ART. XXIII.—*On Kaersutite from Linosa and Greenland;* by HENRY S. WASHINGTON; *with Optical Studies by* FRED. EUGENE WRIGHT.

Introductory Note.—While visiting the small island of Linosa, off the coast of Tunis, for the Carnegie Institution in the summer of 1905, I found small crystals of a black amphibole, accompanied by others of a glassy white, cleavable mineral, apparently a feldspar,* among the lapilli of a small, parasitic cone of Monte Rosso.† The presence of amphibole crystals here had previously been noted by Speciale.‡ Similar crystals were also said to be found near I Faraglioni, but this locality was not visited. Apart from these occurrences, amphibole is quite unknown in the lavas of Linosa, but the peculiar, triclinic aenigmatite (cossyrite) is met with, though not abundantly, and a kaersutite-like hornblende as well, in the lavas of the near-by island of Pantelleria.

Chemical analysis showed that the Linosa hornblende is very high in titanium, and that in this, as well as in other respects, it closely resembles the kaersutite of Greenland, which was partially described in 1884 by Lorenzen.§ A comparative investigation of the two minerals was therefore determined on, the chemical work being done by me and the optical determinations being very kindly undertaken by Dr. Wright, to whom I am deeply indebted for his valuable and hearty collaboration. Through the kindness of Professor N. V. Ussing, of Copenhagen, we obtained a piece of one of the best of Lorenzen's original specimens of kaersutite, and we take this opportunity to express our sincere thanks to him for his courtesy and great liberality, without the aid of which the comparison would have been sadly incomplete.

The Linosa Amphibole.

Physical Characters.—The Linosa amphibole is monoclinic in crystal system and prismatic in habit. It occurs in roughly developed crystals and fragments from 5 to 20^{mm} long by 3 to 8^{mm} thick, and bounded by the faces of the unit prism *m* (110) and the clinopinacoid *b* $(\bar{1}010)$. Terminal endings are usually absent, but a few of the crystals show the common forms *p* $(\bar{1}01)$ and *r* (011), which, however, were too imperfect to admit of accurate measurement with the goniometer. Cleavage parallel to *m* (110) is highly perfect, giving an angle of 55° 22′

---

* A description of this mineral will be given in a separate paper.
† H. S. Washington, Jour. Geol., vol. xvi, p. 10, 1908.
‡ S. Speciale, Boll. Com. Geol. Ital., vol. xv, p. 2, 1884.
§ J. Lorenzen, Medd. Grönl., vii, p. 27, 1884.

(Wright) with observed limits of ± 2′, measured on cleavage fragments with a two-circle goniometer with reducing attachment. The reflection signals were fairly sharp and satisfactory. No cleavage or parting after 100 or 001 was noted with certainty, and whenever cleavage is not developed the fracture is conchoidal. The hardness is 6 and the mineral is very brittle. Before the blowpipe it fuses readily to a black, slightly magnetic bead.

1

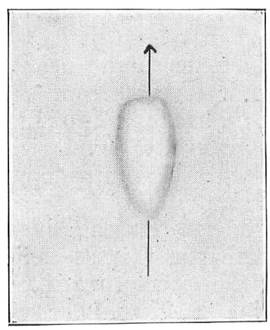


FIG. 1. Kaersutite from Linosa. Etch pit on 110, HF. × 480.

The specific gravity was carefully determined with the pycnometer on about 2 grams of selected fragments, entirely free from adhering bits of scoria or feldspar and quite free from inclusions so far as could be seen with a lens. With this material the density at 13° was found to be 3·336 (Washington), a figure which may be accepted as representing the true value.

Etch figures on *m* (110) were produced by immersing cleavage fragments in hot commercial hydrofluoric acid (on a steam bath at 100°) for a period of 30 seconds. Further action was stopped by plunging the platinum basket containing the fragments into cold water. Under these conditions of experiment well-formed etch pits resulted, from 0·01 to $0·04^{mm}$ long and about half as wide. Different stages of development are illustrated in figures 1–3, which are reproductions of photomicrographs of the figures in reflected light. In each case the vertical edge of the photograph is parallel to the prism-axis. A comparison of these figures with those obtained by Daly,* and later by Wright,† shows that they resemble in certain features the

---

* R. A. Daly, Proc. Amer. Acad. Arts and Sci., vol. xxxiv, pp. 333–429, 1899.

† F. E. Wright, Tschermak's Min. Petr. Mitth. vol. xix, pp. 308–320, 1899.

pits formed on lustrous basaltic hornblende and in other particulars the etch figures on barkevikitic hornblende. The etch figures on the faces of the prism zone prove with certainty that the mineral is monoclinic, and that it belongs in the general group of the dark, highly ferruginous, aluminous amphiboles, which are commonly referred to the hornblendes.

Optically, this amphibole is remarkable in several of its properties. The color is an intense jet black, with highly vitreous, splendent luster. The streak is light brown. In common with amphiboles of this group, it is brown to pale brown in transmitted light, and is strongly pleochroic: 𝔠 = dark brown, almost opaque, 𝔟 = brown, 𝔞 = pale olive brown or olive green; absorption, 𝔠 > 𝔟 > 𝔞. The natural color of the mineral is so deep and the pleochroism so strong that the normal interference colors are greatly modified, and the observation of the optic axes and similar optical phenomena is considerably hindered.

2 3

FIGS. 2, 3. Kaersutite from Linosa. Etch pits on 110, HF. Fig. 2, × 360; fig. 3, × 240.

Owing to the extreme brittleness of the cleavage fragments, it was found difficult to prepare sections parallel to the clinopinacoid, and the extinction angle was measured only on the cleavage face m (110). By using the etch figures as a basis for orientation, the extinction angle $c \wedge \mathfrak{c}$ was found to be +1·4° (in the acute angle β) in white light,[*] as indicated by the arrow in figure 1. This direction presupposes the standard crystallographic orientation of the amphiboles by Tschermak. This extinction angle is noteworthy because of its positive character, and it is readily discernible, although so small that (in the absence of corroborative data) it might be considered to be due to observational error alone in the deep-colored flakes. The dispersion of the bisectrices is very slight, and practically the same value was obtained by using sodium light as that for white light. In convergent polarized light the interference phenomena are only moderately clear and distinct. The optic axes lie in the plane of symmetry (010), and the optical character is negative.

The refractive indices were determined on a very perfect cleavage flake with an Abbé total refractometer, a solution of sulphur in methylene iodide, with refractive index 1·7882, being used. The observations were made in sodium light, and the following values obtained :

	Average angle observed.	Equivalent refractive index.
$\gamma =$	67° 18′	1·760
$\beta =$	65° 8′	1·730
$\alpha =$	62° 33′	1·692

$\gamma - \alpha = 0·068$, $\gamma - \beta = 0·029$ $\beta - \alpha = 0·039$

The optic axial angle calculated directly from these refractive indices is 2V = 79° 54′.

The boundary shadow for α was much more distinct than those for β or γ, and could be determined with greater accuracy. In the values given for β and γ an error of ± 0·002 is easily possible. The fact that light waves vibrating along $\mathfrak{c}$ and $\mathfrak{b}$ were strongly absorbed undoubtedly exerted an influence on the relative intensity of the phenomena observed, and caused the faintness of the β and γ curves of total reflection.

A somewhat smaller value for 2V was obtained by measuring the angle of the optic axes directly in another section cut approximately normal to the acute bisectrix, by the method described by Wright.[†] The deep color of the mineral impaired the accuracy with which the determinations of the positions of the optic axes could be made, so that the results are but approximate at best. In two different portions of the same section thus measured the values 2V = 71° and 72° were obtained.

---

[*] Average of 10 measurements, with observed limits ±0·6°.

[†] F. E. Wright, this Journal, vol. xxiv, p. 317, 1907.

While in general the probable error for this method should not exceed 2°, the intense color of the amphibole has evidently affected this limit appreciably, as it is not probable that differences exist in the chemical composition of the material sufficiently great to cause the optic axial angle to vary 9°. The optic axial angle apparently lies between the two extremes, 71° and 79° 54′, but it is thought that the latter more closely approaches the true value.

Chemical Composition.—For the chemical analysis several grams of selected crystal fragments were coarsely crushed, washed free from dust, and the material (dried at 110°) carefully picked out under a lens. The only adherent impurities were feldspar, limonite, and particles of the scoria, and all fragments showing traces of these were excluded. Thin sections of fragments showed but very few small inclusions of magnetite, but these were separated by treatment with an electromagnet, only a very small amount being thus extracted. It is believed that the material as finally pulverized for analysis was practically free from extraneous matter. Treatment with acid for purification was not resorted to, as the mineral is partially decomposed by acids.*

The methods of analysis employed were those advocated by Hillebrand† and the writer,‡ about one gram being taken in each case for silica, alumina, etc., and for the alkalies; about one-half a gram for ferrous iron; and 0·8 gram for fluorine. The alkalies were determined by Lawrence Smith's method, titanium colorimetrically (a mean of three closely agreeing determinations), and manganese by precipitation with bromine. Ferrous iron was determined twice by the simple Pratt method, freshly standardized permanganate solution being used. The figure given (3·96) is the mean of 3·99 and 3·94. These results indicate that there was no appreciable oxidation of the FeO in the finely ground powder during the interval of a year which elapsed between the two determinations.

---

* In a recent criticism (Geol. Mag., dec. v, vol. iv, p. 161, 1907) of a previous paper of mine, Mr. T. Crook says that evidence is needed of the absence of inclusions of ilmenite, etc., in this hornblende, and he expresses doubts as to "the view that titanium enters vitally and in any serious quantity into the composition of ordinary ferromagnesian minerals." The amount of TiO_2 found would imply, if existent only as ilmenite, the presence of 17 or more per cent of this, and it is hoped that the details given here will suffice to show that but minimal amounts, if any, of ilmenite or titaniferous magnetite were present. As regards his latter doubt, Mr. Crook seems to be unaware of much recent and highly trustworthy work which has been done in chemical mineralogy, and which proves conclusively that titanium does enter vitally and often in considerable amount into the composition of the ferromagnesian minerals.

† W. F. Hillebrand, Bull. No. 305, U. S. Geol. Surv., 1907.

‡ H. S. Washington, Manual of the Chemical Analysis of Rocks, New York, 1904.

SiO_2	40·85	·681
TiO_2	8·47	·106
ZrO_2	none	
Al_2O_3	9·89	·097
Fe_2O_3	8·85	·056
FeO	3 96	·055
MnO	0·12	·002
NiO	0·10	·001
MgO	12·47	·312
CaO	12·16	·217
BaO	none	
Na_2O	2·01	·032
K_2O	0·63	·007
H_2O	0·19	·010
F	0·28	·007
	99·98	

Hornblende from Linosa.* Washington, analyst.

In its general features, this analysis closely resembles many analyses of basaltic hornblendes, such as those made by Schneider.† Alumina is, however, decidedly lower, and a most striking character is the very high percentage of TiO_2, the amount of which is nearly twice that reported for most basaltic hornblendes. The character of the material used for the analysis precludes the possibility that this high figure is due to admixture of titaniferous magnetite or ilmenite, as no appreciable amount of such inclusions could have been present, so that the titanium must be regarded as belonging to the hornblende molecule. The analysis will be discussed later, in connection with others, and attention need be called here only to the figures for the iron oxides and the percentage preponderance of ferric over ferrous oxide.

The Kaersut Amphibole.

Occurrence.—A peculiar, highly titaniferous amphibole from Kaersut, Nugsuaks Peninsula, on the shore of Umanak Fjord, Greenland, was described by J. Lorenzen,‡ who called it kaersutite. According to Steenstrup (as quoted by Lorenzen), the kaersutite occurs in a vein or dike, 2 to 6 inches wide, which cuts a horizontal sheet of peridotite 120 feet thick. It is accompanied by plagioclase, titaniferous ore, an astrophyllite-like mica, and some pyrite, with zeolites, calcite, and quartz as secondary minerals. This sheet of peridotite is

---

* This analysis has been published in Rock Minerals, by J. P. Iddings, New York, 1906, p. 330.

† C. Schneider, Zeitschr. Kryst., vol. xviii, p. 580, 1890.

‡ J. Lorenzen, Medd. Groenland, vol. vii, p. 27, 1884.

undoubtedly the same as that mentioned by Phalen* in his description of the rocks of the Nugsuaks Peninsula, who speaks of it as forming a cliff 200 feet high, calls it picrite, and gives a petrographic description. The kaersutite-bearing vein is not mentioned by him.

The specimens sent us by Professor Ussing show a rather coarsely granular mass of feldspars pierced in all directions by prisms of the black hornblende, which run up to 3^{cm} in length by 5^{mm} in thickness. The rock is far from fresh, and is stained brown and yellow with iron, and here and there a pale green. Small grains of magnetite or ilmenite and many apatite crystals in water-clear prisms 5^{mm} in length are present, and a few small specks of pyrite were seen, but we could not detect with certainty any of the mica megascopically.

In thin section the texture is distinctly that of a granitoid rock rather than that of vein material. The structure is decidedly miarolitic. The most abundant mineral is a plagioclase, in anhedral development, whose extinction angles indicate the average composition Ab_1An_2. (Extinction angle on $001 = 13°$; γ about 1·570 and α slightly $>$ 1·56.) With this is some alkali-feldspar, which shows some microperthitic features and is apparently highly sodic, though it is mostly cloudy and considerably decomposed. The brown kaersutite prisms are prominent, and show the optical properties to be described later. Small stout prisms of fresh augite are not uncommon. For the most part they are colorless in the interior and slightly greenish toward the border, but there are also some small anhedra of a highly pleochroic, brilliant grass-green augite which occasionally forms a border about the less colored variety, and is apparently the chromiferous augite mentioned by Ussing.† Indications only of the violet augite described by Ussing were observed by us.

Small thin plates of light brown biotite occur. These are intensely pleochroic, the color for rays vibrating parallel to the cleavage cracks being a very deep purplish red, while perpendicular to this they are pale yellowish brown. They show no analogy with astrophyllite. Some small grains of opaque ore are present, but these only rarely occur as inclusions in the hornblende and no pyrite was visible in our sections. Deep red goethite was observed as an alteration product of the magnetite or pyrite. Apatite is very abundant, in long, clear prisms, and is a frequent inclusion in the hornblende. It was also noted by Ussing as an abundant constituent. Patches of greenish chlorite minerals occur and are the cause of the occasional green color of the rock.

---

* W. C. Phalen, Smithson. Misc. Coll., vol. xlv, p. 194, 1904.

† In Rosenbusch, Mikr. Phys., vol. i, pt. 2, p. 237, 1905.

A hornblende which apparently resembles that of Kaersut is described by Phalen* as occurring in a fine-grained quartz-monzonite at Alanekerdlak on the Nugsuaks Peninsula. From our examination of the original specimen, kindly loaned by Dr. G. P. Merrill of the Smithsonian Institution, it appears that, while the rock resembles that of Kaersut, except in its finer grain, this hornblende differs from ours, being of a yellow-brown rather than a red-brown color, and with somewhat different pleochroism. The optical characters were not determined, but it would appear to be titaniferous and related to that which we are describing.

Physical Properties.—The Kaersut amphibole is monoclinic and forms prisms which reach a length of 3^{cm} and thickness of 5^{mm} in our specimens. They are bounded by the prism *m* (110) and the pinacoid *b* (010). The terminations are usually poor, but some crystals show the presence of steep domes or pyramids, whose symbols could not be determined. These are also to be seen in the thin sections. Ussing† gives (110), (011), $(\bar{1}01)$, and more rarely $(\bar{1}21)$ and (010), as the forms observed by him. Twinning was observed in several of the sections. In one case the twinning plane was probably a steep dome, making an angle of 13° with the cleavage lines, and showing in several places several narrow lamellae due to repeated twinning. The cleavage lines cut this twinning trace uninterruptedly. This crystal is shown in fig. 4, from a photograph kindly made for us by Prof. J. Volney Lewis. The extinction is parallel to the right of the twinning line and 17° to the left. The crystals are seen in thin section to be frequently crossed by narrow cracks (seen as dark lines in the figure). Some of these are irregular, but many are straight and parallel, crossing the cleavage lines of 110 at about 32°. For the angle $110 \wedge \bar{1}10$ measured on the cleavage surfaces, Lorenzen (p. 29) gives 55° 29′ (the mean of 55° 25′ and 55° 33′), while Ussing obtained 55° 35′. On an excellent cleavage piece, giving sharp reflexion signals, Wright obtained 55° 35′, while on less satisfactory fragments the values were 55° 34′ and 55° 23′. We therefore consider that 55° 35′ best represents the value. For other angles Ussing gives the following: $\bar{1}01 \wedge 011 = 34° 16'$, $\bar{1}01 \wedge \bar{1}10 = 76° 51'$ $110 \wedge 011 = 68° 44'$. The cleavage is highly perfect, and where it is not developed the fracture is conchoidal. We found the hardness to be about 6; Lorenzen gives it as 5·5. The mineral is very brittle, and fuses readily before the blowpipe to a dark, magnetic bead.

The specific gravity as determined by Washington with the pycnometer on about one gram of very carefully selected frag-

---

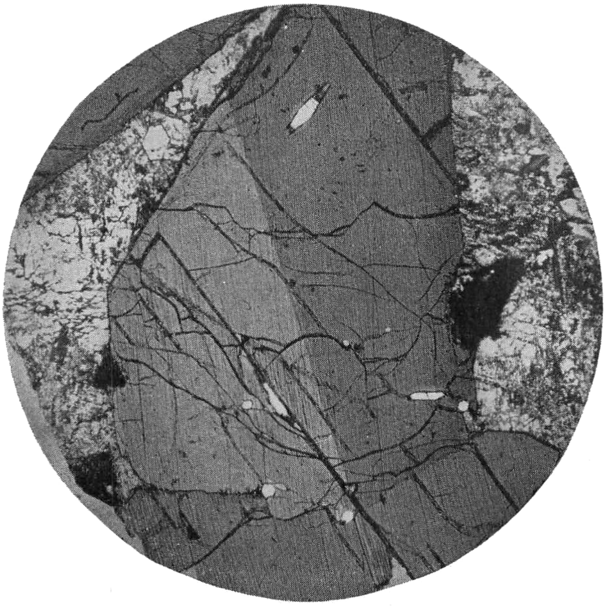
* W. C. Phalen, loc. cit., p. 207.

† N. V. Ussing, in Rosenbusch, Mikr. Phys., vol. i, pt. 2, p. 236, 1905.

ments was 3·137 at 25° C., while Ussing obtained 3·237 (temperature not stated) and Lorenzen 3·04 at 18°.

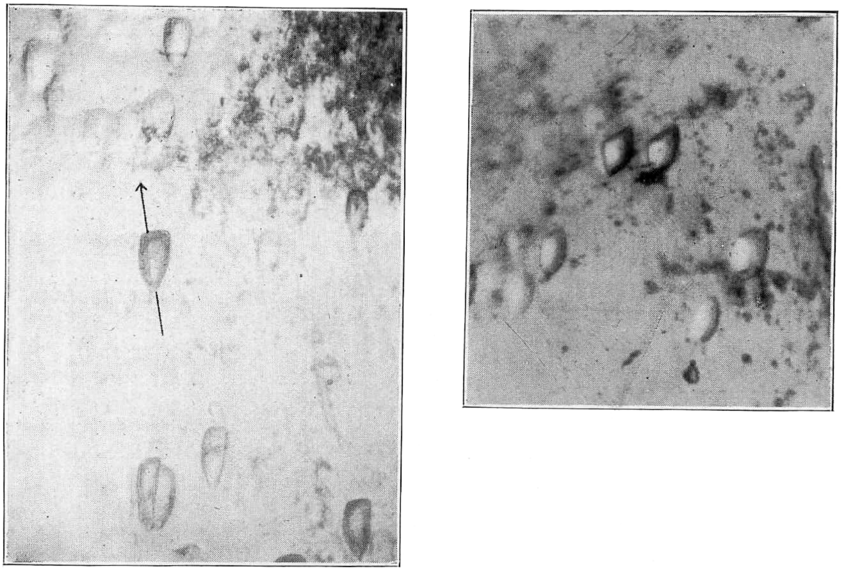
The extinction angle on *m* 110 was found to be $c : \mathfrak{c} = -7{\cdot}8°$ in the obtuse angle β, measured in sodium light (an average of 14 readings on different sections). In Li light the extinction was $c \wedge \mathfrak{c} = -9{\cdot}3°$, which would indicate that there is some slight dispersion of the bisectrices with $c \wedge \mathfrak{c}_{Na} < c \wedge \mathfrak{c}_{Li}$. That it is slight, however, is evident from the comparatively sharp position of extinction in ordinary light. Ussing gives the extinction angle as $c : \mathfrak{c} =$ about 10° in the obtuse angle β, but does not state whether this was measured on 010 or 110. He remarks that it is somewhat greater for red than for green, which is in accord with the observations of Wright. The plane of the optic axes is the clinopinacoid.

4



The refractive indices were determined directly by the method employed in the preceding case, and were found to be as follows: $\alpha = 1{\cdot}676$, $\beta = 1{\cdot}694$, $\gamma = 1{\cdot}708$, the probable error being less than $\pm 0{\cdot}02$. This gives for the birefringences: $\gamma - \alpha = 0{\cdot}032$, $\gamma - \beta = 0{\cdot}014$, $\beta - \alpha = 0{\cdot}018$. The optic axial angle calculated from these indices is $2V = 82° \, 6'$, while measurement of a section nearly perpendicular to the

5 6



FIGS. 5, 6, Kaersutite from Kaersut, Greenland. Etch pits on 110, HF; × 120.

7

FIG. 7, Kaersutite, Kaersut, Greenland. Etch pits on 110, HF; × 480 acute bisectrix on the universal stage gave 2V= 81°. This value can be considered only fairly accurate because of the deep color of the mineral which tends strongly to veil the optical phenomena, but it agrees satisfactorily with the calculated value, much better, indeed, than in the case of the Linosa hornblende.

Chemical Composition.—The chemical analysis was carried out on about 2 grams of carefully selected fragments, which, after crushing and washing free from dust, were treated with an electro-magnet to remove the few particles which contained ore grains. The microscope indicated that but few of these were present as inclusions, and the very small amount thus removed is in harmony with the observations. The only inclusions of note are of apatite, the needles of which penetrate the hornblende to a very considerable extent. As the mineral power was somewhat acted on by acid it was thought best not to remove these inclusions by its use, but to correct the analysis for their presence by determining P_2O_5. Apart from these apatite inclusions the material analyzed was extremely pure, as is shown in fig. 4, in which the enhedral apatites are well seen. It was dried at 110° prior to the analysis, which was carried out by the methods adopted in the previous one.

Lorenzen (p. 30) seems to have had great difficulty, using Doelter's method, in decomposing the mineral with sulphuric and hydrofluoric acids to determine FeO and Fe_2O_3. He reports the value FeO = 6·61 per cent in one case, but prefers to consider all the iron as ferrous in the statement of his analysis. Using the simple Pratt method, I had no difficulty in the solution of the finely powdered mineral in six minutes, and the result given here may be accepted as fully as correct as in the case of the Linosa hornblende, though the amount on hand did not permit of a duplicate determination.

Special search was made for tin, as 0·26 per cent SnO_2 was reported by Lorenzen, but with absolutely negative results. The method adopted was essentially that of Baley as outlined by Classen.* The mineral powder was decomposed by evaporation to dryness with nitric and hydrofluoric acids, which would not lead to loss of tin by volatilization as tin fluoride is decomposed by heating. The residue was dissolved in hot dilute hydrochloric acid, filtered, and the filtrate treated with pure zinc, which would precipitate any tin. Only a very slight residue remained, which was wholly soluble in nitric acid. Neither this solution nor the previous filtrate gave any precipitate with H_2S or other reaction for tin. We therefore consider that our hornblende contains no tin, and that the

---

* A. Classen, Ausgew. Method. Anal. Chem., i, 1901, p. 184.

presence of tin, as reported by Lorenzen, is very doubtful and certainly cannot be considered as characteristic of the mineral, as suggested by him.

Lorenzen's original analysis and the new one are given below, the last two columns showing the figures of the latter as corrected for the 0·77 per cent of apatite present and recalculated to 100 per cent, and the molecular ratios.

	I	II	III	IV
SiO_2	41·38	39·30	39·52	·659
TiO_2	6·75	10·25	10·31	·129
SnO_2	0·26	none	none	
Al_2O_3	14·41	11·16	11·22	·110
Fe_2O_3	none	1·21	1·22	·008
FeO	11·28	8·76	8·81	·122
MnO	n. d.	0·06	0·06	·001
NiO	n. d.	none	none	
MgO	13·51	13·24	13·31	·333
CaO	12·97	11·29	10·93	·195
Na_2O	n. d.	2·93	2·95	·048
K_2O	n. d.	1·06	1·07	·011
H_2O	n. d.	0·59	0·59	·033
P_2O_5	n. d.	0·32	----	
	100·56	100·17	100·00	

I. Analysis by J. Lorenzen, Medd. Groenl., vii, p. 30, 1884.
II. Analysis by H. S. Washington.
III. Analysis II corrected for apatite.
IV. Molecular ratios of III.

There is every reason for the belief that the material analyzed by Lorenzen was essentially identical with that investigated by us, as is also indicated by the agreement in the figures for SiO_2, total iron as FeO, MgO, and CaO, so that the differences between the analyses cannot be ascribed to varying chemical composition. Lorenzen's analysis is seriously defective in the assumption that all the iron is present in the ferrous state, as well as in the non-determination of soda, potash, and water. The last is here of comparatively small moment, but the new analysis shows that about four per cent of alkalies are present, and it is well known that all the basaltic hornblendes and others similar to this contain very notable amounts of soda, with often considerable potash, which cannot be ascribed to inclusions. Lorenzen's figure for TiO_2 is lower than ours by about 3·5 per cent, while his alumina is higher by about the same amount. As our figure for titanium was determined by the colorimetric method, which is capable of a high degree of accuracy, and is the mean of three closely agreeing determinations, we have great confidence in its correctness. It would seem to be highly probable, therefore, that in Lorenzen's analysis part of the TiO_2 was reckoned as Al_2O_3; and this is the more likely as titanium was determined by him by precipitation with sodium thiosulphate, a method which is known to be very uncertain and apt to give either too high or too low results, depending on the amount of acid in the solution and other conditions.

In its general features this analysis much resembles that of the Linosa hornblende, especially in the amounts of silica, alumina, magnesia, lime, and alkalies, as well as in the very high titanium dioxide. The only prominent difference is found in the oxides of iron. The sum of these is considerably higher in the Linosa mineral and the molecular amounts are equal, while in the Kaersut mineral ferrous oxide is largely in excess of ferric, the amount of which is very low.

Interpretation of the Analyses.

The interpretation of the analyses of these two hornblendes in terms of the molecular constitution is rendered subject to grave uncertainty through the presence of the very large amounts of titanium. The uncertainty arises from the fact that this element may be present either as Ti_2O_3 or as TiO_2 or as both oxides together. Potassium permanganate oxidizes Ti_2O_3 to TiO_2 just as it does FeO to Fe_2O_3, so that if the lower oxide of titanium is present it will appear in the ordinary course of analysis as FeO, the apparent amount of which would thus be too high, and that of Fe_2O_3 would be correspondingly low, while the Ti_2O_3 would be determined colorimetrically or gravimetrically as TiO_2.

If all four oxides are or may be present simultaneously, the analytical problem becomes complex and somewhat difficult. A promising line of attack is being developed by Gooch and Newton,* depending on the selective oxidation of the Ti_2O_3 by cupric salts, bismuth oxide, or ferric sulphate, which have no effect on the ferrous oxide. While the results recorded are excellent and show the possibility of very exact estimation under the conditions observed, yet it is uncertain if the methods are applicable, at least without modification, to the analysis of silicate rocks and minerals, owing to their insolubility except in hot hydrofluoric acid and the very ready oxidizability of the hot solutions of Ti_2O_3 and FeO so obtained. It may be suggested that the addition of cupric sulphate to the mixture of hydrofluoric and sulphuric acids employed in determining

---

* Gooch and Newton, this Journal, xxiii, 1907, p. 365; H. D. Newton, this Journal, xxv, 1908, pp. 130 and 343. See also G. Gallo, Chem. Zeitung, 1907, p. 399, and A. Cathrein, Zeitschr. Kryst., vi, 1882, p. 248.

FeO might solve the problem. If under such conditions the cupric salt would oxidize the Ti_2O_3 without acting on the FeO, titration with permanganate of two portions brought into solution both with and without the addition of $CuSO_4$, together with the determination of total iron as Fe_2O_3 and of total titanium as TiO_2 by the usual methods, would furnish all the data needed. The discovery of some such method capable of yielding accurate results under the conditions of silicate analysis is now one of the most important desiderata.

In this connection a peculiarity in the relations of the oxides of iron and titanium may be pointed out. In whole numbers the molecular weights are as follows: $Fe_2O_3 = 160$, $FeO = 72$ $(2FeO = 144)$, $TiO_2 = 80$ $(2TiO_2 = 160)$, $Ti_2O_3 = 144$. That is, neglecting the refinement of decimals, a molecule of ferric oxide is equal to two of titanium dioxide, and one of titanium sesquioxide is equal to two of ferrous oxide. Therefore, to oxidize either FeO to Fe_2O_3 or Ti_2O_3 to TiO_2, one atom of oxygen, equivalent to one-ninth of the lower oxide, will be needed; while conversely, in the case of reduction of Fe_2O_3 to FeO or TiO_2 to Ti_2O_3, one atom of oxygen, equivalent to one-tenth of the weight of the higher oxide, will be subtracted. Exactly the same amount of potassium permanganate, therefore, will oxidize the same weights of iron as ferrous oxide or titanium as sesquioxide to the higher form, as is expressed by the two equations:

$$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + K_2SO_4 + 2MnSO_4 + 8H_2O,$$

$$5Ti_2(SO_4)_3 + K_2Mn_2O_8 + 8H_2SO_4 = 10Ti(SO_4)_2 + K_2SO_4 + 2MnSO_4 + 8H_2O.$$

Fe_2O_3 and $2TiO_2$ on the one hand, and $2FeO$ and Ti_2O_3 on the other, are mutually interchangeable and equivalent as regards titration by permanganate or other such oxidizing aentg. From this it follows that, if Ti_2O_3 is present and the ferrous iron is determined in the usual way, a percentage amount equal to that of the Ti_2O_3 must be deducted from the apparent value for FeO, while an equivalent amount must be added to the apparent amount of Fe_2O_3, and deducted from that of TiO_2.

In the case of minerals whose formulas are simple and well established, readjustment may be made with a fair degree of confidence as to probable correctness, even in the absence of determinations of all four oxides. Such readjustments based on the empirical formula would have still greater weight could it be assumed that ferrous oxide is absent or present in only negligible amounts. This consideration applies to the composition of schorlomite, which we are justified in referring to the garnet group as suggested by Rammelsberg[*] and discussed in detail by Koenig,[†] in which enough of the apparent TiO_2 is calculated as Ti_2O_3 to conform to the garnet formula. The case of the hornblendes offers more difficulties, since their molecular constitution is not well understood at present, and is undoubtedly very complex, as is well known.

In a recent important paper, Penfield[‡] and Stanley explain the presence of the sesquioxides by "their introduction into the metasilicate molecule in the form of various basic, bivalent radicals," the mass effect of the very complex amphibole acid exerting a controlling influence on the crystal form and other physical characters. They also suggest the possibility that the molecule of the amphibole acid has a ring form, analogous to that of the benzene compounds. By assuming various bivalent radicals, composed of R_2O_3 with F, HO, Na, and R'', which combine with SiO_2 in the ratio of 1:1, a final residue of (Mg, Fe)O and CaO is left which conforms to the same metasilicate ratio. As regards tremolite and actinolite their exact ratios show that the molecule $Na_2Al_2Si_4O_{12}$, suggested by Tschermak, cannot be present, as this would "deplete the total silica and destroy the 1 : 1 ratio." In their calculations of their analyses of the aluminous hornblendes this molecule was also neglected, and very exact metasilicate ratios were obtained without the assumption of its presence. As this paper is the latest and one of the most suggestive and illuminating contributions to our knowledge of the constitution of the amphiboles, a study of our two minerals in its light will be of interest.

The two analyses made by me yield the following ratios, MnO and NiO being reckoned in with FeO :

	Linosa.			Kaersut.		
SiO_2	·681		·787	·659		·788
TiO_2	·106			·129		
Al_2O_3	·097		·153	·110		·118
Fe_2O_3	·056			·008		
FeO	·058	·370	·643	·123	·456	·743
MgO	·312			·333		
CaO	·217	·217		·195	·195	
Na_2O	·032	·039		·048	·059	
K_2O	·007			·011		
H_2O	·010	·017		·033	·033	
F_2	·007					

---

[*] C. Rammelsberg, Min. Chem., 1875.

[†] G. A. Koenig, Proc. Acad. Sci., Phila., 1886, p. 354.

[‡] This Journal, vol. xxiii, p. 23, 1907.

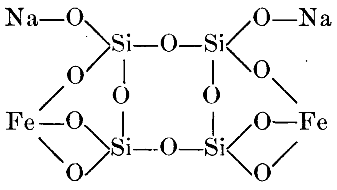
In both cases the ratio of (Si, Ti)O_2 to (R'_2, R'')O is greater than unity, being 1·22 in the Linosa, and 1·06 in the Kaersut hornblende. Such relations differ widely from those presented by the hornblendes analyzed by Penfield and Stanley, in which, where the ratio differs notably from unity, it is always on the side of an excess of RO over SiO_2.

Assuming first that all the titanium is present as the dioxide, if we calculate the composition of the molecules in terms of the bivalent radicals suggested by Penfield and Stanley, we obtain residues of SiO_2, (Mg, Fe)O, and CaO,. which differ widely from the metasilicate ratio $SiO_2 : RO = 1 : 1$, in that the original excess of silica is here greatly accentuated. This is shown in the table below.

	Linosa.		Kaersut.	
$[(Al, Fe)_2O(F, OH)_2]\ SiO_3$	·017		·033	
$[(Al, Fe)_2O_4RNa_2]\ SiO_3$	·039		·059	
$[(Al, Fe)_2O_3R]\ SiO_3$	·097		·026	
(Mg, Fe)O	·234	·451	·370	·565
CaO	·217		·195	
Residual SiO_2		·634		·670

If, on the other hand, we assume that some of the titanium is present as sesquioxide, by making the necessary calculations and readjustments (the results of which it is needless to give here), we find that this will increase still more the ratio $SiO_2 : RO$, in spite of the reduction in the amount of RO_2, through the diminution in the amount of FeO and the taking up of MgO to form one of the complex radicals. We may therefore assume that all the titanium is present as TiO_2, as this shows less divergence from metasilicate ratios.

It is therefore evident that, for our hornblendes at least, the presence of some other bases or radicals must be assumed, which will take up this seeming excess of silica and at the same time conform to the metasilicate ratio $SiO_2 : RO = 1 : 1$. Such may be found in the molecule $Na(Fe, Al)Si_2O_6$, which exists as the ferric or alumina extreme respectively in riebeckite and glaucophane, and whose presence in many amphiboles was suggested by Tschermak, though not found essential to the interpretation of the hornblendes studied by Penfield and Stanley. This, and the analogous $(Mg, Fe)(Fe, Al)_2Si_4O_{12}$, conform to the normal metasilicate ratio, owing to the trivalence of the basic iron and aluminum; and the molecules may be expressed graphically as ring formulas, quite analogous to those suggested by Penfield, as is shown by that of riebeckite, as follows:



If we assume then the presence of the bases Na_2O and $(Fe,Al)_2O_3$, which will form the metasilicates Na_2SiO_3 and $(Fe,Al)_2Si_3O_9$ respectively, the composition of our amphiboles may be calculated as follows, the presence of some of Penfield's radicals being needed to account for the F and H_2O and the excess of R_2O_3 over the alkalies. The distribution can be made mathematically, so that the whole will conform to the metasilicate formula, by the use of equations analogous to those used in the calculation of the norms of igneous rocks.*

	Linosa.		Kaersut.	
$[(Al, Fe)_2O_3(F, OH)_2] SiO_3$ -	·017		·033	
$[(Al, Fe)_2O_3R] SiO_3$ -------	·088		·026	
$[(Al, Fe)_2O_3Na_2] SiO_3$ -----	----		·044	
$Na(Al, Fe)Si_2O_6$ -----------	·039		·015	
$(Mg, Fe) (Al, Fe)_2Si_4O_{12}$ ---	·009		----	
$(Mg, Fe)O$ ---------------	·273	·490	·429	·624
CaO -------------------	·217		·195	
Residual SiO_2 ------------	----	·490	----	·625

Assuming that the amphiboles are metasilicates, as is held by most authorities, and which view is greatly strengthened by the work of Penfield and Stanley, it is clear that the composition of the hornblendes of Linosa and Kaersut may be rationally explained by the assumption of the presence of molecules of the general type $(R'_2, R'') R'''_2 Si_4O_{12}$. The presence of these molecules also seems to be quite unavoidable in the case of such amphiboles as riebeckite and glaucophane, and furthermore they cannot be interpreted only in terms of bivalent radicals such as those suggested by Penfield and Stanley, though some of these may be assumed to be present.

The two authors mentioned do not discuss the question of the presence of such riebeckitic molecules, an omission unhesitatingly to be ascribed to the preliminary and, most sadly, unfinished character of their paper. Such a discussion would have been inevitable had their investigation been extended to the glaucophanes, riebeckites, and other highly sodic amphiboles, as one of us knows to have been the late Professor Penfield's intention. So far as can be learned from the published

---

* Cross, Iddings, Pirsson, and Washington, Quantitative Classification of Igneous Rocks, Chicago, 1903, pp. 194, 195.

paper their objection to the introduction of the molecule under discussion lay in the fact that, according to Tschermak's theory, "a definite basic alumo-silicate molecule is regarded as isomorphous with Ca (Fe, Mg)$_3$Si$_4$O$_{12}$."* As has been shown above, however, such a riebeckite-glaucophane molecule may be regarded as a metasilicate and may be written structurally as a ring formula, exactly analogous to those suggested by the authors named. It is clear, therefore, that the presence of a riebeckitic molecule need not be regarded as a case of isomorphism of two chemically and structurally unlike molecules, or as inconsistent with the views of Penfield as to the structure of the amphibole acid and the mass effect of complex mineral molecules. On the contrary, they are in complete accord, as the matter reduces itself, in the last analysis, to the simultaneous replacement of one hydrogen atom by Na and three by Fe$'''$, just as two atoms are replaced by Ca$''$, (Mg, Fe)$''$, or by one of Penfield and Stanley's bivalent radicals.

These authors noted the highly interesting and probably significant fact that the CaO formed "very closely 25 per cent of the various radicals and bases, or in other words replaces one-fourth of the hydrogen atoms of the amphibole acid." Without giving all the percentage figures, in the Linosa hornblende, as calculated above, CaO forms 33·8 per cent, and in that of Kaersut 26·3 per cent. The latter approximates to one-quarter, while the former is about one-third of the radicals and bases. If this last is substantiated by analyses of other hornblendes, and found to be characteristic of certain kinds, it might be held to indicate that the amphibole acid contains a number of hydrogen atoms which is divisible both by 4 and by 3, such as $H_{12}Si_6O_{18}$, or a multiple of this. But our data are at present far too insufficient for more than a speculative suggestion.

As is well known, the amphiboles which are high in soda and in alumina or ferric oxide, and which there is good reason to believe contain the riebeckite-glaucophane molecule or basic (Al,Fe)$'''$, such as riebeckite, glaucophane, arfvedsonite, crossite, hastingsite, barkevikite, aenigmatite, and those we have been describing, are all intensely pleochroic and show either very distinctive blue colors or very intense reds and browns. Similarly, the pyroxenes which contain the acmite molecule, or basic Na$'$ and (Al,Fe)$'''$, as aegirite, aegirite-augite, babingtonite, etc., are deeply colored and are characteristically pleochroic, in contrast with the common, generally non-pleochroic pyroxenes, which do not contain the acmite molecule. On the other hand, the amphiboles which contain trivalent Al and Fe only in bivalent radicals, on the theory of

---

* Penfield and Stanley, op. cit., p. 49.

Penfield and Stanley, as actinolite or common hornblende, are less deeply colored, are never blue, and are markedly less pleochroic ; and the same is true of the ordinary pyroxenes and augites.

It is commonly supposed* that the blue color of these amphiboles is connected with the presence of abundant iron, and Pirsson† has recently suggested that the blue color is due to the presence of ferrous-ferric molecules, the analogy of Prussian blue and altered vivianite being cited. Since, however, a similar color is characteristic of glaucophane and gastaldite, in which the trivalent element is practically entirely aluminum, ferric iron being either absent or present in small amount, it would seem to be necessary to amend this hypothesis by assuming aluminum to replace the ferric iron either wholly or partially. Similarly the deep browns and reds are supposed to be connected with the presence of titanium and, as pointed out by Brögger,‡ the intensity of the color increases with increasing content in this element, as is shown by the series barkevikite, basaltic hornblende, and kaersutite and aenigmatite.

We have seen above that (Al, Fe)''' may enter the amphibole molecule either in a bivalent radical, such as those suggested by Penfield and Stanley, the radical as a whole acting as a base, or it may itself act as a base, replacing three atoms of hydrogen in the amphibole acid. It would thus occupy different positions and perform very distinct functions in the molecular arrangement. In these different positions, therefore, the trivalent element may reasonably be supposed to affect differently the optical and other physical properties of the minerals into which it enters, in analogy with the well-established fact in the chemistry of the carbon compounds.

Following out this line of thought, it may be suggested that this basic (Al, Fe)''', and not that which forms part of bivalent radicals, acts as a chromophore, as such color-giving radicals are known in organic chemistry, where they are especially notable among the aromatic compounds; and that, furthermore, the property of pleochroism may be connected with its presence, this either causing a mineral variety to be absolutely pleochroic, when varieties in which the basic trivalent element is not present are not so, or intensifying the pleochroism of otherwise weakly-pleochroic complex mineral molecules. That this chromophoric radical does not consist solely of (Al, F)''', but contains Na as well, probably in the ratio 1 : 1, is indicated by the constant presence of much soda in the peculiarly colored and pleochroic amphiboles and pyrox-

---

*Cf. W. C. Brögger, Grorudit-Tinguait Serie, p. 35, 1894.

†L. V. Pirsson, this Journal, vol. xxiii, p. 440, 1907.

‡Brögger, loc. cit.

enes which are under discussion, as well as by the fact that these constituents generally show such a constant ratio, as pointed out by Doelter.* The partial replacement of Na_2 by (Fe, Mg)$''$, sometimes observed, would harmonize this idea with that of Pirsson.

The chromophoric titaniferous radical would seem to be more intensely active or color-producing than the alumo-ferric-soda one, since amphiboles high in titanium, but otherwise chemically like those low in this element, are red-brown rather than blue, as is shown by the relations of aenigmatite and arfvedsonite. But its nature is at present difficult to suggest. The ability of titanium to assume some seven states of oxidation† complicates the problem immensely, even though this possible number is lessened by considering only the oxides most commonly met with, Ti_2O_3, TiO_2, TiO_3. It may only be mentioned here that the violet or blue colors of solutions of Ti_2O_3, and the yellows and deep browns of those containing TiO_3,‡ such as are produced from colorless TiO_2 solutions on the one hand by reduction with zinc or tin, and on the other by the action of H_2O_2, may be possibly significant of the condition of oxidation of the titanium.

The constant, characteristic pleochroism of the colored, common amphiboles, which do not contain the supposedly chromophoric Na (Al, Fe)$'''$ radical, as contrasted with the equally characteristic non-pleochroism of the colored, common pyroxenes (free from the acmite molecule), leads also to the speculative suggestion that the difference is possibly connected with difference in the structure of the molecule. Accepting provisionally the suggestion of Penfield and Stanley that the amphibole acid has a closed chain or ring structure, it might be advanced as possible or probable, in analogy with the carbon compounds, that the pyroxene acid is of the open chain type. Or the relations might be the reverse.§

In our present state of complete ignorance as to the constitution and structure of the mineral molecules any such suggestion as is here made can but be regarded as a hypothesis of the most speculative character. But such a difference in structure would be a fundamental one between the molecules of the pyroxenes and the amphiboles, and it undoubtedly exerts a profound influence on the physical properties of isomers, as the pyroxenes and amphiboles are regarded with reason as being.

* C. Doelter, Zeitschr. Kryst., vol. iv, p. 40, 1880.

† P. E. Browning, Introduction to the Rarer Elements, p. 61, 1903.

‡ A. Classen, Ausgew. Methoden Anal. Chem., vol. i, p. 765, 1901.

§ It is, of course, understood that the terms "open chain" and "closed chain" are used as they are in organic chemistry, without implying that they actually thus represent the structure of the molecule, or the arrangement of the atoms in space.

It might explain the inconsistency of the apparently greater chemical complexity and hence probably greater molecular weight of the amphiboles, as suggested by Tschermak, and the higher specific gravity of the pyroxenes, which Clarke[*] urges as evidence of their greater molecular weight. It might also readily explain the characteristic difference in pleochroism between the two groups noted above.

In this connection the analogy of the carbon compounds is of interest. The greater part of these are referred, as is well known, to two great groups; the aliphatic compounds, derivatives of methane, with an open chain type of formula; and the aromatic compounds, derivatives of benzene, with a closed chain type of formula. These two groups show characteristic differences in general chemical behavior, and also characteristic differences in some physical properties. Thus, the aliphatic compounds are very rarely colored, while colored compounds are quite common among the aromatic bodies. Similarly solutions of members of the first group seldom show absorption bands, while those of the other, when colorless, often do so.

The analogy cannot, of course, be pushed very far, but that such a fundamental difference in molecular structure would not be inconsistent with the alteration of amphibole to pyroxene, or the converse change of pyroxene to uralite, is indicated by the convertibility of members of the aliphatic series into those of the aromatic series, and vice versa. It may furthermore be observed that very many organic compounds are known which contain radicals belonging to both series, such as toluene (methyl-benzene), $C_6H_5.CH_3$, and such pyroxenes as aegirite-augite might be regarded as possible analogues.

Correlation and Name.—In the annexed table are given analyses of several hornblendes which resemble those of Linosa and Kaersut in one feature or another. In their general characters, on the whole, these most approach the basaltic hornblendes, or syntagmatites, as Rosenbush has recently proposed that these should be called,[†] especially in the figures for silica, iron oxides, magnesia, lime, soda, and potash. The alumina of our minerals is distinctly lower than in these, but the figures for this constituent in analyses of the syntagmatites (in this sense) are somewhat discordant. That shown in III is very high, while the analyses of Schneider run rather uniformly between about 14 and about 15. Also TiO_2 is much higher in I and II than in the syntagmatite analyses. The analysis (III) of a typical "basaltic hornblende" shows but little TiO_2, much less than in the analyses of Schneider (cf. IV and VI), where it varies from 4·26 to 5·40. The correct-

---

[*] F. W. Clarke, Bull. No. 125 U. S. Geol. Surv., p. 90, 1895.

[†] H. Rosenbusch, Mikr. Phys., vol. i, 2d half, 1905, p. 236.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
SiO_2	40·85	39·52	39·95	39·75	39·66	40·15	42·46	34·18	43·85	37·92	43·55	24·42
TiO_2	8·47	10·31	1·68	5·40	0·89	5·21	....	1·53	....	7·57	....	9·46
Al_2O_3	9·89	11·22	17·58	15·00	14·83	14·34	11·45	11·52	4·45	3·23	4·96	17·25
Fe_2O_3	8·85	1·22	7·25	7·86	12·37	7·80	6·18	12·62	3·80	5·81	7·97	11·69
FeO	3·96	8·81	2·18	2·89	1·97	4·53	19·93	21·98	33·43	35·88	32.87	11·39
MnO	0·12	0·06	tr.	....	....	....	0·75	0·63	0·45	1·00	1·98	....
NiO	0·10	none	....	....	....	....	....	....	....	....	{ CuO } { 0·39 }	....
MgO	12·47	13·31	14·15	14·16	14·25	13·14	1·11	1·35	0·81	0·33	0·86	12·62
CaO	12·16	10·93	11·96	12·97	12·74	11·75	10·24	9·87	4·65	1·36	2·01	12·43
Na_2O	2·01	2·95	3·16	1·92	2·47	2·31	6·08	3·29	8·15	6·58	5·29	0·67
K_2O	0·63	1·07	1·98	1·61	1·25	1·14	1·44	2·29	1·06	0·51	0·33	0·63
H_2O	0·19	0·59	0·41	....	....	....	....	0·35	0·15	....	....	....
F_2	0·28	....	0·03	....	....	....	....	....	....	....	....	....
	99·98	100·00	100·46	101·56	100·43	100·37	99·64	99·61	100·80	100·19	100·21	100·56

I. Kaersutite. Monte Rosso, Linosa. Washington analyst.

II. Kaersutite. Kaersut, Greenland. Washington analyst.

III. Syntagmatite (basaltic hornblende). Bilin, Bohemia. Stanley analyst. This Journal, xxiii, 1907, p. 40. (Includes 0·13 loss at 110°.)

IV. Syntagmatite (basaltic hornblende). Bohemia. Schneider analyst. Zeitschr. Kryst., xviii, 1890, p. 580.

V. Syntagmatite (basaltic hornblende). Bohemia. Schmidt analyst. Tsch. Min. Pet. Mitth., iv, 1881, p. 23.

VI. Syntagmatite (basaltic hornblende). Härtlingen, Westerwald. Schneider analyst. Zeitschr. Kryst., xvlii, 1890, p. 580.

VII. Barkevikite. Barkevik, Norway. Flink analyst. Zeitschr. Kryst., xvi, 1890, p. 412.

VIII. Hastingsite. Dungannon, Ontario. Harrington analyst. This Journal, i, 1896, p. 210.

IX. Arfvedsonite, Kangerdluarsuk, Greenland. Lorenzen analyst. Min. Mag., v, 1882, p. 50.

X. Aenigmatite. Naujakasik, Greenland. Forsberg analyst. Zeitschr. Kryst., xvi, 1890, p. 428.

XI. Cossyrite (aenigmatite). Pantelleria. Foerstner analyst. Zeitschr. Kryst., v, 1881, p. 354.

XII. Rhönite. Platz, near Brückenau, Rhön. Dittrich analyst. Neues Jahrb., Beil. Bd. xxiv, 1907, p. 498.

ness of the analyses made by Stanley under the direction of so preëminent an analyst as the late Professor Penfield cannot be doubted, and it is not probable that Schneider's figures are seriously in error, especially as he states* that special attention was paid to the determination of this constituent, though he does not mention the method employed.

In passing, a few remarks may be made in regard to Nos. IV and V. The exact localities of these hornblendes are not given by either author, but they both are said to come from Bohemia, and the extremely close similarity in the figures for SiO_2, Al_2O_3, FeO, MgO, CaO, Na_2O, and K_2O makes it probable that they were made on identical amphibole from the same locality. In view of this remarkable agreement of the constituents mentioned, the discrepancies observed in the figures for TiO_2 and Fe_2O_3 are noteworthy. In IV TiO_2 is higher and Fe_2O_3 lower, while in V the reverse is true. The sum of the two in each case is, however, exactly the same, 13·26. The exact agreement is, of course, a coincidence, but taken in connection with the close concordance in the other constituents, and having regard to the methods of analysis, it suggests the explanation that in IV the ferric oxide was determined by reducing the iron by H_2S, which does not act upon TiO_2, while in V the iron was reduced by zinc, which would reduce the TiO_2 to Ti_2O_3, and the latter would appear as Fe_2O_3, after subtraction of the FeO. On this supposition the lower TiO_2 of V, in conjunction with the close agreement between the figures for Al_2O_3, would be explained by the use of the method of boiling an acid solution with SO_2, which is as apt to give too low as too high results, or even possibly by the assumption that the residue left on evaporation of the silica with HF is wholly TiO_2, a not uncommon error, especially in former days. The presumption therefore is that IV represents the true composition more accurately than V. The matter, after all, is of little importance, but serves to illustrate the need of a critical study of analytical data in the light of the methods of analysis.

The blue arfvedsonitic amphiboles (IX) and the triclinic aenigmatite (X and XI) resemble ours in the figures for SiO_2 and K_2O, and especially in the high TiO_2 of the Greenland aenigmatite. TiO_2 was not determined in the analysis of arfvedsonite and the Pantelleria cossyrite, but it is presumably present in both, and almost certainly very abundantly in the cossyrite, as Brogger has shown. Additional reasons for this belief will be given in a forthcoming paper on the rocks of Pantelleria. These hornblendes differ, however, widely from ours in the lower Al_2O_3, the very much higher FeO and Na_2O, and in the very low MgO and CaO. The recently discovered triclinic

---

* C. Schneider, Zeitschr. Kryst., vol. xviii, p. 579, 1890.

rhönite (XII) is unique in its low silica, but in other respects resembles our amphiboles more than it does the triclinic aenigmatite, though the Al_2O_3 is remarkably high.

On the whole, therefore, our amphiboles may be considered to belong to the basaltic hornblendes or syntagmatites, rather than to the arfvedsonite group, and this general relationship is confirmed by the color, the etch figures, and the negative extinction angle of the Kaersut mineral. The very high TiO_2, however, places them in a subdivision apart and, with the small positive extinction angle of the Linosa mineral, indicates a transition toward the arfvedsonite group.

On account of their chemical characters, and also because of the position of the negative extinction angles $c \wedge \mathfrak{c}$, barkevikite (VII) and hastingsite (VIII) may also be regarded as transitional between typical syntagmatite and the arfvedsonites, though in the direction opposite to ours. A similar relation is suggested by Brögger,* who regards kaersutite as an end member of the basaltic hornblendes.

The name kaersutite may well be reserved for such highly titaniferous basaltic hornblendes or syntagmatites, and the mineral from Greenland may be regarded as the type. Whether the same name should be applied to the Linosa hornblende or not is somewhat doubtful. The two are chemically closely similar, but show a marked divergence in the relative amounts of the iron oxides. Also the physical characters are alike in nearly all respects. The only differences of note are the somewhat higher specific gravity and indices of refraction of the Linosa mineral, and the difference in the extinction angle, which last would seem to be the more important. Indeed, while that of the Kaersut amphibole is negative and lies well within the limits of the extinction angles shown by the ordinary syntagmatites, that of the Linosa amphibole is close to the vertical axis, but slightly positive, and indeed occupies a unique position between the extinctions of the riebeckite-arfvedsonite group on the one hand and those of the syntagmatites on the other, though it must be remembered that in the former group the bisectrix which lies nearest the vertical axis is $\mathfrak{a}$, not $\mathfrak{c}$. The physical characters of our two minerals are tabulated below.

The Linosa hornblende might be regarded as an end member of the highly titaniferous syntagmatites, in which case the name kaersutite would apply to it, or its peculiar extinction angle, and the high ferric oxide might justify the separation of it from this group as a distinct subspecies, to which the name *linosite* may be given. In view of the uncertainty of our

---

* Brögger, Grorudit-Tinguait Serie, p. 35, 1894.

	Linosa.	Kaersut.
Specific gravity	3·336	3·137
Crystal system	monoclinic	monoclinic
$110 \wedge 1\bar{1}0$	55° 22′	55° 35′
$\mathfrak{c} \wedge c$ on 110	+1° 24′	−8° 9′
Optical character	negative	negative
Color	deep brown	chestnut brown
Absorption	$\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$	$\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$
α	1·692	1·676
β	1·731	1·694
γ	1·760	1·708
$\gamma - \alpha$	·068	·032
2V	79° 54′	82° 6′
Dispersion	(?) weak	(?) weak

knowledge of the true chemical composition and relations of the hornblendes, the numerous varieties that are constantly being observed and often named, and the fact that many well-recognized species show greater divergence in physical properties and chemical composition than do our minerals, it seems to us advisable not to bestow a new name at present on the Linosa hornblende, but to consider it a kaersutite.

In conclusion attention may be called to the somewhat remarkable coincidence between the finding of kaersutite both in Greenland and on Linosa, and the similar occurrence of aenigmatite in Greenland and the apparently identical cossyrite on Pantelleria, which lies close to Linosa. In both the Arctic and the Mediterranean localities these minerals occur in comparative abundance and as material which can be easily studied, while elsewhere kaersutite is unknown and aenigmatite very rare and the crystals small and unsatisfactory.

Locust, New Jersey, and
Geophysical Laboratory of the
Carnegie Institution of Washington, D. C.