

# Calcite and Skarn Minerals in the Gneisses of the Holsteinsborg District, West Greenland.

By

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## Abstract.

In the course of the field investigations of G. G. U. (Geological Survey of Greenland) in the summer of 1946 some calcite and skarn deposits were found in the surroundings of the Amerdloq Fiord. The various occurrences are described; the refractive indices of the minerals have been measured, and in some cases chemical analyses have been performed. At "Tømmermandens Ø", locality 6, was found a violet mineral, which has been named "Ba-wilsonite". As a result of the examination of the ore minerals the opinion is expressed that the formation of the "rust zones" (the broad, rust-coloured zones that are very frequent in the whole district) has been caused by the disintegration of the pyrrhotite.

In the summer of 1946 I took part in the field investigations of G. G. U. (Geological Survey of Greenland) in the Holsteinsborg district in West Greenland. The investigations in the field were directed by Professor A. NOE-NYGAARD and H. RAMBERG, Ph. D. On our return I was entrusted with the task of describing the calcite deposits and some prominent skarn occurrences of the district<sup>1)</sup>.

The rocks about and north of Amerdloq are hypersthene gneisses belonging to the granulite facies. To the south of Amerdloq the gneiss complex belongs to the epidote-amphibolite facies. The border line is shown on the map, fig. 1.

The sedimentary origin of the rocks, in which, however, numerous pegmatite dykes and schlieren are found, seems beyond doubt. The prevalence of skarn minerals like diopside and scapolite in the district

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<sup>1)</sup> The field work of G. G. U. was continued in 1947 and 48; now an outline of the geology of the country between 66° and 69° n. lat. has been worked out by Dr. RAMBERG (see this volume p. 312), to which the reader is referred for a general description of the area in question.

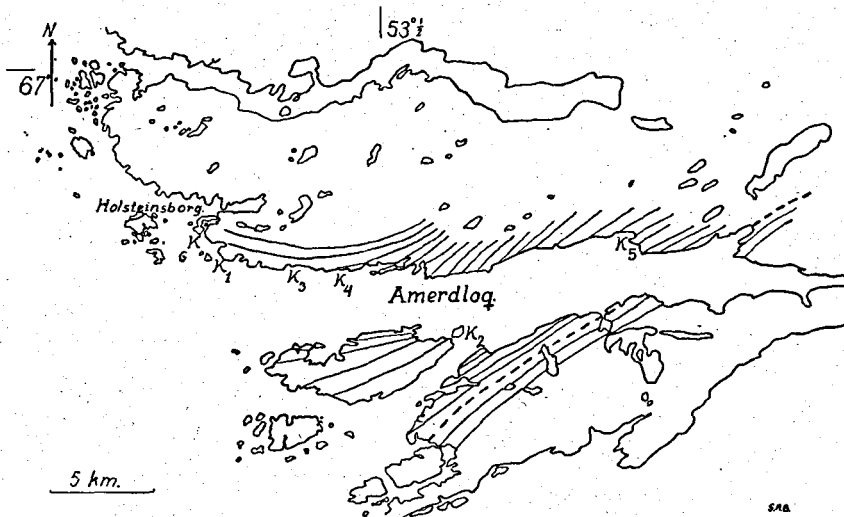


Fig. 1. The Amerdloq Fiord with surrounding district. Division line between the two main facies areas marked by dashed line. The strikes of the rocks indicated by Lines.

suggests a great proportion of limestone in the original sediments. The skarn minerals appear as inclusions generally characterized by an intense green colour, which is due to their contents of diopside. The inclusions are usually rather small — with a diameter of 10 or 20 cm — but at certain places they are large enough to make the skarn the predominant rock.

The map roughly indicates the strikes of the rocks surrounding the fiord of Amerdloq. The calcite and skarn localities, partly situated on the northern border of Amerdloq, partly on a small island in the outer part of the fiord, are marked by numbers 1-6. (It is clearly seen that the localities 6, 1, 3, and 4 belong to one zone, defined by the strikes of the rocks; correspondingly the localities 2 and 5 constitute another zone.)

Locality 1 (fig. 2) was known as early as 1871, when Mr. KRARUP-SCHMIDT brought home some specimens, which are now kept in the collections of the Mineralogical Museum of Copenhagen. The calcite, which is here salmon-pink, covers many square metres, but strange to say it has not been mentioned before in literature. Neither has locality 2, which is at least just as prominent, been noticed. At the other localities the pink calcite does not occur; at one place a

very little white calcite has been found, but apart from that only completely metamorphosed lime-rich minerals — the skarn minerals diopside, scapolite, sphene, etc. — remain.

The skarn deposits of the localities 3, 4, 5 are chiefly characterized by the great amount of diopside in the inclusions. The diopside has an intense green colour, ranging from rather pale to dark green. Even at a distance the skarn localities are conspicuous, revealing the places where lime has been a chief constituent of the original sediments. The grain size of the surrounding gneiss is frequently 2 or 3 mm. Normally the grain size of the diopside-scapolite rocks is a little more than one mm, so that these rocks are somewhat more fine-grained than the gneiss; but where greater quantities of diopside occur, the single individuals may be rather large; individuals of nearly 8 cm occur, but with ill defined crystal boundaries, and generally very impure. Together with these minerals sphene is found as small grains but in rather great quantities. The general size of the grains is a little less than 1 mm; rarely individuals of 3 mm are found; crystals occur, but are badly developed. The usual "envelope-shaped" forms of the crystals predominate. Mica occurs, but only as small grains. At locality 5 one rather large hornblende crystal (4–5 cm) was found, and at the same locality some magnetite occurs.

Locality 6 stands much apart from the other localities, the mineral assembly being characterized by greater quantities of mica and here and there by concentrations of carmine garnet. Finally occurs a mineral of a violet colour — much like lepidolite. Scapolite and diopside are found in great, diopside even in very great quantities, and on the whole the rock of locality 6 exhibits a highly varied view. Through the green of the diopside-bearing rock run veins of white feldspar. Microscopic examinations show that it is antiperthite, lamellae of orthoclase patching an albitic plagioclase (fig. 3). The connection with the large calcite deposit of loc. 1 seems undoubtable, as they are situated in one zone, clearly defined by the strikes. A closer investigation of locality 6 might reveal a number of new interesting details.

The two large calcite deposits (of loc. 1 and loc. 2) are on the whole identical. The existing specimens show that the minerals of locality 1 — apart from wollastonite and a pale yellow garnet — reappear at loc. 2. The proportion of the constituents is the same at either place. At loc. 2 the calcite appears as a wall against a steep slope of gneiss. The calcite lens is about 10 m long and at the



Fig. 2. The Amerdloq Fiord. Skarn rocks and a little of the calcite layer of locality 1 in the foreground.  
(A. NOE-NYGAARD phot.)



Fig. 3. A calcite lens (rather small) at locality 1, situated in the green diopside rock. (A. NOE-NYGAARD phot.)

ends it passes into a green diopside-scapolite rock. The whole deposit forms an inclusion in the gneiss.

The calcite deposit on the beach 3 km south-west of Holsteinsborg — loc. 1 — is composed of several bodies of calcite, and an important part of the neighbouring rock consists exclusively of skarn with diopside and scapolite as its chief constituents. The scenery is highly variegated, the salmon-pink calcite contrasting with the intense green of the rock, which is further traversed by pegmatite dykes and schlieren. On account of the position of the locality no vegetation veils the details of the scenery (fig. 4).

The calcite of these localities is coarsely crystallized, the grains being of much the same size, viz.  $1-1\frac{1}{2}$  cm. As mentioned above the colour is pink; towards bounds or inclusions it may be paler, although entirely white calcite does not seem to occur. Towards the boundaries entirely white zones may end the series of changing colours; apparently they consist of calcite, but a more detailed investigation proves the change of colour to be due to an altering in the mineral assembly, i. e. the white zones mostly consist of quartz and scapolite. This phenomenon will be discussed more closely under the description of an inclusion in the calcite.

Quartz, scapolite, and diopside occur as single grains scattered in the calcite. Fig. 5 shows the calcite to be evenly interspersed with black spots; they represent the dark green diopside, and in a similar manner appear quartz and scapolite, which, however, are generally found together. Here and there small grains of apatite may be found; the colour is pale yellowish green, and the grains are of the same size as the diopside, 1-3 mm. By close examination it appears that small grains of titanite are often found together with the diopside. They have a size of  $\frac{1}{4}$ -1 mm, rarely more, and appears in a pale yellowish brown and a dark brown variety. The single grains are characterized by having a peculiarly corroded appearance, whether the grains of a natural surface are studied or the sample is broken and fresh surfaces are used for the examination. This is especially clear, when the calcite is dissolved in acid and the granules of the residual, consisting of diopside, quartz, scapolite, and titanite, are examined (fig. 6).

The diffuse distribution of apatite is commonly interpreted as the result of gases, rich in phosphorous compounds, advancing from a magma. The diffuse distribution of diopside may suggest the presence of dolomite in the original rocks. This distribution of the diopside

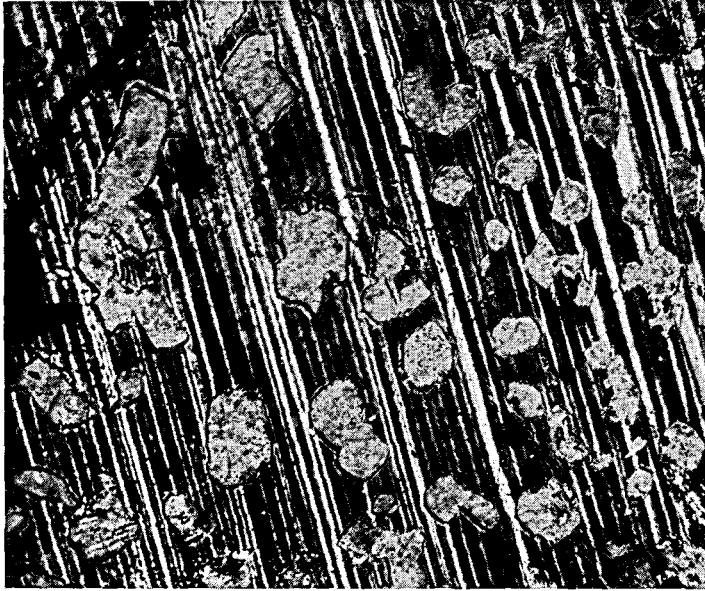


Fig. 4. Antiperthite. +N. 85x. (CHR. HALKIER phot.)

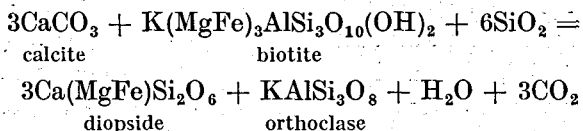
may also be explained by assuming a migration of Fe - Mg - Si, which may have caused the formation of the minerals of the diopside-hedenbergite series; in the calcite such a migration involves the migration of Na, K, Al, and Ti, which causes the formation of scapolite, titanite, etc. As the surroundings are very rich in Ti, and the calcite is sprinkled with titanite, the most probable explanation is that elements from the surrounding rocks have invaded the pure calcite.

As mentioned above inclusions are found in the calcite. They are exceedingly frequent and divided between the following types: dark diopside-bearing inclusions, light quartz-scapolite-orthoclase-bearing inclusions, and diverse veins and schlieren, chiefly made up of light material, here and there containing calcite, and generally rather fine-grained as compared with the surrounding calcite. The veins and schlieren may be due to re-crystallization posterior to the general metamorphism of the rock. Often the confining borders of the inclusions are rather irregular, but in a considerable number of cases the outlines of the dark inclusions are surprisingly regular; most striking are rectangular or square inclusions. It is hardly possible that such regular inclusions should have been formed by the metamorphism of the calcite, they must have existed by that time, although

with other constituents than found now. These original inclusions represented parties that were instable to the pressure and the temperature of the surroundings, consequently a migration took place, which caused great alterations in the mineral assembly.

Another evidence of this supposed migration is the zonal structure which is especially found in the light inclusions; fig. 7 clearly shows this structure. As a border these inclusions have a zone (1) with diopside and a little scapolite and quartz, then follows a zone (2) with exclusively scapolite and quartz, characterized by being entirely white. The central part of the inclusions (3) consists of scapolite, quartz, and orthoclase, arranged in the so-called pavement-structure. In zone 1 a little titanite occurs, which reappears in zone 3, where also some few grains of diopside occur. As far as examination has made it possible to state, orthoclase is only found in zone 3, this being the only way in which it occurs in the calcite.

Besides this apparently typical distribution another feature is noticed in the inclusions: the scapolite of zone 2 is intergrown with the quartz forming a remarkable symplektite recalling a myrmekitic intergrowth (Fig. 8). The quartz occurs as worm-shaped individuals in the scapolite; and over large areas these quartz-grains may have the same orientation. This intergrowth is only found where those two minerals occur in the described inclusions, but not if they appear together as dispersed minerals in the calcite. There can be little doubt that all these phenomena originated in reactions that took place between the lime, the various impurities occurring in it, and the migrating elements. The occurrence of quartz in all the zones suggests that the reactions took place in a surplus of  $\text{SiO}_2$ , in which a reaction between calcite and biotite would result in the actual constituents:



If it is supposed that rocks of a granitic composition — quartz, biotite, and feldspar — existed in the original sediments, we actually have the material which would be able to produce the minerals in the light inclusions in reaction with  $\text{CaCO}_3$ . It is very interesting that the zonal structure found here entirely resembles the structure described by VON ECKERMANN originating from a reaction between

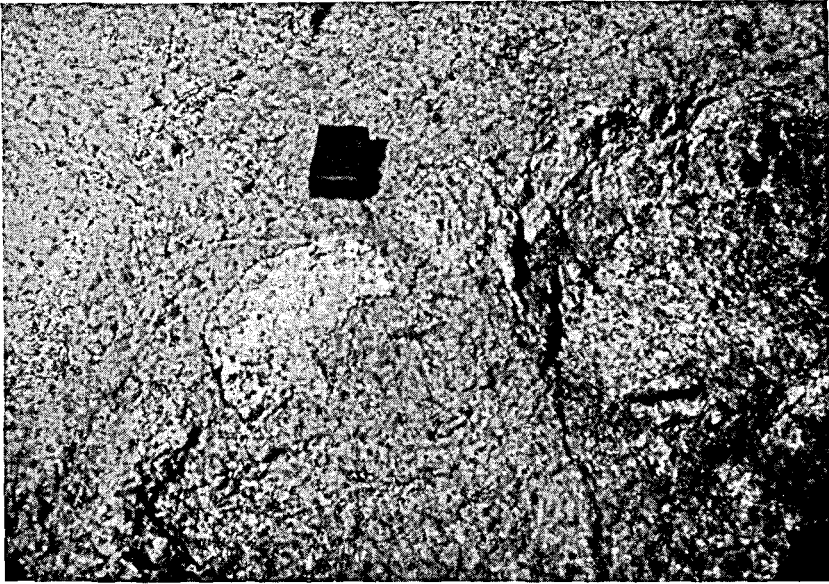


Fig. 5. Calcite sprinkled with diopside. A light inclusion is seen in the centre of the picture; note the narrow black border of the inclusion. (A. NOE-NYGAARD phot.)

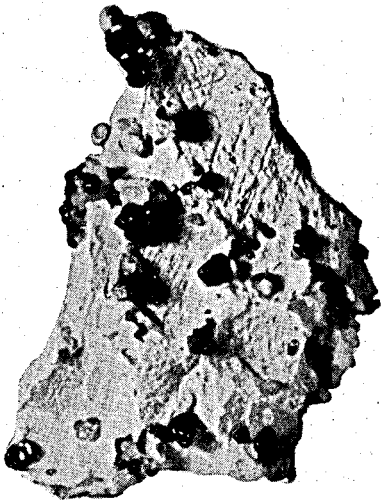


Fig. 6. Calcite partly dissolved in HCl. The rounded shapes of the dispersed minerals are seen.  $\times 2$ . (CHR. HALKIER phot.)



Fig. 7. Inclusion from the calcite, showing zonal structure. Nat. size. (CHR. HALKIER phot.)



pegmatite and lime in the Mansjø district; circumstances have there favoured a formation of mica and a further development of the diopside zone. The calcite formations in the Holsteinsborg district seem to correspond closely to those of the Mansjø district, only on a smaller scale.

The microscopic examination revealed that the specimens from locality 1 contained some wollastonite, appearing as a thin crust on a surface of the specimen. On the opposite side of the sample the calcite has been dissolved, and small garnet individuals intimately mixed with quartz remained. Both wollastonite and garnet are yellowish, and in the field they may easily be mistaken for a pale coloured calcite. The occurrence of wollastonite indicates a metamorphic grade, which is a little higher than that indicated by the surrounding rocks, and which corresponds to the higher facies in Orijärvi (BARTH, CORRENS, & ESKOLA p. 355). Though easy to understand it is much to be regretted that the singularity of this specimen was not noticed in the field, in which case more information might have been obtained. It would have been very interesting to know its position in the calcite; and further an investigation in the field would have revealed whether the occurrence is merely a local phenomenon, or a large district corresponds to the metamorphic grade indicated by the wollastonite.

On the whole the following minerals were found at the mentioned localities (the minerals are arranged according to the groups in which they occur at the localities):

mineral: calcite	locality: 1 & 2
apatite	1 & 2
diopside	all
scapolite	all
quartz	all
orthoclase	1 & 2
titanite (sphene)	all
wollastonite	1
garnet, yellow	1
hornblende	5
garnet, carmine	6
mica	especially 6
Ba-wilsonite	6

To these are added the following ore minerals, found partly in the skarn rocks, partly in the pegmatite veins in the neighbourhood of the calcite, partly in the surrounding gneiss:

magnetite	pyrite	various altera-
ilmenite	chalcopyrite	tion products,
hematite	pyrrhotite	limonite etc.

The *calcite* microscopically has a rather misty look probably due to the pigmentation that macroscopically appears as the characteristic pink colour. It has

$$N_o = 1.660$$

i. e. only very little higher than normally, WINCHELL giving  $N_o = 1.6584$ .

A partial analysis performed by Miss M. MOURITZEN, civil engineer, gave:

SiO <sub>2</sub>	0.39 %
TiO <sub>2</sub>	nil
Al <sub>2</sub> O <sub>3</sub>	nil
Fe <sub>2</sub> O <sub>3</sub>	0.44 %
MnO	traces
MgO	nil
CaO	55.71 %

i. e. a rather pure calcite. The pink colour is probably due to its content of iron.

The *apatite*, which as mentioned above only occurs in the calcite proper, is of a pale greenish yellow colour. It is uniaxial and has

$$N_o = 1.639$$

$$N_e = 1.635$$

$$N_o - N_e = 0.004$$

A sulfate apatite from Laacher See (WINCHELL II p. 130) is reported to have given  $N_o = 1.6383$  and  $N_e = 1.6350$ . The approximate agreement of the indices, it is true, is not sufficient for identifying the two minerals, but a sulfate test — made on very scarce material — it proved positive; is therefore possible that the apatite from locality 1 is a sulfate apatite.

On account of its colour the *diopside* is the most remarkable mineral, being especially predominant in the skarn rocks. In the

calcite it rarely reaches a size of more than 1–2 mm, whereas elsewhere individuals of nearly 8 cm may occur. The small grains are rather pure, while the larger ones are so impure that it is hardly possible to gain sufficient material for the analysis. Indeed, it may be said of most of the minerals of the limestone deposits in question that they contain a smaller or greater quantity of impurities, generally so small that it is impossible to analyse them more closely. What is here termed "diopside" represents an essential part of the diopside-hedenbergite series. This is seen even macroscopically, as there is a variation in colour ranging from entirely pale green via intense green to almost greenish black.

The diopside that occurs most commonly in the calcite is dark green. It is clearly pleochroic:

$$\begin{aligned} 2V &= \text{ab. } 60^\circ \\ N_g &= 1.718 \\ N_m &= 1.698 \\ N_p &= 1.693 \\ N_g - N_p &= 0.025 \end{aligned}$$

According to WINCHELL this corresponds to a variety containing 40% hedenbergite and 60% diopside. Another variety that occurs in the calcite is a somewhat paler diopside with lower refringence. Those varieties of diopside also occur in the surrounding skarn rocks.

A rather coarse-grained, dark diopside from the skarn rock close to the calcite is characterized by its strong pleochroism, varying from yellowish green to dark bluish green:

$$\begin{aligned} 2V &\text{ ab. } 60^\circ \\ N_g &= 1.729 \\ N_m &= 1.711 \\ N_p &= 1.704 \\ N_g - N_p &= 0.025 \\ r &> v \end{aligned}$$

This variety is the most hedenbergitic of all diopsides. According to WINCHELL the optical data correspond to 55% hedenbergite and 45% diopside.

The determination of the composition is based on the content of Ca - Mg. A certain amount of Ti, Al, Fe<sup>III</sup>, and Mn will, however, also influence the refringence, and to get an impression of this influence on the diopside here examined it was desirable to obtain a

complete chemical analysis. Mr. A. H. NIELSEN, analyst at "Kryolit-selskabet Øresund", Copenhagen, was so kind as to perform this analysis at the laboratory of the mentioned company:

For the analysis 1.5 g material was used.

SiO <sub>2</sub> .....	50.66 %
TiO <sub>2</sub> .....	0.27 %
Al <sub>2</sub> O <sub>3</sub> .....	2.16 %
Fe <sub>2</sub> O <sub>3</sub> .....	2.18 %
FeO.....	10.88 %
MnO.....	0.45 %
MgO.....	10.53 %
CaO.....	23.02 %
Cr <sub>2</sub> O <sub>3</sub> .....	nil
BaO.....	nil

sum total... 100.15

This analysis shows that the hedenbergite content only makes up ab. 40% of the mineral. The divergence between the refringence corresponding to 40% hedenbergite and the actual refringence corresponding to 55% hedenbergite must then be due to the rather great quantity of Ti, Al, Fe<sup>III</sup>, and Mn. The divergence is so great that — as far as this variety is concerned — it must be said that the refractive indices are not sufficient for characterizing the mineral. This observation must probably also be applied to the other varieties of diopside. It would be interesting to examine the relation between the refractive indices and the contingent of kations, and if possible the diopsides from these localities will later on be subjected to further examinations.

The lowest refringence was observed in a very pale green diopside from locality 5. The optic data are:

$$\begin{aligned}
 2V &= \text{ab. } 60^\circ \\
 N_g &= 1.700 \\
 N_m &= 1.681 \\
 N_p &= 1.671 \\
 N_g - N_p &= 0.029
 \end{aligned}$$

According to WINCHELL these data correspond to a diopside with only 10% hedenbergite and 90% diopside.

The commonest diopside from the skarn rocks is intense green;

it occurs in a fine-grained (1–2 mm) and a coarse-grained variety and not rarely it occurs as included “buns” without connection with skarn rocks proper. Its optic data are:

$$\begin{aligned} 2V &= \text{ab. } 60^\circ \\ N_g &= 1.712 \\ N_m &= 1.692 \\ N_p &= 1.685 \\ N_g - N_p &= 0.027 \end{aligned}$$

The corresponding variety mentioned by WINCHELL contains 30% hedenbergite and 70% diopside. When possible to measure ZAC, this value was determined at ab.  $43^\circ$ .

Whenever the diopside grains are of a certain size ( $1/2$  cm) they show well developed parting on 100 and 001, i. e. they have the character of diallage.

The next important mineral is the *scapolite*. The refractive indices of the various specimens examined showed no variation. It was observed that the mineral sometimes appeared with a certain pigmentation — smoky to greyish black — when occurring in the skarn rocks. This phenomenon effected a sort of pleochroism. It has:

$$\begin{aligned} N_o &= 1.589 \\ N_e &= 1.557 \\ N_o - N_e &= 0.032 \end{aligned}$$

According to WINCHELL this corresponds to a composition of 70% Me and 30% Ma.

The scapolite always occurs together with quartz, which has

$$\begin{aligned} N_o &= 1.545 \\ N_e &= 1.553 \\ N_e - N_o &= 0.008 \end{aligned}$$

The *orthoclase*, which occurs together with scapolite and quartz, is the purest of all the minerals (i. e. it has the smallest content of inclusions). It has

$$\begin{aligned} N_g &= 1.526 \\ N_m &= 1.523 \\ N_p &= 1.519 \\ N_g - N_p &= 0.007 \end{aligned}$$

In the skarn rocks occurs a dark brown titanite, which is also found in the calcite. In the latter there are also single grains of a

rather pale brownish yellow type, of which it was only possible to obtain very scarce material, not sufficient for an analysis. The pale type had:

$$\begin{aligned} N_g &= 1.95 \\ N_p &= 1.870 \\ N_g - N_p &= 0.08 \end{aligned}$$

The dark type had:

	Dark titanite	Grothite from Parainen
$N_g$	$= 1.992$	$= 1.975$
$N_m$	$= 1.899$	—
$N_p$	$= 1.875$	$= 1.84$
$N_g - N_p$	$= 0.117$	$= 0.135$
		$2 V_\gamma = 38^\circ$
		$c/\lambda\gamma = 50^\circ$

On the dark titanite the following analysis was made by Mr. A. H. NIELSEN at "Kryolitselskabet Øresund", Copenhagen:

	Dark titanite	Grothite from Parainen
SiO <sub>2</sub>	30.59 %	30.32 %
TiO <sub>2</sub>	35.16 %	33.70 %
Nb <sub>2</sub> O <sub>5</sub>	—	0.69 %
Ta <sub>2</sub> O <sub>5</sub>	—	0.03 %
V <sub>2</sub> O <sub>5</sub>	—	0.09 %
Al <sub>2</sub> O <sub>3</sub>	3.53 %	4.44 %
Fe <sub>2</sub> O <sub>3</sub>	1.23 %	nil
FeO	0.36 %	0.20 %
MnO	0.04 %	0.01 %
MgO	0.11 %	0.16 %
ZrO	—	0.06 %
CaO	28.10 %	28.40 %
SrO	—	0.005 %
BaO	—	0.003 %
Na <sub>2</sub> O	—	0.13 %
K <sub>2</sub> O	—	nil
rare earths	—	0.30 %
H <sub>2</sub> O <sup>+</sup>	} 0.22 %	0.54 %
H <sub>2</sub> O <sup>+</sup>		0.18 %
F	nil	1.40 %
Cl	—	nil
Cr <sub>2</sub> O <sub>3</sub>	nil	0.02 %
	<hr/> 99.34 %	<hr/> 100.02 %

For comparison the refractive indices and the chemical analysis of a titanite from Parainen are cited according to TH. G. SAHAMA: On the Chemistry of the Mineral Titanite. The agreement of the optic data as well as of the analyses is striking. Just as remarkable is the absence of F in the Holsteinsborg titanite. As the mineral is decomposed by conc.  $H_2SO_4$ , a detection of F by KÜHNEL HAGEN'S method is absolutely reliable; and this test here proved negative.

The *wollastonite* is only known from rather few localities in Greenland. Wollastonite is generally characterized by the variable sign of elongation. It is remarkable that this feature has not been noticed in any of the hitherto known samples from Greenland; it was observed, however, in the specimen now examined. It has:

$$\begin{aligned} N_g &= 1.634 \\ N_m &= 1.633 \\ N_p &= 1.619 \\ N_g - N_p &= 0.015 \end{aligned}$$

The *garnet* occurring together with the wollastonite is pale yellowish. The refraction is

$$N = 1.758$$

In thin section it is observed that it occurs as small grains in the quartz. Due to condition of the specimen it was impossible to gather sufficient material for further examination.

At locality 5 an almost black *hornblende* occurs together with the diopside that has the lowest refringence. The hornblende has:

$$\begin{aligned} N_g &= 1.676 \\ N_m &= 1.666 \\ N_p &= 1.655 \\ N_g - N_p &= 0.021 \end{aligned}$$

Its pleochroism is very obvious from bluish green to pale yellow.

At locality 6 a *carmine garnet* occurs together with mica of a rather dark colour. The refringence of the garnet was found to be

$$N = 1.802$$

The *mica* had

$$N_m = 1.603$$

while the mica that occurs together with the violet mineral was found to have

$$N_m = 1.588$$

Both types of mica have a small optic angle and show pleochroism in pale brown colours.

When found in the field the violet mineral from locality 6 was first regarded as calcite or some other carbonate, but was not studied more closely. The microscopic examination revealed a mineral with the optic angle varying from  $0^\circ$  to *ab.*  $10^\circ$ . The powdered mineral appeared to have micaceous cleavage, while the sample produces the effect of a dense, almost talc-like mass with a greasy luster. The hardness is about  $3\frac{1}{2}$ . Under microscope it exhibits aggregate-polarization and interference colours of the first order (fig. 9). This recalls VON ECKERMANN'S description of amphodelite (the hardness of which, however, is stated to be 4-5). The refringence of the violet mineral is about 1.58, which is also in accordance with VON ECKERMANN'S amphodelite. The mineral occurs together with mica, which partly surrounds it, partly is found as inclusions in it. Further scapolite and feldspar occur in close connection with it. A preliminar spectral analysis gave the result that the mineral contained Al, Mg, Ca, and a little Fe, Mn, and Ba. This looked very interesting, and Miss M. MOURITZEN was so kind as to perform a partial chemical analysis on the mineral. It was not possible to exclude a small portion of mica and diopside. The following figures were obtained (for comparison analyses made on amphodelite (VON ECKERMANN) and wilsonite (DOELTER) have been given):

Violet Mineral		Amphodelite (v. E.)	Wilsonite (DOELTER)
SiO <sub>2</sub>	48.83	44.51	43.55
TiO <sub>2</sub>	0.00	—	—
Al <sub>2</sub> O <sub>3</sub>	—	27.90	27.94
Fe <sub>2</sub> O <sub>3</sub>	1.49	1.41	0.20
MnO	0.08	—	—
MgO	—	2.34	3.81
CaO	—	13.45	6.50
Na <sub>2</sub> O	2.09	1.29	1.45
K <sub>2</sub> O	8.24	3.27	8.37
H <sub>2</sub> O <sup>+</sup>	4.32	} 5.51	} 8.61
H <sub>2</sub> O <sup>+</sup>	0.62		
BaO	0.41	—	—
F	—	0.24	—
Cl	—	0.00	—
		99.92	100.43



This cannot be said to correspond with VON ECKERMANN's amphotelite, the K content being much greater; the Ba content (ab. 3%) is less than in the amphotelite. The examination of thin sections suggested an alteration of scapolite, and the analysis corresponds very well to wilsonite (mentioned by DOELTER as an alteration product of scapolite). The existing analyses of wilsonite are, however, not sufficiently supported by optic data for permitting any conclusion. The Ba content is of great interest, as it suggests the presence of Ba in the original mineral. In future analyses of minerals from Greenland, especially Holsteinsborg, attention should be given to the possible occurrence of Ba. It seems unadvisable to propose a new mineral name for the violet mineral, but the great content of Ba seems to justify the use of Ba-wilsonite as a preliminary appellation.

Magnetite and ilmenite are the most frequent ore minerals; further a little hematite occurs together with those two minerals. Pyrite is almost as frequent as magnetite, where it occurs. Some pyrrhotite is found together with chalcopyrite. Finally occur some alteration products of pyrite and pyrrhotite.

For a further examination of the relations of these minerals within the rocks of locality 1 some samples were taken from 1) pegmatite dykes, 2) fine-grained skarn rocks, 3) a vein with calcite, and 4) a "rust zone". (Fig. 10).

It appears that the calcite does not contain any ore minerals at all (zone 3). In the dark, fine-grained zone 2 a little ilmenite and a very small quantity of pyrite occur. The pegmatitic zone 1, which is seen to carry dark inclusions, contains a little pyrrhotite and chalcopyrite and some pyrite; and in the dark inclusions a little ilmenite occurs. Zone 4, which has been named "rust zone", chiefly contains pyrite; further occurs a good deal of pyrrhotite, and finally rather considerable amounts of chalcopyrite are found. These minerals may represent up to 10 per cent of even quite large samples; of this percentage pyrite and pyrrhotite in almost equal quantities make up  $\frac{3}{4}$ . The pyrite and the chalcopyrite are generally unaltered, while the pyrrhotite very often has been subjected to considerable alteration and weathering. It has partly been attacked by an alteration causing the so-called "birds' eye" structure; partly—possibly proceeding from this stage—limonite has been formed. The characteristic appearance of the zone, which has caused the name of "rust zone", consequently originates in the alteration of the pyrrhotite. This is rather interesting, as this zone contains the same ore minerals as the

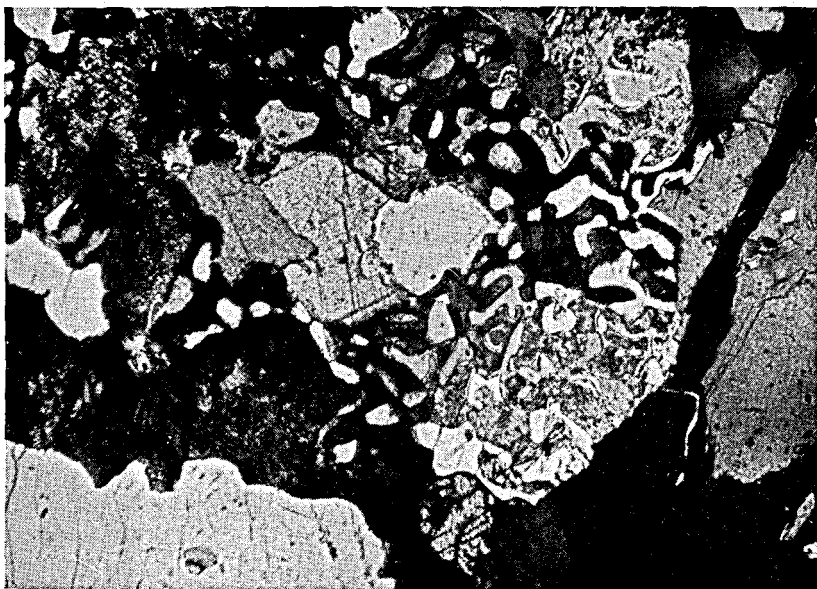


Fig. 8. Quartz-scapolite symplektite. + N. 25 x. (CHR. HALKIER phot.)

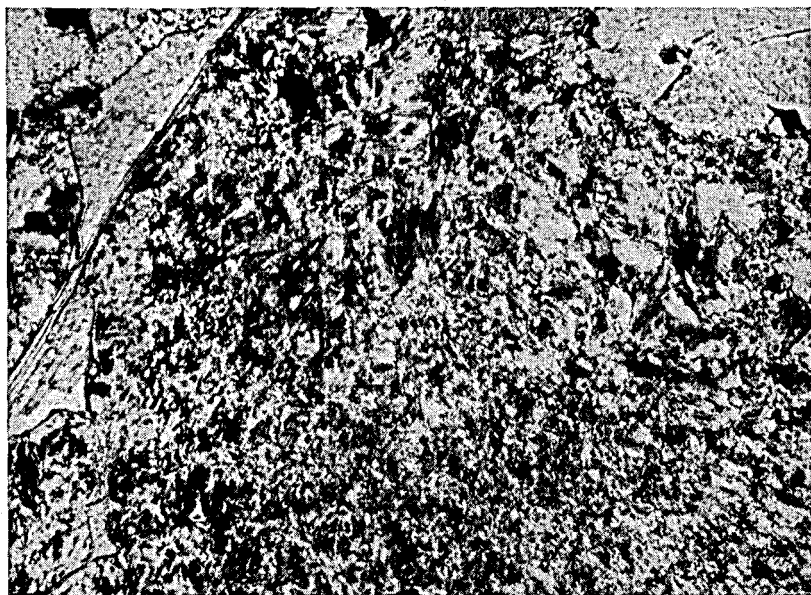


Fig. 9. Aggregate-polarization of Ba-wilsonite. In the right top corner scapolite is seen, to the left some mica, and in left top corner diopside. + N. 85 x. (CHR. HALKIER phot.)

vast "rust zones" which are met with everywhere in the district, and also outside it, and which constitute a characteristic feature of the whole complex (cfr. RAMBERG 1948). In this connection it might be of interest to mention that most of the samples of pyrrhotite

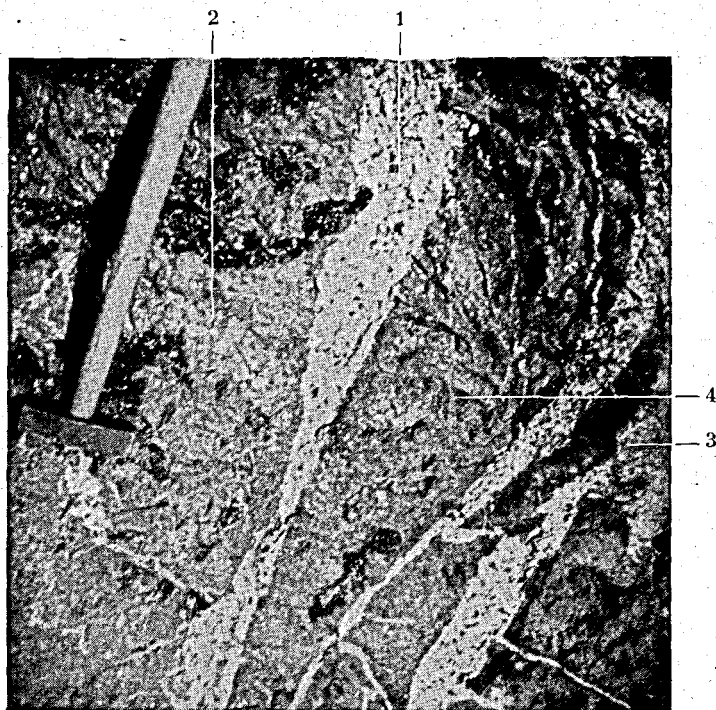


Fig. 10. Skarn rock at the border of a calcite crop. 1) Pegmatite zone. 2) Finegrained diopside-scapolite rock. 3) Calcite. 4) "Rust zone". (CHR. HALKIER phot.).

from Greenland that have been examined under the ore-microscope show signs of the abovementioned "birds' eye" structure.

To get a more definite idea of the occurrence of the sulfides it has been necessary to examine some rocks outside the skarn deposits proper under the ore-microscope. As amphibolitic inclusions frequently occur, it was desirable to extend the examinations even to these.

Fortunately one of our samples could be prepared as a polish slab exhibiting gneiss, transition rock, and amphibolite, as seen from photo (fig. 11). In the sample, which is ab. 4 cm long, 53 grains are found, discernable as entirely white grains. Of these 12 occur in the gneiss, 33 in the transition zone, and 8 in the amphibolite. 3 grains consist of pyrite or perhaps pyrrhotite, they occur in the gneiss.

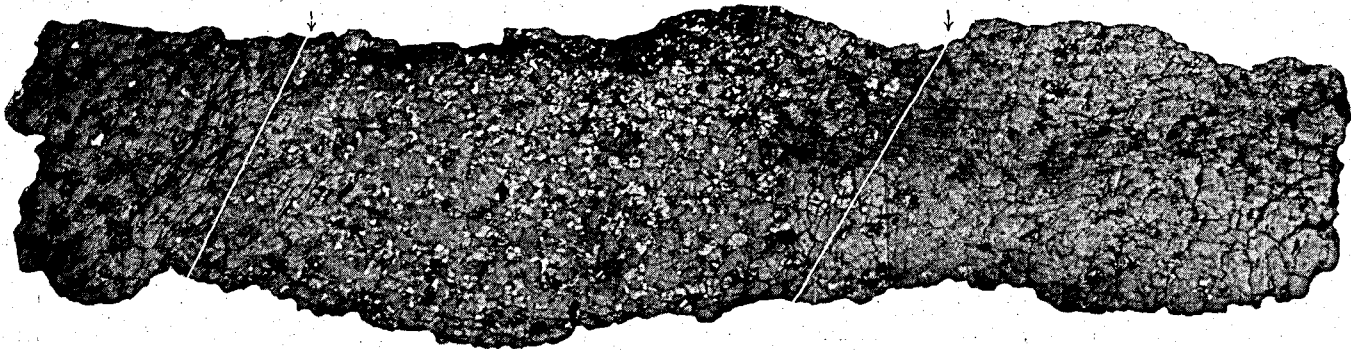


Fig. 11. Polished slab. Gneiss to the left, amphibolite to the right, transition rock in the middle. The ore is seen as perfectly white grains. 4× (CHR. HALKIER phot.)

The rest consist of magnetite and ilmenite, in some cases in the form of magneto-ilmenite. Magnetite occurs pure in 2 grains situated in the gneiss; 4 grains consist of ilmenite with lamellae of magnetite (magneto-ilmenite) or ilmenite intergrown with magnetite; and the rest—44 grains—consist of pure ilmenite. The magneto-ilmenite and the ilmenite-magnetite grains occur as far as 3 grains are concerned on the border between the amphibolite and the transition rocks, and the fourth grain is found in the gneiss. As is clearly seen, the sulfides are of no importance here. The distribution of the ore clearly shows that its occurrence is due to a reaction between the original minerals, now represented by the amphibolite, and the surrounding originally sedimentary rocks.

As the ore-microscope used for the examinations only permitted a magnification of 600 x, it cannot be stated with certainty if the ilmenite, apart from the mentioned cases of magneto-ilmenite, has no exsolution lamellae of magnetite; however, the distribution of these grains does not seem to have any connection with the structure of the specimen, and therefore the question may be regarded as being of little importance here. It may further be mentioned that the magneto-ilmenite appears with coarser and finer lamellae, suggesting two generations of magnetite. The ilmenite-magnetite grains are remarkable, as the border between them is a perfectly straight line.

At places schlieren were found in rust zones containing rather large amounts of sulfides (grains of about 1 cm). It is interesting that the very frequent pegmatites often contain great quantities of magnetite and ilmenite. The ore may be found in the shape of pieces as large as a fist in almost pure quartz pegmatites. In a single specimen ilmenite occurred with several generations of hematite lamellae along with magnetite grains, distinguishable from the ilmenite by having comma-shaped non-opaque grains of spinel (and of course by being isotropic and of different colour). This preliminary examination of the material seems to permit the following conclusion: The district is rich in iron. It is particularly characterized by a singular concentration of titanium, chiefly occurring in ilmenite, though in this connection it must be mentioned that rather great quantities of titanite occur in the skarn rocks. It may be supposed that iron and titanium were constituents of the original minerals (pyroxenes and biotite) of the basic bands in the originally sedimentary rocks; the granitization processes caused the metamorphism of the sedimentary rocks into gneiss, and of the basic bands into amphibolite, the

latter process resulting in the formation of magnetite and ilmenite.

The magnetite-ilmenite bearing quartz-pegmatites at "Tømmermandens Ø" prove that some of the oxides of Fe-minerals owe their origin to the formation of pegmatite. Sulfides only occur in the so-called "rust zones" in the gneiss (to which the sulfide deposit of locality 1 belongs); their formation has probably been caused by the granitization of the sedimentary rocks. No connection seems to exist between the "sulfide zones" and the "magnetite pegmatites". The latter form distinct pegmatite dykes, while the outlines of the former are rather vague, the "rust zones" gradually passing into the surrounding gneiss.

As far as can be judged from the examinations that have been carried out, the occurrence of ilmenite and magnetite contributes greatly to the comprehension of the whole complex of rocks, and further the studied specimens of these minerals contain such interesting structures that more detailed investigations will certainly prove fertile.

The determination of the refractive indices was carried out according to the dispersion method, and the indices of the liquids were measured by means of a hollow prism. About the construction of this, see PAULY (1948).

I wish to take this opportunity to thank my teacher, Professor A. NOE-NYGAARD, for giving me the chance to take part in the expedition to Greenland in 1946, and for entrusting me with the material for this study. Professor NOE-NYGAARD also helped me in the course of my examinations and kindly permitted me to publish some of his photographs.

During my studies I have learned much from discussions with the Inspector of the Mineralogical Museum, Miss K. CALLISEN, Ph. D., with H. CLAUSEN, mag. scient., Lecturer in the University of Copenhagen, and with H. RAMBERG, Ph. D.

Mr. A. H. NIELSEN, Analyst at "Kryolitselskabet Øresund", and Miss M. MOURITZEN, Civil Engineer, have kindly performed the chemical analyses.

Mr. CHR. HALKIER, Conservator at the Mineralogical Museum, has undertaken the laborious work of making all the microphotographs, some of which have presented great difficulties.

My fellow undergraduate K. ELLITSGAARD RASMUSSEN has performed the preliminary spectral analysis for me, and A. S. BERTHESEN has made several thin-sections and drawings.

## Resumé.

### Kalk- og skarnmineraller i gnejserne i Holsteinsborg distrikt, Vest-Grønland.

Under Grønlands Geologiske Undersøgelses arbejde i sommeren 1946 fandt man en del kalk- og skarnmineralforekomster omkring Amerdlog fjorden. De forskellige mineralforekomster er beskrevet; for de enkelte mineraller er der udført lysbrydningsmaalinger og i nogle tilfælde kemiske analyser. Paa Tømmermandens Ø, lokalitet 6 paa kortet, blev der fundet et violet mineral, som er blevet kaldt Ba-wilsonit. Ud fra undersøgelsen af malmminerallerne fremsættes den anskuelse, at det er magnetkisens omdannelse, der foraarsager dannelsen af rustzonerne, d. v. s. de brede, rustfarvede strøg, som optræder meget hyppigt i hele distriktet.

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