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GUNNBJARNITE, A NEW MINERAL
FROM EAST GREENLAND

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TRICHOPHYA DANAE SP. NOV.,
A SUCTORIAL PROTOZOAN FROM
GREENLAND WATERS

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NOTES ON THE MICROBIOLOGY OF SOIL
FROM NORTHERN GREENLAND

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GUNNBARNITE, A NEW MINERAL FROM EAST GREENLAND

By O. B. BØGGILD

In the summer of 1946 Dr. EIGIL NIELSEN collected some specimens of a peculiar, brown, micaceous mineral on the Hold With Hope peninsula. On his return it became apparent that the mineral was previously unknown, and he therefore collected a more plentiful material during the following summer.

The name Gunnbjarnite is formed from the name of the Norseman GUNNBjørn Ulfsson who, about the year 900, came to a great land and some small islands the later so famous "Gunnbjarnarsker"; it is assumed that he reached one or another part of East Greenland, and he is generally regarded as the first discoverer of Greenland.

The following information concerning the occurrence of the mineral is given by EIGIL NIELSEN: "The mineral is collected at about 475 m above sea-level from a 3 m thick basalt dyke which cuts the Triassic and Cretaceous sediments in the north-easterly part of Steensbys Bjerg (Mt. Steensby). It appears in the basalt as irregular, often branched veins about 0.5 to 3 cm in thickness".

The available material shows a remarkable constancy in mineral composition, the specimens being composed almost exclusively of gunnbjarnite and calcite. In a few instances some apparently very impure, and certainly indeterminable earthy material was found after solution of the calcite. In a single instance the gunnbjarnite was found in a very fine-grained mass of quartz or chalcedony. The two main minerals, which compose by far the greater part of the veins, are often rather irregularly distributed, but it is most typical that they occur in thin plates or layers. The calcite occurs in different forms: in many cases it is irregularly granulous, but in general it is fibrous, not, however, particularly regularly, or obviously so except in microscopical preparations. The fibres are generally parallel with the layers mentioned above and seem furthermore to be parallel with the a-axis of the gunnbjarnite. Layers of calcite with the fibres placed either at right angles to the

surface or obliquely are, however, also of common occurrence. No crystal form has been seen in this calcite. The colour is whitish or greyish.

The crystal form of gunnbjarnite is rhombic. It has not been possible to find free crystal faces as there have certainly been no cavities in the dykes in which crystals could develop. One could perhaps think that it would be rather easy to free the crystals of gunnbjarnite by solution of the calcite, but the crystals are so permeated by calcite that they are disrupted during the solution, and the mineral which is very brittle becomes even more so by the action of the acid, even if this is cold and rather weak. The thin sections give the impression that the crystals are in most cases flat plates limited by the best developed cleavage, but no clear impression of the shape of the plates is given. Individual crystals can be several centimetres in both length and breadth, but the thickness is most often only a fraction of a millimetre and at most a few millimetres.

There are two cleavages, of which the one must be described as perfect and the other as very strongly developed. In order to simplify the following description the first is called basal (001) and the other (010). The basal cleavage-flakes are micaceous, and are flexible and elastic in the one direction; while in the other direction they are easily broken into lath-like fragments. The greater part of the powdered material is seen to consist of such ribbon-like fragments with straight sides and ragged ends. The basal cleavage surface exhibits a most striking phenomenon; it being strongly folded or wrinkled parallel with the *a*-axis, and therefore also with the direction of weaker cleavage. The phenomenon, which is shown on fig. 1, is clearly to be seen on all crystals. In many cases it seems as though one is concerned with a fibrous aggregate, but in other cases one has a clear impression of a single surface which is extensively corrugated.

The hardness is 2—2.5. The colour is dark brown with a pronounced pearly lustre on the basal cleavage surface. Crystals thicker than *c.* 0.5 mm are opaque, but the majority of the crystals are very thin and transparent, with a lighter or darker colour according to the thickness. The colour is so intense that it is impossible to find a colourless flake in spite of the perfectly developed cleavage. The ordinary specimens, which are composed of the thin crystals intermixed with calcite, have a rather unimpressive appearance, and remind one in some degree of rotten wood, but the characteristic properties of gunnbjarnite can be recognized under the microscope. The streak is very light brown.

The specific gravity and other physical properties of the mineral are rather variable; this can possibly be connected with the presence, later to be mentioned, of a large amount of loosely bound water. For apparently quite pure pieces I have obtained values from 2.025 to

2.134 (average 2.075) using Thoulet's fluid. By weighing larger pieces in water I have obtained various values, mostly between 2.2 and 2.3, but in this case the ever-present calcite doubtless increases the specific gravity.

The mineral is optically negative; the axial plane is parallel with (010), and the acute bisectrix is at right angles to (001). In the powdered material which, as previously mentioned, is composed of laths parallel with (001) the sign of elongation is always positive.



Fig. 1. Gunnbjarnite. 1 : 1. HALKIER fot.

The optic axial angle which can be observed in the majority of regularly developed microscopical fragments is somewhat variable. The most typical is that the hyperbolae, on rotation, pass out of the field and one can set $2E$ at a little over 100 ($2V = c. 60^\circ$).

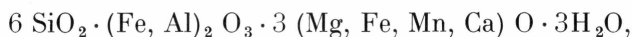
The refraction is unusually variable. The indices β and γ can be determined in nearly every case owing to the lath-like shape of the grains, and it is easy to see that there is but slight agreement among the grains. In any powdered sample there will, however, always be a number of grains which are fairly uniform, and by using these it has been possible to determine the following values, all on apparently very fresh material: $\beta = 1.553$ (1.540—1.571), $\gamma = 1.579$ (1.561—1.593). The refractive index α , which is at right angles to the strongest cleavage, is only with difficulty to be observed. Among the microscopic fragments are found some which are very slender, thread-like, and sometimes twisted about their long axis. Among these are found some which transversely show a refractive index less than that of Canada balsam, which is what one would expect

from the previously mentioned values. But any direct calculation of α from these values must be regarded as quite hopeless.

The chemical analysis was undertaken by Mr. A. H. NIELSEN, with the following result:

		Quot.
SiO ₂	43.15	0.719
TiO ₂	0	
Al ₂ O ₃	3.29	0.032
Fe ₂ O ₃	14.57	0.091
FeO	1.06	0.015
MnO	0.13	0.002
MgO	12.98	0.324
CaO	3.66	0.064
H ₂ O (+ 110)	7.19	0.399
H ₂ O (— 110)	12.17	
CO ₂	n.d	
	<hr/> 98.20	

It is impossible to find a formula which corresponds exactly to the above composition. With Al considered together with Fe one will obtain an approximate formula such as:



but it is also possible that Al is connected with Si, in which case the formula will be somewhat different.

The large amount of water below 110° is, at least in part, extremely loosely bound. Mr. H. A. NIELSEN has demonstrated this by the following experiment. A sample of the mineral, which had been kept for some time exposed to normal room air, was placed in a dessicator over concentrated sulphuric acid. The mineral lost weight rapidly during the first two days, and thereafter more slowly, until the sample had lost 8.3 % of its weight after 210 hours. When the sample was thereafter again placed in room air it rapidly (in about 24 hours) regained its original weight.

Mr. H. A. NIELSEN has furthermore investigated the dehydration by heating to 300°, with the following results for loss of weight:

	Total loss of weight	
to 50°	5.17 %	5.17
50— 80°	2.85	8.02
80—110°	1.45	9.47
110—140°	0.83	10.30

		Total loss of weight
140—170°	0.30	10.60
170—206°	0.7	11.3
206—234°	0.5	11.8
234—262°	0.3	12.1
262—300°	0.3	12.4

It will be seen that the curve which is very steep for the lower temperatures, becomes almost horizontal for the higher temperatures. When the remaining water is freed has not been investigated, but it is presumably at red heat. Just as water can readily be liberated or taken up under differing external conditions, so can it also readily be exchanged with other fluids. A splint of the mineral was placed in Thoulet's solution and showed a specific gravity of 2.12. After remaining in the solution for several days the specific gravity was shown to have become 2.32, and a repetition of the experiment gave very nearly the same results. It is possible that the strongly varying values which one obtains both for the specific gravity and refractive index, not only of gunnbjarnite, but also of the related nontronite minerals are due to this property since these characteristics can ordinarily only be determined by placing the mineral in different solutions.

Gunnbjarnite is almost infusible in the blow-pipe flame (almost like mica) and only very thin splints can fuse to a black magnetic mass. The mineral is unusually easily decomposed by hydrochloric acid, and the finely divided mineral becomes a snow-white mass after only a few seconds treatment. This mass is, according to the investigation of H. A. NIELSEN, composed of almost pure SiO_2 . The refraction is, as is usual for amorphous SiO_2 , very close to that of glycerine. A quite marked double refraction is, however, preserved, together with the same optical features as in the original mineral, the optic axes being also similarly arranged. It may be that it is the very slight cation residue (perhaps a few per mille of the original amount) which causes this double refraction, but it may also be the arrangement of the silica particles as in the original mineral, which is the cause of these optical features.

The above-mentioned properties indicate that gunnbjarnite may be rather closely related to the nontronite minerals, and it will therefore be practical to give a survey of these. The many different minerals which are strongly hydrated ferric silicates, generally amorphous or micro-crystalline and only in a few cases having so large a grain-size that their optical properties can be investigated, are here referred to the Nontronite group. Under such conditions it is clear that one cannot certainly separate the different mineral species. The number of names

which have been given to these minerals is very large. Apart from nontronite, one can mention the following: morencite, chloropale, pinguite, fettbol graminite (gramenite), hisingerite, degeröite, hoeferrite, müllerite (zamboninite) and canbyite, as well as a number of others which are more divergent in composition. The majority of these minerals may possibly be identical with nontronite, but on the other hand it seems that some of the minerals which are described and accepted as nontronite, cannot be thus referred. As I have not had specimens of the crystalline individuals of these particular minerals available, I will, in so far as cleavage and optical properties are concerned, only refer to the literature.

Cleavage is probably that property which is most differently stated. LACROIX¹⁾ describes the mineral from Nontron as being composed of microscopic flakes with strong double refraction and strong pleochroism; an acute bisectrix with negative sign, and a rather large axial angle are observed.

WEINSCHENK²⁾ describes a nontronite from Passau; it is composed of flakes with a very perfect cleavage in one direction (basal), and also a perfect cleavage on a prism at 63° — 64° . The negative acute bisectrix is not exactly at right angles to the basal cleavage, but has an obliquity of about 5° — 6° . The axial angle is rather small ($2E = c. 55^{\circ}$).

BERGEAT³⁾ describes a nontronite from Conception del Oro in Mexico, which has arisen as a recent decomposition-product of wollastonite. The mineral is composed of fibres and flakes: the fibres have a positive elongation, the Z-axis forming a very small angle with the length of the fibres. One sees the "seitlichen Austritt einer Achse" on the flakes, the X-axis being approximately at right angles to the length of the fibres. So far as one can see from this description there is some similarity with the properties of gunnbjarnite.

LARSEN and STEIGER⁴⁾ describe a nontronite from Woody, California. It is composed of small fibres and laths with Z parallel to the elongation and X normal to the flat face, or cleavage. It is optically negative with a small axial angle. There is here complete agreement with gunnbjarnite in all important properties. A statement of the cleavage and optical properties of the "morencite" from Morenci in Arizona, which agrees largely with that given for nontronite, is also to be found in the same paper.

It will be apparent from the above, that that which is called "nontronite" must represent at least two different minerals, since the

1) Bull. Soc. Fr. de Min. 18, 1895, p. 429.

2) Zeits. Kryst. 28, 1897, p. 152.

3) Centralbl. Min. etc. 1909, p. 161.

4) Amer. Journ. of Sci. 15, 1928, p. 4.

nontronite described by WEINSCHENK from Passau has a pseudohexagonal cleavage which is quite different from the nontronite from Woody. Which of these occurrences should be called nontronite cannot be determined until a closer investigation of the original nontronite from Nontron has been undertaken.

As far as the canbyite described by HAWKINS and SHANNON¹⁾ from Wilmington, Del., is concerned, although there is a somewhat greater content of Fe_2O_3 the composition is very similar to that of the minerals under discussion. There is also, just as in these other minerals, a negative double refraction, but the obtuse bisectrix is here normal to the strong cleavage-face, and it can therefore not belong to this group.

In so far as other properties are concerned there will here be given a brief comparison between gunnbjarnite on the one hand and the minerals of the Nontronite group on the other. Regarding the occurrence and mode of formation nothing general can be said, since the nontronite minerals are very diverse. There is however no example of an occurrence similar to that of gunnbjarnite. Regarding the structure there is the very conspicuous difference that the nontronite minerals are amorphous or micro-crystalline, and only in a few cases attain such a grain-size that the optical properties and cleavage can be observed; while gunnbjarnite is, as mentioned, never amorphous or micro-crystalline, but as far as one can see, is always found as isolated, often rather large crystals.

The colour of gunnbjarnite is black, or in very thin flakes brown, while most of the nontronite minerals are rather light, mostly with yellowish or greenish colours. Hisingerite is generally black, but in the case of the Greenland minerals the colour is, as Steenstrup²⁾ has shown, light olive-green when the mineral is quite fresh, but becomes black in the course of a few minutes.

Such different values are given for the specific gravity of nontronite and related minerals that, even if one disregards those containing large amounts of Al_2O_3 , and therefore forming a transition to beidellite, there are values from 1.97 to 2.727. The majority lie certainly between 2.2 and 2.4, but it is impossible to make any comparison between nontronite and gunnbjarnite on the basis of these determinations.

The values which are given for the refractive indices vary just as much as the other properties. The average for nontronite is, perhaps slightly greater than that given above for gunnbjarnite. The optic axial angle is generally given as rather small, but LARSEN and STEIGER have, however, found $2E = 66^\circ$ which is also smaller than that given above.

The poor fusibility is common to all the minerals concerned. Solubility in hydrochloric acid is again variously stated; nontronite itself is

¹⁾ Amer. Mineralogist, 9. 1924, p. 1.

²⁾ Vid. Medd. Naturh. Foren. Copenhagen, 1875, p. 284.

said to gelatinize, while most of the closely related minerals behave like gunnbjarnite, the metals being readily dissolved while the silica remains.

There seems to be no difference among all these minerals in respect of the loss of water on heating or dessication.

It will be apparent from the comparison that there is no single character which absolutely separates gunnbjarnite from the minerals of the Nontronite group, and if the chemical composition were the same, one would be unable to consider the first-named mineral as an independent species, even though its appearance is so different from that of minerals of the Nontronite group. The most important difference in the composition is, however, the amount of MgO, which in gunnbjarnite is 12.98 %, while nearly all the nontronite minerals have very little of this constituent. The majority of analyses indicate 0—2 % of MgO, a few show slightly more, so gunnbjarnite cannot be considered as the same mineral as these.

There exist, however, a few minerals which contain markedly greater amounts of MgO, but which still appear to be close to the nontronite minerals. Of these the following will be mentioned:

A mineral from Orijärvi in Finland described by ARPPE¹⁾ under the name scotiolite. The colour is dark green, nearly black, the mineral is stated to be completely amorphous, without trace of crystallization²⁾. The analysis gave the following composition:

SiO₂ 40.97, Al₂O₃ 0.60, Fe₂O₃ 13.04, FeO 11.70, MgO 15.63, CaO 0.38, H₂O (—100°) 7.63, H₂O (+100°) 8.79 = 98.74.

The mineral is decomposed by hydrochloric acid with the separation of silica. The specific gravity is strangely enough given as 3.09, which is far greater than in all the associated minerals. Certain features of the chemical composition agree with gunnbjarnite, but the large amount of FeO shows, however, that the two minerals cannot be closely related.

CLEVE³⁾ has analyzed a mineral from Långban which he also calls scotiolite, and which is said to form brownish-black, amorphous masses. The composition is:

SiO₂ 36.73, Fe₂O₃ 34.97, FeO 3.09, MnO tr. MgO 8.75, H₂O (+100°) 9.20, H₂O (—100°) 6.30 = 99.04.

¹⁾ Acta Soc. Sci. Fennica. V. 1858, p. 479.

²⁾ In this connection it must however be remarked that at that time the use of the polarizing microscope was in its infancy, and it is therefore possible that the mineral may have been micro-crystalline.

³⁾ Öfersigt K. Vet. Ak. Handl. 23, 1866, p. 171.

This analysis does not agree particularly well, either with the scotiolite from Orijärvi, or with gunnbjarnite; it differs from the latter particularly in the large amount of Fe_2O_3 . In the same paper CLEVE has given an analysis of an "hisingerite" from Tunaberg which contains 6.06 % MgO.

These are the only examples which I have been able to find where the amount of MgO is fairly large, and it is quite precluded that gunnbjarnite can be closely related to any of them. It must be considered, therefore, that the establishment of the mineral as a species is completely justified.
