absorption spectrum is characteristic; two strong lines are observable in the red at 6802 Å and 6787 Å, further weak lines in the red at 6653 Å, 6652 Å and 6458 Å. In the yellow part of the spectrum a broad band is present centred at 5778 Å.

Finally two vague narrow bands occur in the blue at 4740 Å and 4672 Å; while the violet is absorbed altogether.

With microscopic examination straight bands can be seen parallel to the extinction position Z and perpendicular to X. Although the specimen is not deeply cut and therefore not deeply coloured, it shows the change in colour between day- and artificial light very well and our Museum can be proud of this stone.

No. 3: *Spinel of unknown origin*

(No. 539 in the Gem collection of the Museum)

This mixed-cut stone has an indigo blue to violet colour and weighs 10.46 carats.

The size is 14.8 × 11.5 × 7.2 millimeters. It is a splendid transparent stone, a rare specimen in respect of its size and curious colour.

The specific gravity is 3.635 and the refractive index N = 1.720, though on some back facets it is measured N = 1.721 and 1.722. This spinel has an anomalous double refraction and contains curious black mineral inclusions (see fig. 2). These inclusions form together four systems of crystal feathers, each of them having a definite direction. In addition straight bands can be observed.

The spinel has a characteristic absorption spectrum. A weak band at 6310 Å in the orange part of the spectrum and a weak band at 5913 Å in the yellow are present. In the green a stronger band at 5541 Å can be seen, while in the blue part of the spectrum a strong sharp band at 4795 Å and a strong broad band centred at 4587 Å can be observed.

Under the Chelsea colour filter the spinel has a deep red colour.

No. 4: *Sinhalite from Ceylon*

The stone is mixed-cut and has a yellowish brown colour. The size is 17.0 × 15.8 × 7.5 millimeters, its weight is 18.23 carats.

The transparent sinhalite has a distinct pleochroism of pale brown, green and dark brown.

The highest and lowest values for the refractive indices are $N_z' = 1.708$ and $N_x' = 1.670$, the specific gravity is 3.504.

This new mineral, first described by Claringbull and Hey (1952), formerly was thought to be brown olivine which it closely resembles.

Besides a difference in chemical composition and optical properties, sinhalite has also a different absorption spectrum from olivine.

In the absorption spectrum of sinhalite one may observe a vague band at 5264 Å in the green; in the blue part of the spectrum two sharp strong lines at 4932 Å and 4746 Å; a broad strong band centred at 4630 Å and a weaker band at 4524 Å can be seen while there is an over-all absorption of the violet. These data agree very well with those mentioned for sinhalite by ANDERSON in 1952.

Fig. 2. Crystal feathers in spinel (No. 3). × 30.

Finally it may be noted that by viewing the back facets with a pocket lens through the table a doubling of these facets can be observed. This is due to the strong double refraction (0.038) of sinhalite.

No. 5: *Diopside from Madagascar* (St. 55585) [1])

This mixed-cut stone is bottle green coloured. The size is 12.4 × 9.0 × 6.5 millimeters, its weight is 5.07 carats. The stone is transparent and shows a distinct pleochroism in tones of yellowish green and dark green.

[1] Registration number of the Rijksmuseum van Geologie en Mineralogie, Leiden.

The inclusions which can be observed are crystal feathers (see fig. 3) consisting of liquid inclusions together with curious flat extended vanes, probably internal cleavage planes.

The specific gravity is 3.292, the refractive indices are $N_z' = 1.700$ and $N_x' = 1.672$.

The rather strong double refraction (0.028) causes a doubling of the

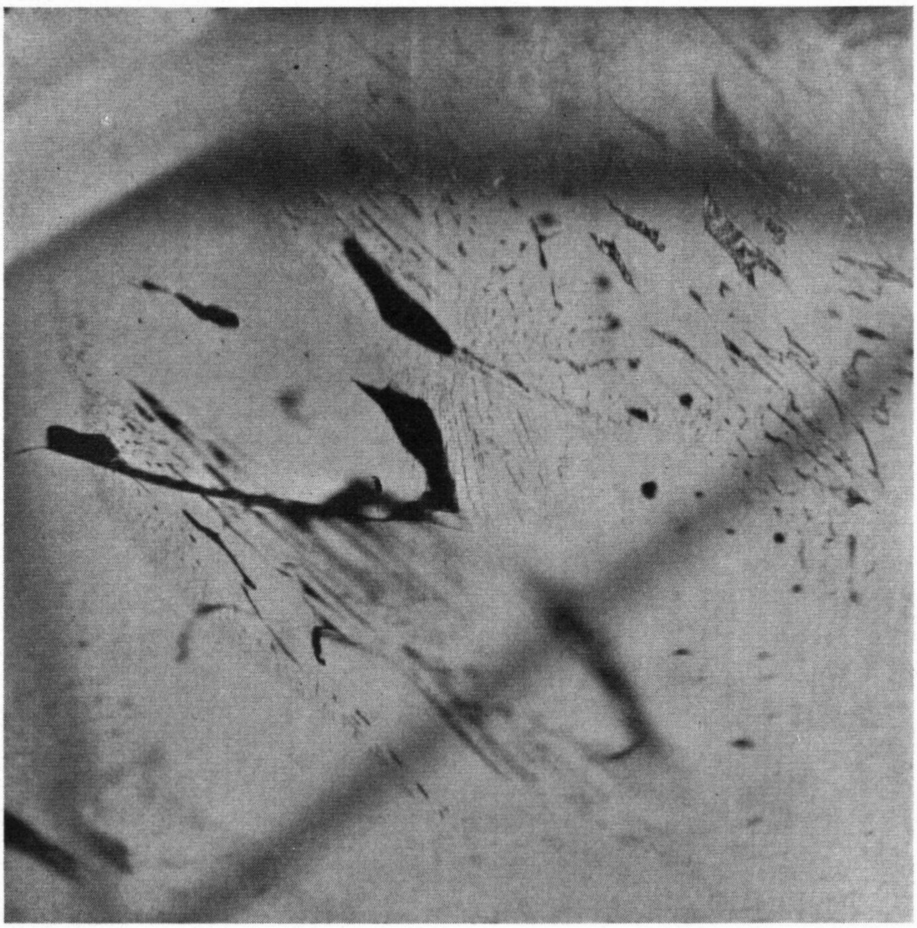

Fig. 3. Liquid feathers in diopside (No. 5). × 30.

back facets when viewed with a pocket lens through the table. The stone is bluish green coloured under the Chelsea colour filter. Although diopside, being a pyroxene, is an important rock-forming mineral, a cut specimen of gem quality must be considered as an unusual phenomenon.

No. 6: *Bronzite from Mysore, India*

This stone has a deep red-brown colour which is a rarity in a gemstone collection. Generally orthopyroxenes, important in gemmology, have a green colour (enstatite). The mineral is trap-cut and transparent. Its weight is 2.48 carats, the size is 12.6 × 5.4 × 3.5 millimeters.

The specific gravity is 3.331, which agrees very well with the value mentioned by MITCHELL in 1953 for the same material (3.33). The refractive indices are $N_z' = 1.678$ and $N_x' = 1.669$.

The most curious phenomenon is the pleochroism in tones of orange-red, pale grass-green and pale orange; this is very strong and characteristic for this mineral.

The absorption spectrum is also characteristic, a moderate band at 5490 Å and a strong narrow line, surrounded by some weaker lines, occur at 5057 Å in the green, further a weak line can be observed at 4838 Å in the blue and a weak line at 4496 Å in the violet part of the spectrum.

These data agree with those stated by TRUMPER in 1954 for the same material.

Under the microscope straight lines can be seen and here and there needle-like signs of cleavage. We have called this stone "bronzite" because of the following reasons:

Mr. R. K. MITCHELL, F. G. A., who calls this mineral "hypersthene-enstatite" was so kind as to place at our disposal some rough pieces of the mineral for investigation.

The optical properties of this sample have been measured as follows by Mr. A. C. TOBI: $N_z = 1.6817$, $N_y = 1.6760$ and $N_x = 1.6683$.

The double refraction is 0.0134, the optic axial angle $2V = -80°$, the mineral has a weak dispersion ($\rho < v$).

Further an X-ray powder diagram has been produced from a mixture of 70 % orthopyroxene and 30 % quartz. (Camera diameter 9 cm, $FeK\alpha_1$-radiation with $\lambda = 1.93597$ Å.)

With the aid of a method which has been described in detail in the doctoral thesis of the writer (ZWAAN, 1955), the molecular per cent enstatite (mg) has been determined as follows:

The relative distance between the pyroxene reflections 1031 and 060 $= 0.74$ mm $\rightarrow$ mg $= 89.5$ or 80.

The relative distance between quartz reflection $21\bar{3}1$ and pyroxene reflection 060 $= 3.45$ mm $\rightarrow$ mg $= 88.5$ or 84.

The relative distance between quartz reflection $(20\bar{2}3)(30\bar{3}1)$ and pyroxene reflection 1131 $= 1.30$ mm $\rightarrow$ mg $= 76.0$ or 85.

The latter mg's of these three measurements approximate rather closely.

They give an average value of mg = 83.

From this value of mg it appears further that the atomic proportion of Al, calculated on the base of six oxygen atoms is about 0.045 in B^{VI} position and the atomic proportion of Ca is about 0.050.

The relative distance between above mentioned reflections are measured with a Cambridge Universal Measuring Machine.

From a diagram in KUNO (1954) it is further seen, that for $N_z = 1.6817$ with Al < 0.070 the molecular per cent enstatite will be 84.5 which agrees rather well with the value obtained from the röntgenographic investigation. Since, according to the newest nomenclature which among others is used by KUNO, all orthopyroxenes with mg between 90 and 70 are called bronzite, we have called this orthopyroxene, with mg = 84.1, bronzite.

No. 7: *Kornerupine from Ceylon*

This mixed-cut stone has a brownish green colour and weighs 1.93 carats. The size is 8.3 × 7.0 × 3.7 millimeters.

The specific gravity is 3.329; this is rather high for, according to WEBSTER (1947), the S. G. of kornerupine varies from 3.27 to 3.32, although TRUMPER (1954) reports a S. G. = 3.41 for a kornerupine from Ceylon.

The highest and lowest values of the refractive indices are 1.681 and 1.670. The stone is transparent and strongly pleochroic, observable with the naked eye if the stone is turned between the fingers. The colours being bluish green, yellowish brown and pale brown.

The stone contains inclusions of crystals, which have a prismatic habit and are doubly refractive; it is not known, however, what mineral has been enclosed by the kornerupine.

Although the physical properties of kornerupine agree rather well with those of bronzite No. 6 and it will therefore be rather difficult to distinguish bronzite from kornerupine by means of these properties, the absorption spectrum of kornerupine is quite different from that of bronzite or enstatite.

In the spectrum of kornerupine one may see the following: a weak band at 5497 Å in the green, further a broad band, centred at 4980 Å in the green-blue, the rest of the spectrum is generally absorbed from 4650 Å on. This absorption spectrum can be observed with difficulty in contrast with that of bronzite or enstatite. These results agree with those mentioned by TRUMPER in 1954.

No. 8: *Andalusite from Brazil*

This trap-cut stone is a donation of Mr. P. N. J. BODES, F. G. A. and Mr. A. G. BODE of The Hague. The stone has a yellow-green colour with orange flashes and is transparent.

The sizes are 7.1 × 5.3 × 2.8 millimeters, its weight is 1.00 carats.

The specific gravity is 3.146 and the refractive indices are $N_z' = 1.643$ and $N_x' = 1.633$.

The pleochroism is so strong, that it is easily observable with the naked eye, the different colours are bright grass-green, yellowish and deep red.

The absorption spectrum shows a rather strong line at 4548 Å in the blue, which agrees with WALTON's (1952) figures for the spectrum of andalusite, further there is a general absorption of the violet.

Under the microscope a crystal feather of liquid inclusions and straight bands are visible (see fig. 4).

This andalusite, very rare in the market, is a valuable possession in the collection of the Museum.

No. 9: *Apatite from Durango, Mexico*

This stone is greenish yellow coloured, transparent and trap-cut. Its weight is 2.01 carats, the size is 8.4 × 6.3 × 4.2 millimeters.

The specific gravity is very high (3.217), as the normal value for such apatites is stated to be 3.18.

WEBSTER (1947) says, that the S. G. may vary from 3.15 to 3.22. The highest and lowest values of the refractive indices are 1.637 and 1.634 respectively.

It is difficult to read these values using the normal RAYNER refractometer and an ANDERSON-PAYNE spinel refractometer would be more useful in this case.

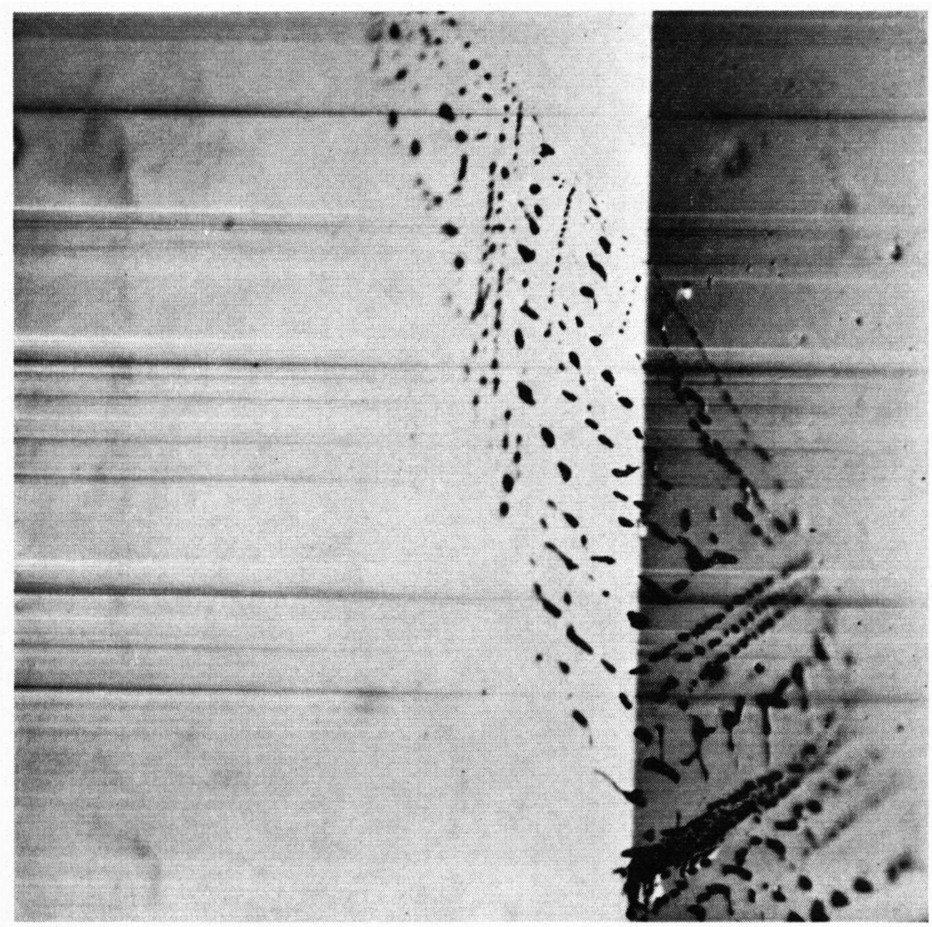

Fig. 4. Liquid feather and straight bands in andalusite (No. 8). × 30.

The pleochroism in tones of pale green-yellow and gold-yellow is weak, it is only observable with the aid of a dichroscope. The stone has a characteristic, strong didymium absorption spectrum, with lines at 5820 Å in the yellow part of the spectrum and some sharp lines at 5277 Å in the green. The spectrum can be better observed in reflected light. The stone contains needle-like fine channels (see fig. 5).

RUTLAND (1954) has also described such inclusions in apatite from Durango.

The photograph also shows fractures on some facet edges due to the low hardness, which clearly indicates the unsuitability of apatite for wearing.

No. 10: *Scapolite from Madagascar* (St. 55584)

This square-cut stone has a pale yellow colour and is very transparent. The size is 6.2 × 6.2 × 4.4 millimeters, its weight is 1.26 carats.

The specific gravity is 2.685. The measured refractive indices are $N_o' = 1.572$ and $N_e' = 1.551$. The dichroism in tones of pale yellow and colourless is distinct. Rutile needles occur as inclusions.

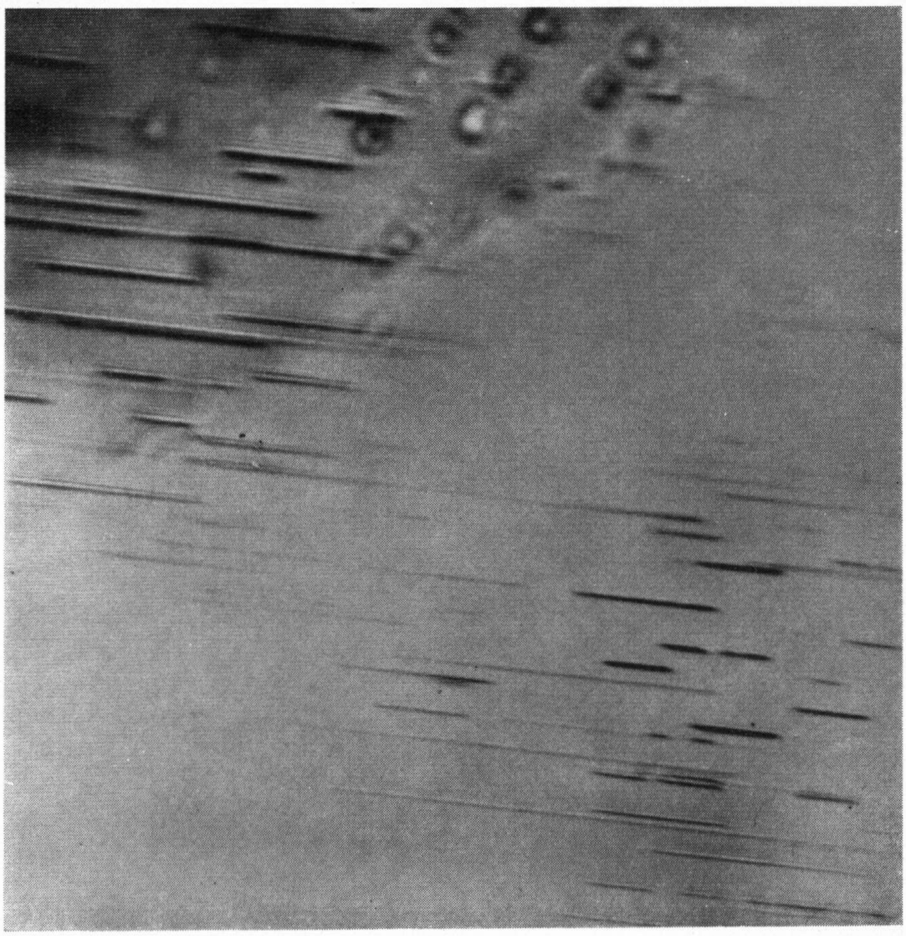

Fig. 5. Needle-like channels in apatite (No. 9). × 100.

The absorption spectrum shows some weak bands in the green, blue and violet part of the spectrum. They are so weak that measurement is difficult and inaccurate, so we will omit giving values. Under the light of an ultraviolet lamp the scapolite has a pale orange-yellow fluorescence. This scapolite is one of the most attractive stones in the collection.

Immersion contact photograph

In 1952 ANDERSON described a simple new method to determine approximately the refractive index of a stone. Although this method cannot replace other immersion techniques for the determination of refractive index, it has its importance because it is very simple, aesthetically very rewarding and besides may serve as a "fingerprint" for the stone.

The principle of the method is that, by immersion of gemstones in a liquid, all stones with a higher refractive index than that of the surrounding liquid will have a black border to their shadows due to total internal reflection at the edges of the stones when illuminated from above and seen on the other side through a transparent piece of paper or through ground glass. Stones with a lower refractive index than that of the liquid have a white border. Stones with a black border have white outlines to the facets, those with a white border have black facet edges.

Fig. 6 is a slightly enlarged immersion contact photograph of the described stones in monobromonaphthalene. This picture has been made as follows: first the immersion cell with stones and surrounding liquid was placed on a Gevaert diapositive contrast glass slide. This was exposed during three seconds with 150 watt frosted bulb at a distance of about 50 centimeters, mounted in an enlargement equipment. The result was a negative contact picture. This was enlarged on Ilford Bromide normal printing paper. The resulting positive print was inscribed with the text and after that photographed on a 32° Gevaert Superchrom glass slide. From the latter a positive print was made (fig. 6) by printing on Ilford Bromide normal printing paper.

It is now seen that spessartite (No. 1) has a heavy dark border and white facet edges due to its high refractive index. In addition the inclusions can be easily recognized.

Alexandrite (No. 2) has a thinner black border due to its smaller refractive index but still higher than that of the liquid. At the same time it can be observed that the stone is irregularly cut.

Spinel (No. 3) has, as could be expected, a thinner black border. Not much detail of the facet edges can be seen due to many inclusions to the thickness of the stone and to the low transmission in the blue-violet regions.

Sinhalite (No. 4) has a narrow black border, the mean refractive index of this stone is only a little higher than that of the surrounding liquid. The junctions of the facets cannot be seen clearly because the stone is rather strongly coloured and thick. It is also due to the low transmission in the blue-violet regions.

Diopside (No. 5) has a dark rim approximately equal to sinhalite; they have about the same mean refractive index. Other internal features can be observed in this diopside.

Although bronzite (No. 6) and kornerupine (No. 7) have a mean refractive index higher than that of the liquid, in the photograph they show a thin white border and black facet edges. This is due to the fact that the film is most sensitive for blue-violet light and for this light the refractive index of monobromonaphthalene is actually higher than that of bronzite and kornerupine due to the high dispersion of the liquid. Here is a difference between sensitivity of the film and the eye. To the eye, the reverse effect is visible by viewing through a piece of transparent paper.

Andalusite (No. 8) with a mean refractive index of 1.638 has a sharp white border and black facet edges. At the same time straight bands can be clearly observed.

Apatite (No. 9) has a somewhat broader white border than andalusite (No. 8), which would be expected.

Finally a heavy white border and broad black facet edges can be seen in scapolite (No. 10).

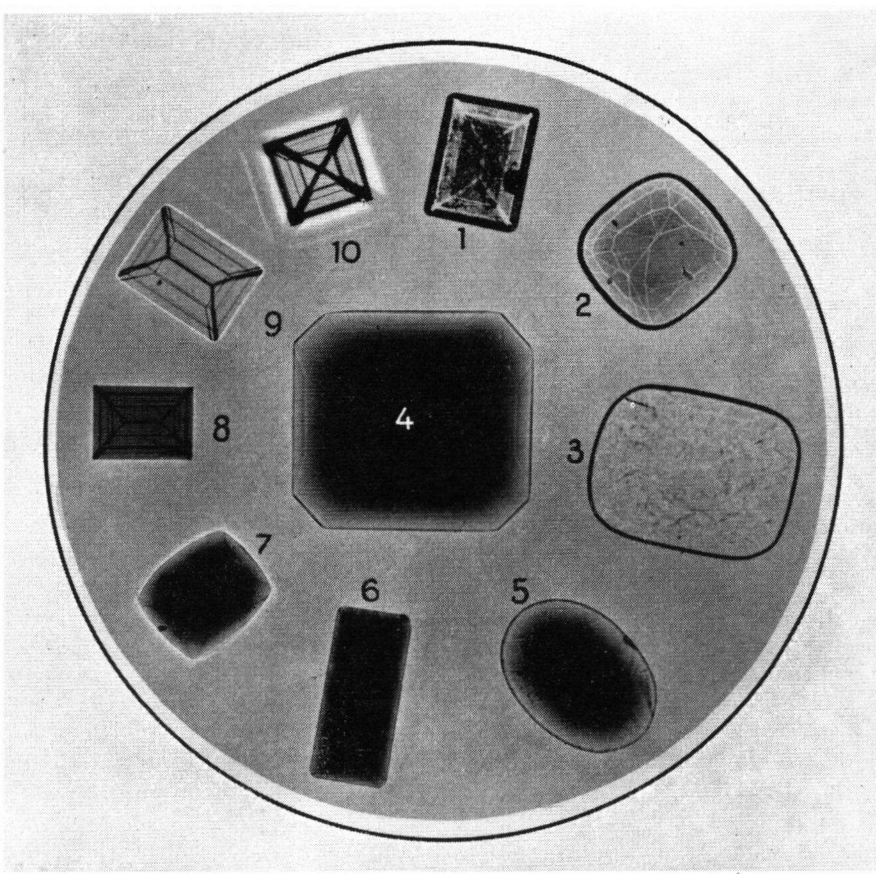

Fig. 6. Immersion contact photograph of all the described stones in monobromonaphthalene (N = 1.66). × 1.8.

It appears that from the thickness of the border the approximate difference between te refractive index of the stone and that of the liquid can be deduced by using different liquids with known refractive indices; it is possible to determine the refractive index of a stone, approximately. Moreover internal features can often be distinguished and the photograph can serve as a "fingerprint" of the stone.

In view of its simplicity this method can be used with success by those who have no expensive instruments at their disposal. This is an important advantage of the method.

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