# 5. Determinations of the power of refraction of a number of allanites.

By

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In the course of the two last years I have undertaken some approximative determinations of the refraction of certain allanites. As our knowledge of the refractive power of allanite has remained very imperfect up to the present time, and my determinations partly refer to previously analyzed specimens, it seems to me that my results might deserve publication.

In the mineralogical and petrographical literature I have found only three statements referring to the numerical values of the refractive indices of allanite. These three determinations have been carried out by MICHEL-LÉVY and LACROIX. According to their measurements allanite from Pont-Paul at Morlaix, Départ. Finistère, France, had a medium refraction $> 1{,}78$ (Bull. Soc. Franç. de Min., 1888, T. 11, p. 67), allanite from Næskilen in Norway $\beta = 1{,}682$, and allanite from Edenville $\alpha > 1{,}78$ (MICHEL-LÉVY et LACROIX, Minéraux des roches, Paris 1888, p. 185).

All the allanites examined by me occurred in, at least, comparatively large fragments or individuals; for this reason there was, in general, no difficulty in obtaining pure material for the investigations. If there was, in some case, any doubt whether the mineral to be investigated was really allanite, blowpipe- or other tests were made in order to make the determination certain.

A thin-section having shown me that an allanite from Vargholmen at Gottenvik in Östergötland, Sweden, was completely isotropic and looked rather homogenous, I was at first interested to see, if it would be possible to get its refractive index so simply as by means of the total refractometer. A polished surface of a piece of the mineral in question was placed upon the refractometer, but, though the polish was very high and total reflection took place, it was quite impossible to discern any limit of total reflection. I next tried the immersion method, and then stated that, as was to be expected, the allanite substance was not in reality homo-

genous; the small fragments of the pulverized, isotropic mineral showed different refractive index, and the variation was within comparatively wide limits.

In all the following determinations I only used the immersion method. In order to study the relation between refractive index and density of the allanites, I also determined their specific gravity. If possible, fragments of the allanites were brought to suspension in the common heavy solutions, in the remaining cases the sp. gr. was determined by weighing in benzol. As the density of allanite evidently varies somewhat even within the limits of a rather small piece of the mineral, I naturally used quite the same material for the determinations both of density and refractive index. All the small pieces used at the determination of the sp. gr. were afterwards crushed together, and the investigation of the refraction was executed upon the intimate mixture of small fragments thus obtained.

The computation of the medium refractive index of a certain allanite was performed in the following way: The solutions used were the standard ones with an original difference of refraction of $0{,}005$ between two consecutive members of the series of solutions, their actual refractive indices having been established by means of the total refractometer, when found necessary. Different portions of small fragments out of the crushed part of an allanite were examined in the different solutions, until the limiting values of the power of refraction had been sufficiently carefully determined. Besides, for every solution with a refractive index falling between these values, there was made a rough estimate, how many of the fragments momentarily placed under the microscope had a refractive index above, equal to and below that of the solution just used. In order to secure a somewhat higher degree of accuracy, such determinations were very often repeated two or three times with different portions of fragments in the same solution. Afterwards there was no difficulty in determining an approximative value of the medium refractive index of the allanite substance, a value, the incertitude of which in most cases could not exceed a few units in the third decimal place. In the following I have, in general, expressed the medium values in question with three decimals, though the last one is put in a paranthesis, because of the incertitude just referred to. The points corresponding to the more trustworthy couples of sp. gr. and medium refractive index were plotted into a diagram (fig. 1).

As the allanites, even when unaltered, have no constant chemical composition, and are generally to be found in, at least, a somewhat altered condition, it is not to be expected that the relation between their sp. gr. and medium refractive index should be so simple that it would be possible to express it by means of a single curve. Nevertheless, the relation mentioned is of such a nature that the points corresponding to the different allanites, altered or not altered, occupy an area in the form of a straight, narrow strip of considerable length. Broadly viewed, the

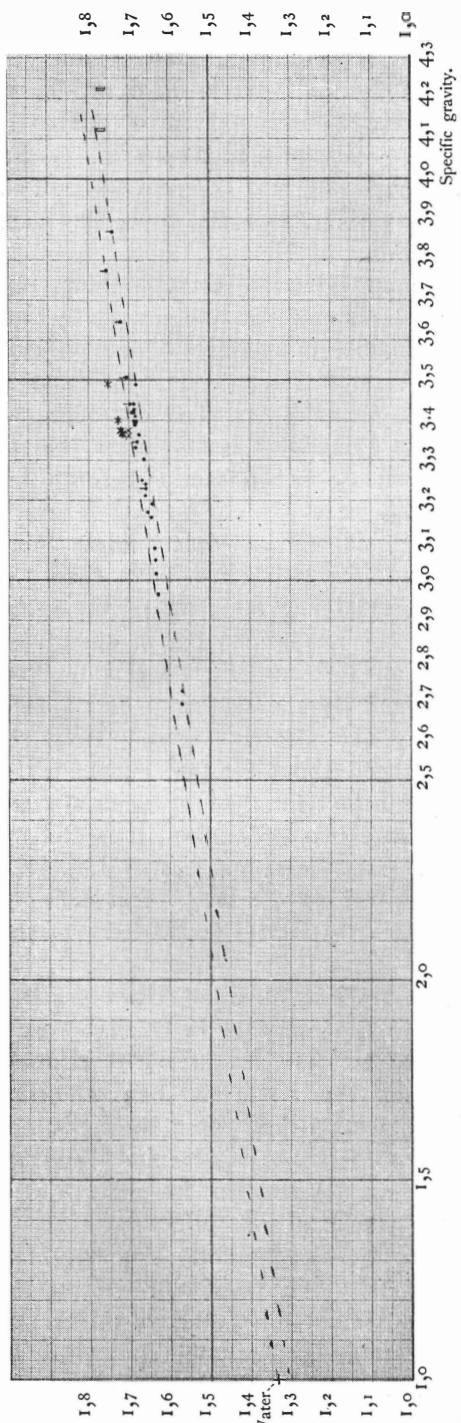


Fig. 1. Graphic representation of the relation between specific gravity and medium refractive index of allanites and their alteration products.

↓ Allanite, anisotropic.
• » , isotropic (sometimes containing polarizing alteration products).
× Zoizite.
* Clinozoizite and epidote.
▮ Gadolinite, isotropic.

medium refractive index of allanite fairly regularly decreases with diminishing sp. gr., and, in the case of different parts of the same allanite individual, or allanites from the same locality, no exception to this rule was found. The sp. gr. of the allanites examined (altered allanites included) varies from 4,15 (No. 1. Bastnäs) to 2,678 (No. 39. Karlberg) or somewhat less (No. 40. Skeppsholmen), and the refraction of single grains from a value higher than 1,78 (No. 1. Bastnäs) to at the least so low a value as 1,53 (No. 40. Skeppsholmen).

The allanites with high sp. gr. and corresponding, high medium refraction are birefracting and pleochroitic and evidently unaltered or only slightly altered. The substance of allanites with a sp. gr. lower than 3,50 and a refractive index lower than 1,70 in most cases has lost its original birefracting power and is isotropic. The observations upon the allanite No. 22. Snarum with a sp. gr. = 3.23 still show that there exists allanite substance which does not lose its birefraction before it has assumed so low a refractive index as 1,65.

There has not been observed any isotropic allanite substance with higher sp. gr. than 3,50 and higher refractive index than 1,70. In this respect gadolinite behaves differently. Specimens of the isotropic gadolinites from Kărarfvet and Ytterby in Sweden had a sp. gr. of 4,123 and 4,223 respectively. By means of the immersion method I found that in both cases the fragments obtained by the crushing of the pieces used in the determination of the density had refractive indices that were invariably higher than 1,74, but did not exceed (though in part equalled) 1,78. Though these determinations are not sufficient for a more exact statement of the medium refractive indices of these two gadolinites, it is still evident that the medium values referred to must be about 1,76 or 1,77. A gadolinite with the sp. gr. 4.36 from Hitterö in Norway yielded fragments with a strong double refraction. All of them had higher refracting power than 1,78.

The substance of even birefracting allanites sometimes in part shows itself somewhat turbid owing to the presence of small bodies which evidently represent alteration products. The allanites with relatively low sp. gr. (about 3,1 and less) have long been known to be more or less strongly weathered, and under the microscope they often show distinct traces of this alteration. These traces are partly represented by individualized alteration products. The latter do not seem to be evenly distributed, but occur in highly varying amounts in neighbouring parts of such allanite individuals that are of low sp. gr. throughout. You may find a piece, all the fragments of which consist of a mostly brownish yellow, nearly limpid, isotropic substance, and in an other part of the same individual this isotropic matrix may be more or less thickly crowded with very small bodies which make it turbid.

Some of the descriptions in the following pages refer to allanite substances, portions of which were rich in more or less distinctly indi-

vidualized alteration products. Repeatedly it was possible to state that such new formed bodies had refractive indices approximately equal to or somewhat less than 1,60, and, in the cases under consideration, falling within the limiting values of the refractive indices of the mostly isotropic matrix itself. (This fact is not specially mentioned in the descriptions just referred to, since I have endeavoured to make them as short as possible.) Thus the medium refractive indices of these allanites would probably retain nearly the same value, no matter whether the medium refractive index is made to refer to the (isotropic) matrix alone or to the whole mass, the individualized alteration products included. As I have sought to obtain corresponding values of sp. gr. and refraction in all the other cases, and as the sp. gr. has been determined upon the whole mass, I have chosen the latter alternative. However, since the medium values of refraction obtained for these allanites are more uncertain than in the remaining cases, and since it might be questioned, whether it would be appropriate to give them in the diagram, they have not been introduced into it. The diagram thus only shows the points corresponding to allanites free from or with only subordinate amounts of individualized alteration products. Still, if the values thus omitted were placed in the diagram, they would not in the least change its general appearance of a long, narrow, straight strip, but would only make it more distinct.

The macroscopical appearance of the allanites examined I have, in the following, in most cases not deseribed in detail. Unless otherwise stated, they had a black colour, and, if more or less isotropic but not too strongly altered, a pitchy luster and a conchoidal or subconchoidal fracture. In small fragments under the microscope they showed the well-known variations of colour and absorbtion. The highly altered allanites with, macroscopically, a brownish black, reddish brown or yellowish brown colour gave brownish yellow fragments, often intermingled with others, showing the greenish colours generally characteristic of the less altered allanites. Evidently the latter fragments mostly represented less altered parts of the allanites, showing higher refraction than the brownish yellow fragments. But it is to be observed that in several instances greenish fragments had a refraction lower than that of many brownish yellow fragments in the same sample.

From the data given by C. KLEIN, E. WEINSCHENK, E. H. FORBES and P. TERMIER etc., the medium refractive indices of some zoisites, clinozoisites and epidotes have been computed, and afterwards their corresponding points marked in the diagram fig. 1. According to TERMIER[1] zoisite from Bobbio has a sp. gr. = 3,36, and from the values of the refractive indices given by him, the medium refractive index of this zoisite has been calculated to be 1,699. WEINSCHENK[2] has determined the sp. gr. of zoisite from Gorner Gletscher at Zermatt to be 3,3720, and his values

[1] Bull. de la Soc. Franç. de Min., 1898, T. 21, pp. 150, 153.

[2] Zeitschr. für Kryst., Bd. 26, 1896, p. 171.

of the refractive indices give a medium refraction of 1,701. The investigations of FORBES[1] upon the clinozoisite from Huntington give a medium refractive index of 1,718, corresponding to a sp. gr. of 3,367. Clinozoisite from Goslerwand has a sp. gr. of 3,3720 according to WEINSCHENK,[2] while his determinations of the refractive indices in this case lead to a medium refraction of 1,720. According to the same author the epidote from Rothenkopf[3] has a sp. gr. of 3,3985, and from his determinations of the refraction I have calculated a medium refractive index of 1,729.

C. KLEIN has determined the refractive indices of epidote from Knappenwand in Untersulzbachthal,[4] and from these values a medium refraction of 1,751 may be computed. As he did not determine the sp. gr. of the material optically investigated by him, the point of the diagram fig. 1, corresponding to this epidote, naturally cannot be absolutely fixed. To judge from the rather small variations in sp. gr. and chemical composition of epidote from Knappenwand, indicated by the determinations and analyses referred to in HINTZE's »Handbuch der Mineralogie», it seems safe to assume a sp. gr. not far from 3.49.

The determinations upon zoisite, clinozoisite and epidote thus show that their medium refractive indices lie between, approximately, 1,70 and 1,75. Among the allanites examined by me only No. 1. Bastnäs and No. 3. Ural have higher medium refraction than the last value given, and from the whole appearance of the diagram it is evident that so high a refraction for an allanite must always be associated with a very great density, probable greater than 3,75. Compared with an epidote or zoisite of the same sp. gr. as a certain allanite, the latter shows a somewhat lower refraction, as is shown by the diagram fig. 1.

The figure also shows that the narrow »allanite strip» stretches straight towards the point corresponding to water. Remembering the great rôle that water plays in the composition of altered allanites, the question may be asked whether the allanites in general should be considered simply as mixtures (solid solutions) between allanite molecules and water? As a matter of fact, in a diagram constructed in such a manner as fig. 1, the points corresponding to the different solutions in varying proportions of two substances in each other, together should form a straight line.

The question can immediately be negatived with regard to the more evidently altered allanites with low sp. gr. The analyses of such substances that are at hand indicate very important changes of the quantitative chemical composition of the original allanite substances besides the taking up of water. When taking the other allanites into consideration, we also immediately find another important factor influencing their sp. gr.

[1] Amer Journ. of Sc., Ser. IV, Vol. I, pp. 27, 28.
[2] Zeitschr. für Kryst., Bd. 26, 1896, p. 169.
[3] Ibid., pp. 165—166.
[4] Neues Jahrb. für Min. etc., 1874, pp. 1—21.

and refraction, namely the conversion from the crystalline state into the amorphous without any change of the quantitative chemical composition. With regard to the actual course of the »allanite strip», it may be remarked that a very great number of chemical compounds have their corresponding points lying within or in the immediate neighbourhood of it.

I now proceed to give brief descriptions of the allanites examined by me, all belonging to the Mineralogical Dep. of the Nat. Hist. Museum:

## Examined allanites.

No. 1. »Cerin» from **Bastnäs,** Riddarhyttan, Sweden.
In a thin-section comprising a rather large number of the comparatively small allanite individuals from this locality the allanite substance was found to have a high birefringence and a very strong pleochroism[1] with $\mathfrak{a}$ = light greenish yellow, $\mathfrak{b}$ = dark brown, $\mathfrak{c}$ = dark reddish brown. The absorbtion was $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. Twins according to (100) were common. It was evident that the allanite had a rather large axial angle, but agreed with the allanites proper from the Christiania territory in being optically negative and having the axial plane normal to the plane of symmetry[2] ($\mathfrak{c} = b$) There were found no sections parallel to (010) upon which the extinction angle could be determined.
The fragments of a small crystal with a *specific gravity = 4,15* showed the same pleochroism as that above mentioned, and an evidently quite fresh allanite substance. Even $\alpha$ was found to surpass 1,78.
CLEVE has made two analyses which refer to allanite from Bastnäs.[3,4,5] In one case[3] the allanite analyzed had a sp. gr. = 4,103 — 4,108, in the other[4] 4,15, just as that investigated by me.

No. 2. **Österby,** Dalarne (Dalecarlia), Sweden.
The fragments of the pulverized mineral were generally birefringent, and strongly pleochroitic. The presence of some few isotropic allanite fragments was observed. In parts the allanite substance was somewhat turbid.
*Sp. gr. = 3,87.*
The refraction of the fragments was between 1,745 and less than 1,680; in general 1,745 — 1,735. *Medium index of refraction = about 1,74.*

[1] Cfr. A. SJÖGREN, Om Gadolinitens, Orthitens samt med dessa likartade mineraliers förhållande under mikroskopet. Geol. Fören. i Stockholm Förh., Bd. 3, 1876—77, p. 261.
[2] V. M. GOLDSCHMIDT, Die Kontaktmetamorphose im Kristianiagebiet. Vidensk. selsk. Skrifter, I, Mat. Naturv. Klasse, 1911, No. 11, p. 420.
[3] Öfversigt af K. Sv. Vet. Akad. i Stockholm Förh., Bd. 19, 1862, p. 425.
[4] NILS ENGSTRÖM, Undersökning af några mineral, som innehålla sällsynta jordarter. Dissertation, Upsala 1877, 4:o, pp. 19, 20.
[5] Zeitschr. für Kryst., Bd. 3, 1879, pp. 195, 196 in an exhaustive abstract by W. C. BRÖGGER of the fore-going paper.

No. 3. **Ural.**
From the portion left by ENGSTRÖM after having selected material for his analysis No. 2.[1, 2]
The fragments showed themselves to be birefringent, somewhat turbid, and strongly pleochroitic.
*Sp. gr.* = 3,771. (For the analyzed portion 3,67 according to ENGSTRÖM.)
The refraction of most fragments was found to vary between 1,768 and 1,747. In very rare cases, the refraction descended to somewhat less than 1,738. *Medium refractive index = about 1,75 (6).*

No. 4. **Greenland.**
From the portion left by CLEVE after having selected material for his analysis No. 9.[3, 4]
Part of the fragments under the microscope had a dirty green or greenish brown colour and were isotropic. Yet most of them were birefringent (birefringence partly high), and showed a strong pleochroism in brown and green colours. Mostly the fragments showed a limpid allanite substance.
*Sp. gr.* = 3.645. (The analyzed portion 3,37 according to CLEVE.)
The refraction was found to vary between 1,738 and 1,677. The isotropic fragments had a refractive index between 1,697 and 1,677, while the (much more numerous) birefringent ones nearly in all cases exceeded 1,697. *Medium refractive index = about 1,72 (0).*

No. 5. **Hitterö,** Norway.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 1.[6, 4]
The fragments under the microscope showed the substance to be rather limpid, birefringent, pleochroitic, although not strongly. The presence of completely isotropic substance could be stated only in purely exceptional cases.
*Sp. gr.* = 3,507. (The analyzed portion 3,52 according to ENGSTRÖM.)
The refraction varied between 1,728 and 1,695. Most of the fragments had indices between 1,713 and 1,702. *Approximate medium refractive index = 1,70 (7).*

No. 6. **Alve** (the label shows the wrong spelling »Alvö»[7]), Norway.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 7.[8, 6]
The fragments showed themselves to be isotropic. The substance was somewhat turbid; polarizing alteration products were rather rare.
*Sp. gr.* = 3,490. (The analyzed portion 3,39 according to ENGSTRÖM.)

[1] ENGSTRÖM, l. c., pp. 11, 16.
[2] Zeitschr. für Kryst., Bd. 3, pp. 193, 194.
[3] ENGSTRÖM, l. c., pp. 20, 22.
[4] Zeitschr. für Kryst., Bd. 3, pp. 196, 197.
[5] ENGSTRÖM, l. c., pp. 10, 16.
[6] Zeitschr. für Kryst., Bd. 3, pp. 193, 194.
[7] Cfr. the remark by BRÖGGER, Zeitschr. für Kryst., Bd. 3, p. 193.
[8] ENGSTRÖM, l. c., pp. 13, 17.

The refraction of the fragments varied only between 1,687 and 1,677; *medium refractive index = 1,68(2).*

No. 7. **Laurinkari,** Finland.
The fragments under the microscope were seen to be only *faintly* birefracting.
*Sp. gr. = 3,44.*
The refractive index of the fragments varied between 1,705 and 1,690; *medium refractive index = 1,69 (8).*

No. 8. **Sofiakyrkan,** Stockholm, Sweden.
The allanite substance was generally isotropic, only some few fragments showed themselves to be faintly birefracting. Only small, sparse spots of polarizing alteration products were to be seen.
*Sp. gr. = 3,439.*
The refractive indices of the fragments varied only between 1,690 and 1,685; *medium refractive index = 1,68 (8).*

No. 9. **Næskilen,** Arendal, Norway.
From the portion left by CLEVE after having selected material for his analysis No. 6.[1, 2]
The allanite substance showed itself to be isotropic and in general rather limpid, but there were some not quite negligeable spots of polarizing alteration products.
*Sp. gr. = 3,427.* (The analyzed portion 3,47 according to CLEVE.)
The refraction varied between 1,697 and less than 1,682; but, with exception of some few ones, the fragments had indices between 1,693 and 1,682; *medium refractive index* thus = *about 1,68 (8).*

No. 10. **Hitterö,** Norway.
The allanite substance was only partly isotropic, partly it was faintly birefracting. In general it was rather limpid.
*Sp. gr. 3,42.*
The refraction of the fragments varied between 1,705 and less than 1,680; in general it was 1,705 — 1,680. *Medium refractive index = about 1,69 (0).*

No. 11. **Egedes Minde,** Greenland.
The allanite substance was isotropic and rather limpid.
*Sp. gr. = 3,42.*
The refractive indices of the fragments varied between 1,695 and less than 1,670, mostly between 1,695 and 1,690. *Medium refractive index = 1,69 (2).*

No. 12. **Slättåkra,** Småland, Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 4.[3, 4]

[1] ENGSTRÖM, l. c., pp. 20, 21.
[2] Zeitschr. für Kryst., Bd. 3, pp. 195, 196.
[3] ENGSTRÖM, l. c., pp. 12, 17.
[4] Zeitschr. für Kryst., Bd. 3, pp. 193, 194.

The substance of the fragments was rather limpid and, in general, isotropic. Still patches of polarizing alteration products were present in some quantity.
*Sp. gr.* = 3,41. (The analyzed portion 3,38 according to ENGSTRÖM.) The refractive indices of all fragments were included between 1,697 and 1,670. In most cases the variation was only within the limits 1,687 and 1,677. *Medium refractive index* = 1,68(2).

No. 13. **Skeppsholmen,** Stockholm, Sweden.
The substance was, in general, isotropic and limpid. The amount of polarizing alteration products was very subordinate.
*Sp. gr.* = 3,396.
The refraction of the fragments was found to vary between 1,690 and 1,680; *medium refractive index* = 1,68 (5).

No. 14. **Skeppsholmen,** Stockholm, Sweden.
The examined specimen formed a fragment of a larger crystal, and was partly bounded by rough crystal faces. Against these the black allanite substance with pitchy luster and subconchoidal fracture rapidly turned into a brownish yellow substance with dull luster, and of 1 mm. thickness at most, evidently a weathering crust. This altered, brownish yellow allanite substance forms the following No. 25. The macroscopically black substance was isotropic, only seldom somewhat turbid by polarizing alteration products.
*Sp. gr.* = 3,396.
The fragments of the macroscopically black substance had refractive indices varying between 1,685 and 1,680; *medium refractive index* = 1,68 (3).

No. 15. Neighbourhood of **Arendal,** Norway.
The substance was isotropic, and in general almost limpid.
*Sp. gr.* = 3,39.
The refraction of the fragments varied between 1,695 and less than 1,670; mostly it was 1,695 — 1,675. *Medium refractive index* = 1,68 (4).

No. 16. **Egedes Minde,** Greenland.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 8.[1, 2]
The allanite substance was isotropic, generally limpid. Still there was to be seen a certain amount of polarizing alteration products.
*Sp. gr.* = 3,363. (The analyzed portion 3,32 according to ENGSTRÖM.) The refraction of the fragments was found to vary between a maximum value of 1,682 and, in single cases, a minimum value of less than 1,664. Most fragments had indices between 1.677 and 1,672. *Medium refractive index* = 1,67 (5).

No. 17. **Blackstadbro,** Froland, Norway.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 10.[3, 4]

[1] ENGSTRÖM, l. c., pp. 13, 18.
[2] Zeitschr. für Kryst., Bd. 3, pp. 193, 194.
[3] ENGSTRÖM, l. c., pp. 14, 18.
[4] Zeitschr. für Kryst., Bd. 3, pp. 193, 195.

Most fragments were birefracting, although often only faintly. A number of them were found to be isotropic. The substance of the fragments was generally rather limpid. The birefracting grains had higher refraction than the isotropic ones.
*Sp. gr.* = 3,346. (The analyzed portion 3,28 according to ENGSTRÖM.) Nearly all fragments had a refraction between 1,693 and 1,653. Most of them had indices between 1,687 and 1,672. *Medium refractive index* = 1,68 (0).

No. 18. **Voge,** parish of Moland, Norway.
The substance of this allanite was isotropic in general. Some fragments were faintly birefracting. The substance was mostly almost limpid.
*Sp. gr.* = 3,33.
The fragments had refractive indices between 1,690 and 1,675; *medium refractive index* = 1,68 (3).

No. 19. **Stockholm,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 11.[1, 2]
The fragments showed an isotropic and throughout rather limpid substance. Only very small quantities of polarizing alteration products were to be seen.
*Sp. gr.* = 3,301. (The analyzed portion 3,22 according to ENGSTRÖM.) The refractive indices of the fragments varied between 1,677 and 1,648. In most cases the indices had values between 1,666 and 1,658. *Medium refractive index* = 1,66 (2).

No. 20. **Ytterby,** Uppland, Sweden.
The fragments of this allanite under the microscope showed themselves to be, in general, isotropic and limpid.
*Sp. gr.* = 3,250.
The refraction of the fragments varied between 1,680 and less than 1,650, in most cases between 1,680 and 1,660; *medium refractive index* = 1,66 (9).

No. 21. **Stockholm,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 11. (Cfr. allanite No. 19.)
The fragments were isotropic and rather limpid. Polarizing alteration products were to be found only in small quantities.
*Sp. gr.* = 3,240. (Cfr. allanite No. 19.)
The refractive indices of the fragments were found to lie between 1,672 and 1,643. Most fragments had indices between 1,664 and 1,653. *Medium refractive index* = 1,65 (9).

No. 22. **Snarum,** Norway.
The grains showed an allanite substance that was more often faintly anisotropic than isotropic. Mostly it was comparatively limpid. In a thin-section cut from the same allanite individual the extinction was

[1] ENGSTRÖM, l. c., pp. 15, 19.
[2] Zeitschr. für Kryst., Bd. 3, pp. 193, 195.

uniform throughout the whole slice, and there could be no doubt that the faint double refraction was a remnant of the original birefringence of the allanite.
*Sp. gr.* = 3,23.
The different fragments had refractive indices varying between 1,665 and 1,650; *medium refractive index* = 1,65(8).

No. 23. **Vargholmen** at Gottenvik, Östergötland, Sweden.
The allanite substance was isotropic, generally limpid.
*Sp. gr.* = 3,211.
The fragments varied in refraction between 1,675 and 1,640, mostly between 1,670 and 1,650. *Medium refractive index* = 1,66(0).

No. 24. The neighbourhood of **Kragerö,** Norway.
The isotropic substance was somewhat turbid.
*Sp. gr.* = 3,19.
The refraction of the fragments varied between 1,660 and 1,630, in most cases between 1,650 and 1,630. *Medium refractive index* = 1,64(2).

No. 25. Cobalt-mine of **Tunaberg,** Södermanland, Sweden.
The grains of this allanite, about 1 cm. in diameter, are embedded in »blå vattkalk», an old local name for a pyroxene-calcite rock. Under the microscope almost all fragments showed themselves to be limpid and quite isotropic.
*Sp. gr.* = 3,170.
The refraction of the fragments varied between 1,660 and 1,645. *Medium refractive index* = 1,65(3).

No. 26. **Tunaberg,** Södermanland, Sweden.
Mode of occurrence similar to that of allanite No. 25. Under the microscope almost all fragments showed themselves to be limpid and quite isotropic.
*Sp. gr.* = 3,157.
The refraction of the fragments varied between 1,645 and 1,640. *Medium refractive index* = 1,64(3).

No. 27. **Ytterby,** Uppland, Sweden.
From the portion left by ENGSTRÖM after having selected material for one or both of his analyses No. 5 and 12.[1, 2, 3]
The fragments were isotropic and nearly always limpid. Almost no polarizing alteration products were visible.
*Sp. gr.* = 3,080. (According to ENGSTRÖM one of the portions of allanite from Ytterby, analyzed by him, had a sp. gr. of 3,39 the other one 2,92.)

[1] ENGSTRÖM, l. c., pp. 12, 15, 17, 19.
[2] Zeitschr. für Kryst., Bd. 3, pp. 193—195.
[3] The label of the specimen in question only carries a note (written by G. LINDSTRÖM) that the material has been analyzed by ENGSTRÖM. There is only one box with such a note, and this fact can be taken in favour of the view that the material of ENGSTRÖM'S analyses of allanite from Ytterby has been chosen from the same specimen in both cases.

The refraction of the fragments was found to vary between 1,664 and 1,614. Most fragments had indices between 1,648 and 1,624. *Medium refractive index = about 1,63 (6).*

No. 28. **Ytterby,** Uppland, Sweden.
From the portion left by ENGSTRÖM after having selected material for one or both of his analyses No. 5 and 12. (Cfr. allanite No. 27.)
The substance was isotropic and rather limpid, yet not always in so high a degree as that of No. 27. Only small quantities of polarizing alteration products were to be seen.
*Sp. gr.* = 3,05. (Cfr. allanite No. 27.)
The fragments were found to have refractive indices between 1,653 and 1,610. In most cases the indices varied between 1,643 and 1,624. *Medium refractive index = 1,63 (4).*

No. 29. **Ytterby,** Uppland, Sweden.
From the portion left by ENGSTRÖM after having selected material for one or both of his analyses No. 5 and 12. (Cfr. allanite No. 27.)
The substance was isotropic and generally limpid. Almost no polarizing alteration products were visible.
*Sp. gr.* = 3,017. (Cfr. allanite No. 27.)
The refractive indices were found to vary between 1,658 and 1,610. Most of the fragments had indices between 1,639 and 1,617, with a maximum of frequency at about 1,633. *Medium refractive index = about 1,63 (3).*

No. 30. **Ytterby,** Uppland, Sweden.
From the portion left by ENGSTRÖM after having selected material for one or both of his anlyses No. 5 and 12. (Cfr. allanite No 27.)
The substance was isotropic and generally limpid. The amount of polarizing alteration products was very small.
*Sp. gr.* = 2,964. (Cfr. allanite No. 27.)
The refractive indices of almost all grains fell between 1,648 and 1,617. One single fragment was found to surpass the higher value mentioned. Most of them had indices between 1,633 and 1,624. *Medium refractive index = 1,62 (8).*

No. 31. **Ytterby,** Uppland, Sweden.
From macroscopically brownish black parts of an allanite individual, from which No. 36 is also derived.
The fragments were in general isotropic, and comparatively limpid.
*Sp. gr.* = 2,963.
The refractive indices of the fragments varied within the wide limits 1,660 and 1,570. *A very approximate value of the medium refractive index = 1,61.*

No. 32. **Karlberg,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 13.[1, 2]
Designated by ENGSTRÖM as altered.
A great part of the allanite substance under the microscope looked

[1] ENGSTRÖM, l. c., pp. 17, 19.
[2] Zeitschr. für Kryst., Bd. 3, pp. 193, 195.

rather turbid, and about half of it was altered to polarizing substances. There was also some isotropic, yellowish brown, more clear substance. Single isotropic grains with a green colour were also visible.
*Sp. gr.* = *2,819*. (The analyzed portion 3,07 according to ENGSTRÖM.)
The refraction of the fragments varied between 1,617 and 1,540, the great mass of them having indices between 1,590 and 1,570. *Medium index of refraction = about 1,58.*

No. 33. **Karlberg,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 13. (Cfr. allanite No. 32.)
Designated by ENGSTRÖM as altered.
As for the appearance of the fragments under the microscope, the only difference from No. 32 is that the substance mostly showed itself more limpid. The greater part of the substance consisted in polarizing alteration products af allanite.
*Sp. gr.* = *2,741*. (Cfr. allanite No. 32.)
Single grains had a refractive index higher than 1,590 or lower than 1,560; most fragments had indices between 1,585 and 1,570. *Rather approximate medium refractive index = 1,58.*

No. 34. **Karlberg,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 13. (Cfr. allanite No. 32.)
Designated by ENGSTRÖM as altered.
The mineral substance under the microscope showed itself to be mostly isotropic and, in general, rather limpid.
*Sp. gr.* = *2,724*. (Cfr. allanite No. 32.)
The refraction of the fragments was found to vary between 1,590 and 1,555. Most of them had indices between 1,580 and 1,560. *Medium refractive index = 1,57 (o).*

No. 35. »Vasit»[1] from **Rönsholmen,** not far from Ytterby, Uppland, Sweden.
The specimen represents a reddish brown variety. The substance was mostly isotropic and rather limpid; partly it was strongly turbid.
*Sp. gr.* = *2,697*.[1]
The fragments had refractive indices between 1,600 and 1,550, in most cases 1,580 — 1,560. *Medium refractive index = 1,57.*

No. 36. **Ytterby,** Uppland, Sweden.
Yellowish brown parts of the same allanite individual as No. 31; the yellowish brown and the brownish black parts imperceptibly grade into each other. Most of the substance was found to be

[1] In connection with this »vasit» it may be proper to make the following remark: In his abstract in Zeitschr. für Kryst., Bd. 3, pp. 191—201 of ENGSTRÖM's paper, BRÖGGER does not give any figures for the sp. gr. of the two varieties of »vasit» which have been analyzed by ENGSTRÖM (p. 199 of the abstract). In his paper, however, ENGSTRÖM (l. c., p. 26) mentions that the blackish brown variety, analyzed by him, had a sp. gr. = 2,86, and the red variety = 2,61. Neither does HINTZE, in his »Handbuch der Mineralogie», give these determinations of the sp. gr.

isotropic and rather limpid. Partly, however, it was turbid by the presence of polarizing alteration products.
*Sp. gr.* = 2,69.
None of the fragments had a higher refractive index than 1,600, and only a few lower than 1,550. In most cases the variation was within the limits 1,580 and 1,560. *Medium refractive index* = 1,57.

No. 37. **Eriksberg,** Stockholm, Sweden.
From the pegmatite dikes at this locality the Mineralogical Department of the Natural History Museum of Sweden possesses some specimens of the more or less yellow alteration products of allanite, known as »Xanthorthit».
The old label of two of the specimens gives the analysis by J. F. BAHR.[1] Possibly the material for his analysis was taken from these specimens. In any case they now carry only small quantities of »Xanthorthit». I procured some very small fragments of it for an optical examination. As they included rather numerous feldspar grains, it has not been possible for me to make any trustworthy determination of the sp. gr. The label tells us that BAHR determined the sp. gr. of the material analyzed to 2,77.[1] Under the microscope, the substance was partly rather limpid and isotropic, partly turbid by polarizing alteration products.
The fragments had refractive indices between 1,600 and 1,560.

No. 38. **Eriksberg.** Stockholm, Sweden.
This old specimen is only labelled as being from the locality mentioned. It carries an other representative of »Xanthorthit», both macroscopically and microscopically very similar to No. 37. The sp. gr. of a fragment was determined to be 2,68, but this figure is not reliable, as the fragment, also in this case, showed itself to contain not insignificant quantities of feldspar.
The refractive indices of the fragments varied between 1,600 and less than 1,550; mostly the indices were between 1,580 and 1,550. *Medium refractive index* = 1,56—1,57.

No. 39. **Karlberg,** Sweden.
From the portion left by ENGSTRÖM after having selected material for his analysis No. 13. (Cfr. allanite No. 32.)
Designated by ENGSTRÖM as altered.
A great part of the mineral substance was rather turbid. The larger part of it was isotropic, the rest consisted of polarizing alteration products.
*Sp. gr.* = 2,678. (Cfr. allanite No. 32.)
Only in very rare cases the refraction of the fragments was higher than 1,585. The lowest refraction observed was 1,550. Most of the fragments had refractive indices between 1,580 and 1,560. *Rather approximate medium refractive index* = 1,57.

No. 40. **Skeppsholmen,** Stockholm, Sweden.
The small fragment investigated formed part of the brownish yellow weathering crust of that allanite crystal from which No. 14 was derived.

[1] Öfversigt af K. Sv. Vet. Akad. i Stockholm Förh., Bd. 2, 1845, p. 89. Here the sp. gr. of the material analyzed is recorded (by L. SVANBERG) to have been 2,78.

Under the microscope it showed itself to consist of a generally isotropic base which was mostly more or less turbid by the presence of faintly polarizing alteration products.

The sp. gr. was determined to be 2,50 by suspension in methylene iodide, but I feel rather sure that this value is somewhat too low, as there is reason to suspect that there was some air adhering to the very small fragment.

The refractive indices of the separate fragments varied between 1,600 and less than 1,530, in most cases between 1,580 and 1,540. Very approximate medium refractive index = 1,56.

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