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THE UIVFAQ DIKE AND RELATED HYBRID DIKES FROM SOUTHERN DISKO, WEST GREENLAND

FIELD RELATIONS

BY

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WITH 12 FIGURES AND 2 TABLES IN THE TEXT

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Abstract

A geological and magnetic study of the Uivfaq locality in southern Disko, which is known for its large boulders of telluric iron, has confirmed that the telluric iron is associated with a dike and not, as was formerly believed by some people, with a basalt flow.

A hitherto unknown dike, situated 15 km west of Godhavn at Kitdlît, seems to be closely related to the Uivfaq dike. The dike has the same strike and dip as the Uivfaq dike and also contains both graphitic xenoliths and native iron. The dike, which intrudes the N–S trending gneiss ridge exposed at several places in southern and central Disko, leaves the gneiss at Kitdlît and continues northwards solely in the basalt.

The dike at Igdlukúnguaq in south-eastern Disko, which contains a large inclusion of nickeliferous pyrrhotite, was also re-examined. Graphitic xenoliths are also present in this dike, which indicates a relationship to the Uivfaq dike.

The xenoliths from the Uivfaq dike consist mainly of basic plagioclase with small amounts of red spinel and graphite. The xenoliths from Kitdlît and Igdlukúnguaq are much more complex and different parageneses involving the following minerals have been found: Corundum, spinel, sillimanite, cordierite, plagioclase.

According to the supratelluric theory the telluric iron would have originated through assimilation of carbon-rich sediments by the basalt. Such sediments are indeed present in the Disko-Nûgssuaq area. However, the fact that the Kitdlît dike intrudes gneiss but nevertheless contains telluric iron suggests that this theory may be invalid.

Another, but narrower dike situated at Kitdlît has a peculiar composition, which together with the xenoliths, may give a hint about the origin of the hybrid constituting the three dikes examined and may explain the origin of related rocks found elsewhere in the Disko-Nûgssuaq area.

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INTRODUCTION

Very little has been published about the field relations of the Uivfaq dike since the 1870's when NORDENSKIÖLD (1870), STEENSTRUP (1875), and NAUCKHOFF (1872) published the preliminary results of their expeditions to western Greenland.

When NORDENSKIÖLD first visited the place, he interpreted the Uivfaq occurrence as a dike. However, in keeping with the way of thinking at that time, he wrongly assumed that the iron, which occurs in three large boulders and several smaller ones, was of meteoric origin.

STEENSTRUP, on the other hand interpreted the occurrence as being part of a basalt flow. He interpreted the iron boulders as being of telluric origin.

Investigations in the following 10 years by STEENSTRUP (1882), confirmed the telluric origin of the native iron especially because iron was found elsewhere on Disko, disseminated in basalt.

During may stay in Godhavn in 1968–70, working at the Geophysical Observatory of the Danish Meteorological Institute, I visited the Uivfaq occurrence several times, with the object of solving the problem regarding the mode of occurrence.

In the same period I searched southwestern Disko for other dikes, especially in the Kitdlît area (Fortunebay) from where one of the first iron samples from Greenland originates. It was in this area that NORDENSKIÖLD first concentrated his search for meteoric iron. I have mapped a dike with telluric iron here and probably the iron sample mentioned originates from this dike (the so-called rudolphian iron).

The story of the discovery of the iron in southwestern Disko has been related by me elsewhere (1972).

This paper will deal mainly with the field data with reference to some petrographic data already obtained.

Summary of the geology of the Disko-Nûgssuaq area

A regional description of the stratigraphy and tectonics of the area is given by ROSENKRANTZ & PULVERTAFT (1969). The data presented here are mainly extracted from their work.

The area is dominated by the presence of a pile of basalt flows belonging to the Brito-Arctic Tertiary basalt province.

The maximum thickness of the basalts has been estimated to be about 8 km. The volcanism was initiated with the eruption of a basalt breccia, in which pillows or fragments of pillows are characteristic. A period with eruption of picritic basalt followed the breccia and the upper basalt series comprises tholeitic basalts.

Interlayered sediments between the basalt beds are present on Nûgssuaq and on Disko, but the period of eruption can be said to have been almost uninterrupted.

Dikes, sills and volcanic vents are seen, the last-mentioned especially on Ubekendt Ejland and northern Disko. Dikes cutting the upper series seem to be seldom, and eruptions from a volcanic centre have been proposed. At Aumarûtigssat east of Godhavn many dikes cut the sediments, and in the Precambrian in the Jakobshavn-Christianshåb district thick diabases, often running over long distances are found.

The plateau basalt rests directly on gneiss in eastern Nûgssuaq, and upon a gneiss ridge in central and southern Disko. The gneiss is often deeply weathered (Nûgssuaq, Godhavn). In the central part of the Disko-Nûgssuaq area the plateau basalt rests upon Cretaceous-Tertiary sediments. The sediments comprise shale and sandstone of non-marine and marine origin. Coal seams are present in the sandstone *e.g.* at Qutdligssat and Aumarûtigssat. Bituminous shales are particularly common in parts of Nûgssuaq. Some relative vertical movements have occurred since Tertiary times. Thus the central area of the sedimentary basin around Vaigat has been uplifted relative to the western part of Disko, giving a westerly dip of the plateau basalts. In south-western Disko (*cf.* beneath) the basalt layers are very nearly horizontal.

A large fault running through Nûgssuaq has been postulated by ROSENKRANTZ & PULVERTAFT (1969). This fault follows a gneiss escarpment. Exposures are seemingly poor here. On the other hand good exposures of the gneiss-basalt contact are found near Godhavn, and no tectonic movements have occurred along the steep N–S trending gneiss ridge found here. Because of the importance of the relationship between the iron-xenolith dikes and the host rock, the geology of the area west of Godhavn will be outlined in the following. Reconnaissance mapping has been done by many geologists visiting the Godhavn area, STEENSTRUP has drawn the main features of the geology, and descriptions of some localities are found in STEENSTRUP (1874).

The gneiss west of Godhavn and its relationship to the volcanic rocks

Only reconnaissance mapping of the gneiss itself was undertaken, but contacts between the gneiss and the basalts were carefully examined.

The gneiss is banded or foliated with E–W strike and low dip towards N, at least at Godhavn. Small layers or irregular inclusions of amphibolite, in places with diopside, are seen at some places (*e.g.* harbour of Godhavn, Ûnartorssuaq, Tine). Simple pegmatites are seen all over the area. Some granitisation seems to have occurred. Examples are seen in a small stockpile exposure near Tuapagssuit, and in the western part of Kitdlît, where a rather big area beneath a low angle fault or thrust situated in the upper part of the exposure is granitoid.

The gneiss is also exposed in two small valleys east of Itivdleq and again on both sides of Disko Fjord. The ridge rises abruptly from sea level to more than 300 m and shows a rather rugged relief, well preserved beneath the basalt.

This is well illustrated in an E–W profile from Kitdlît to Godhavn.

East of the peninsula Kangârssuk the gneiss rises abruptly to a height of about 300 m. A stream follows the contact and reveals an undisturbed pile of basalt. On the separate basalt flows, lying lower than the top of the gneiss, gneiss blocks and gravel have been swept some distance out onto the solidified basalt.

Towards Tuapagssuit the gneiss surface falls gently off and reaches sea level at this locality. 400 m up in the valley at a small waterfall the contact is exposed. On the eroded and weathered gneiss surface a conglomerate with gneiss boulders is seen. It is followed by a loose sandstone with coalified wood stems. A columnar basalt marks the beginning of the volcanic activity at this place. The conglomerate and sandstone presumably represent infilling of a valley in the old gneiss landscape because to the east the gneiss again rises abruptly to heights of 300 m.

The next contact is exposed in a steep gorge cut by the stream Akuarut. The denudation plane of the gneiss is here almost horizontal, and large gneiss boulders with a diameter of up to 1 m are weathered *in situ*, and preserved in Tertiary basalt breccia.

The breccia begins just a little west of this locality and thickens gradually towards the east, reaching a thickness of more than 100 m just east of Godhavn, where the gneiss disappears at sea level.

Two other exposures of the contact can be seen at Ûnartuarssuk. One of these shows poorly consolidated sandstone with fossil wood fragments. The sandstone may have been deposited in a cleft in the basement surface. The other exposure shows the breccia with gneiss boulders resting upon a weathered gneiss.

In conclusion it can be stated that the contacts show undisturbed relationship between the gneiss and the basalt. Also the basalt flows show no sign of tectonic disturbances.

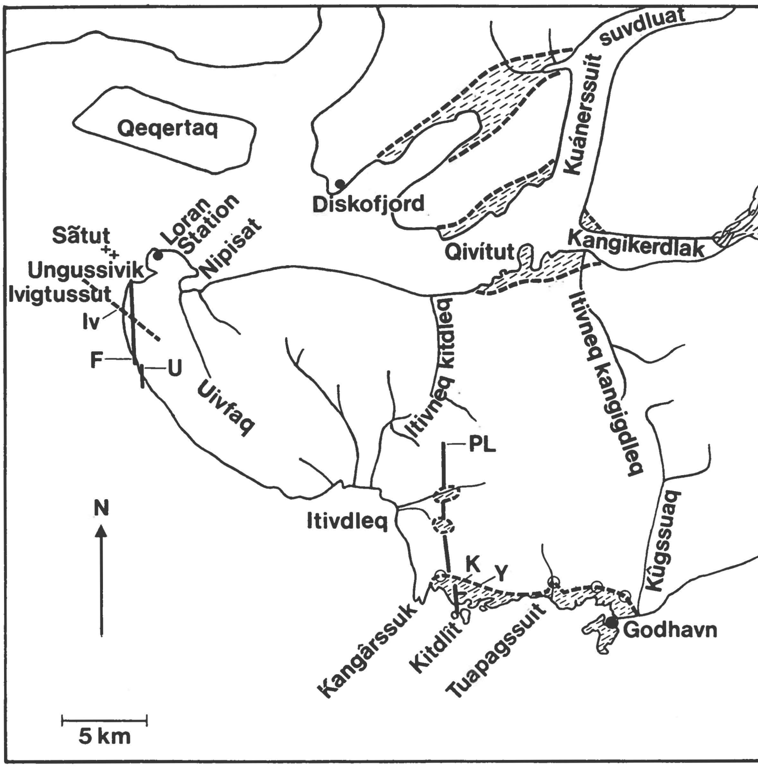

Fig. 1. The south western part of Disko showing the main geological features mentioned in the text. U = The Uivfaq dike, K = The Kitdlît dike, Y = The Y-dike, PL = The Plateau dike, F and Iv = Two diabases. The outline of the gneiss exposed is also shown on the map.

The Uivfaq dike

The location is shown on fig. 1. The occurrence is covered at high tide when the waves break on the overlying thick talus.

The dike is situated between Nûk qiterdleq and Nûk kitdlît 125 m SE of a little cape composed of talus. Nûk kitdlît consists of the extension of the dike marked F on fig. 1.

100 years of erosion on the hard coast and extensive sampling in 1871 have altered the exposure; comparison with the earliest observations is no longer possible.

Both NORDENSKIÖLD (1870), STEENSTRUP (1875), and NAUCKHOFF (1872) mention some N–S trending ridges in the beach gravel. A drawing by STEENSTRUP (1875) gives, as he himself mentioned, the impression of a dike. In spite of this he argued that the ridges belong to a basalt flow, although his arguments seem to be a little confusing.

In 1969 there were only three exposures. They are easily found because of the rusty blocks strewn westwards from the locality. The easternmost of these constitute a 2 m long erosional residue of a dike, 60 cm wide, and rising to about 50 cm above the beach gravel. On the dike wall the strike and dip were found to be N10°W, 60°W. The basalt in this dike is rather drak coloured medium to fine grained without any sign of iron ore or other inclusions. A few amygdules are present. Jointing vertical to the dike walls is distinct. Where the exposure disappears beneath the talus, a small contact with the iron-bearing dike could be seen. It appeared to be somewhat glassy, but no sample could be obtained.

The two other exposures are rounded ridges with more or less rusty surfaces. Small inclusions of iron, somewhat like schlieren, but only of a few centimetres long vere found; no sample could be taken with the tool at hand.

Apparently the iron-bearing part of the exposure ends as a tongue around mean tide level. The rock surrounding the iron-bearing part is light coloured with a few rusty spots and graphitic xenoliths and has a total width of 5 m.

An amygdule filled with siderite was found. This mineral does not appear to have been reported previously from Uivfaq. Petrographic samples are most easily collected along the beach. Basalt blocks with disseminated iron are frequent, but only one sample with compact iron was found (*cf.* magnetic measurements).

The composite character of the dike makes a misinterpretation easy. STEENSTRUP, who assumed the dike rock surrounding the iron-bearing rock to be part of a basalt lava flow, was thus misled.

Magnetic measurements

Because of the uncertainties in the interpretation of the observations on the small exposure, a magnetic measurement was undertaken on the winter ice.

The instrument used was a Minimag, produced by the Geological Survey of Norway. The measurements were corrected for disturbances with the aid of the Z-variograph at the Geophysical Observatory in Godhavn.

The grid was arranged as shown on fig. 2. It was hoped that the closely spaced grid of 2×2 m on the shore could reveal the existence of iron boulders, and that the profile lines off-shore could show a continuation of the dike.

The anomaly picture is, as could be expected, rather complicated near and on the shore, because the field of force is the superposition of the magnetism in the dike (which is composite) and erratic blocks. The

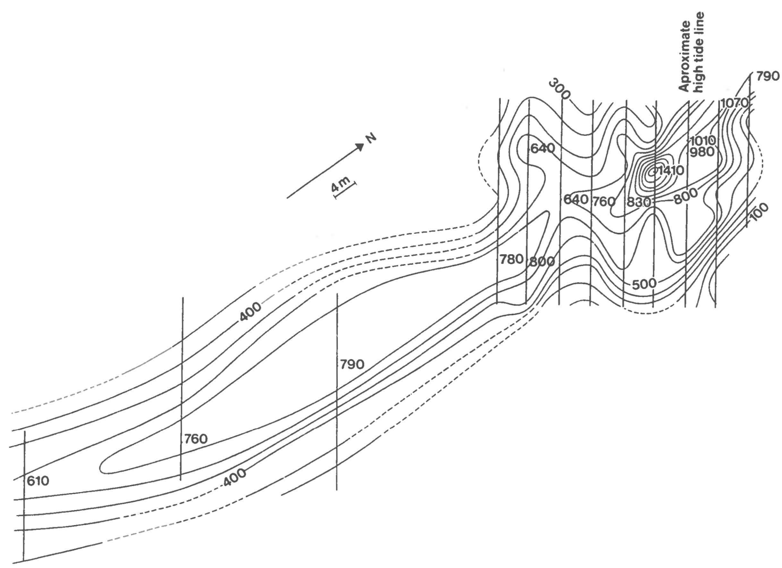

Fig. 2. Relative vertical intensity measured from the coast and of shore above the Uivfaq dike, southwestern Disko. Equidistance 100 γ. Parallel lines show the trend of profiles along which measurements have been made for every 2 metres.

strong anomaly of about 1400 γ was found the following summer to originate from an iron boulder the size of a football. Another iron boulder may be situated beneath the 640 γ maximum.

Off-shore a rather even maximum in Z can be followed for a distance of 125 m (measurements stopped at the ice edge).

The strike of the anomaly coincides with the strike measured on the small dike in the outcrop.

No upward continuation of the Uivfaq dike can be seen in the basalt beds above the talus, nor has the dike been found north of Uivfaq.

(A magnetic body known to cause a compass deviation on ships passing the shallow sound between Sãtut and Ivigtussut was found to be a dike marked I on fig. 1. This dike has a very high magnetisation, strikes N50°W with vertical dip. The anomaly measured 1 m above exposure is 5–6000 γ. Both this dike and the dike marked F (shown on fig. 1) are conventional diabases and no xenoliths or native iron have been found in them.)

In conclusion it can be said that all the evidence points to a dike as being the carrier of the iron and graphitic xenoliths at Uivfaq. According to my knowledge, STEENSTRUP is the only scientist who has stated that a dike is impossible. Because of his otherwise well founded and skillful field work in the Disko-Nûgssuaq area his interpretation of the Uivfaq occurrence has not been rejected.

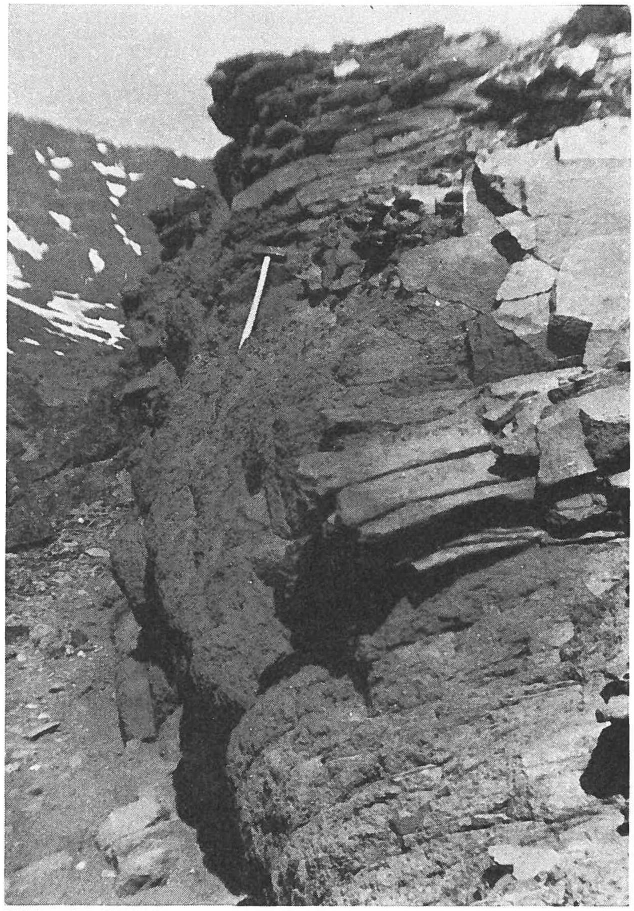

Fig. 3. Jointing vertical to the contacts in the Kitdlît dike. In addition the breccia-form rock is seen beneath the hammer.

However, the new field work together with the petrographic results indicates as will be shown below, a very close relationship to the Igdlukúnguaq dike as well as to the newly discovered Kitdlît dike.

The Kitdlît dike

Kitdlît (also called Fortunebay) is situated 15 km west of Godhavn. Mapping the Precambrian exposed here revealed two dikes, one with graphitic xenoliths and iron, and another of a rather peculiar composition, described beneath as the Y-dike.

Exposures of the Kitdlît dike are found on a small island and at several places intruding the gneiss on the coast, where it rises up to 300 m. Strike and dip can be measured on good contacts and are N10°W, 60°W, which are the same as for the Uivfaq dike. Jointing normal to the contacts is common as is shown on fig. 3. The dike is 8 m wide. It is a diabase, fine-grained at the contacts but otherwise medium-grained. In the best exposure on the mainland of Disko near the shore, a somewhat brecciaform rock is seen (see fig. 3). The rock weathers relatively fast here, and the harder rock seems to consist of graphitic xenoliths. Xenoliths are found everywhere, but only sparsely, and are most easily seen on the weathered surface. The size and form differs greatly, and as examples can be mentioned elliptical, cylindrical, schist-like, angular. The bigger ones are mostly schist-like. Even almost pure graphite as small-sized xenoliths is found. Iron occurs sparsely, the size never bigger than a pea. Both single grains and clusters of grains are seen. They are most easily found on the beach pebbles. Vesicles partly filled with limonite are seldom seen, and the same can be said of the pyrrhotite grains and hisingerite amygdules.

Although looked carefully for, iron has only been found in the exposure near the shore, which may be due to the difficulties of identifying iron grains on the weathered surface of the diabase.

The diabase dike ends in the gneiss, presumably at a low angle fault or thrust in the gneiss, which has forced the diabase to penetrate a little westward in the thrust. There is no doubt that the dike does not continue in the gneiss above the thrust. This will be discussed in connection with the Plateau dike.

Measured off-shore a small negative anomaly in Z is found over the dike. Consequently the dike must be reversely magnetized. A petrographic study of the xenoliths from this dike brought out some very interesting features. A sorting in hand specimen proved later to be useless, but in any case the type recognized were:

1) Very graphite-rich xenoliths, occuring either as small spheroidal bodies or as more angular bodies.

2) Fine-grained, black xenoliths with less graphite than 1), often angular and polygonal in section, but even schistose or cylindrical.

3) Coarse-grained black, often angular, xenoliths.

4) Unclassified xenoliths.

The first three types are mostly simple xenoliths of the type described from Uivfaq, and consist of basic plagioclase red spinel and graphite, possibly with pockets of dioritic material. They have been described by NAUCKHOFF (1872), TÖRNEBOHM (1878), MELSON & SWITZER (1966), VAASIOKI (1965), SMITH (1879), LORENZEN (1882), NICOLAU (1901) and PEDERSEN (1969).

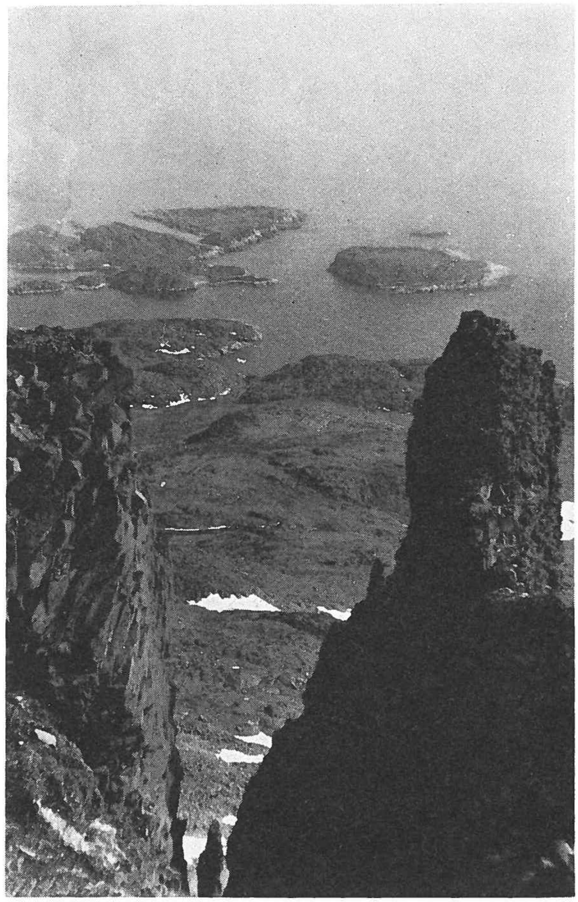

Fig. 4. A view through the conposite part of the Plateau dike towards south. The Kitdlît dike is situated in the valley running toward the coast. A small exposure is even found on the small island seen in the upper right corner on the photograph.

The last group mainly comprises different parageneses among the following minerals, often with reaction relations in between: Corundum-spinel-sillimanite-cordierite-basic plagioclase, always with more or less graphite. The amount of the respective minerals differs greatly from xenolith to xenolith, but one xenolith very rich in sillimanite was found.

The parageneses belong to the quaternary system MgO-Al_2O_3-CaO-SiO_2.

(A similar assemblage has been described by Thomas (1922) and Pedersen (1969), who both favour an assimilation of aluminous shale). In conclusion it can be said that the relationship to the Uivfaq dike is evident, and in addition, much more information can be gained from the Kitdlît dike because of its better exposure.

The Plateau dike

In the wall of basalt facing Kitdlît the beginning of what will be called the Plateau dike can be seen. It is marked on fig. 1 with PL.

The dike is peculiar in that it runs solely in the basalt above the gneiss ridge mentioned above. Nowhere does it cut the gneiss. The dike is a xenolithic diabase like the Kitdlît dike, and is presumably an extension of this toward the north.

In the basalt wall there are three thin dikes (fig. 4), all with horizontal jointing, which join rapidly toward the north forming one dike 7 m wide.

Because of the rough terrain contacts were unapproachable, but beneath in the talus glassy rock fragments were collected which later petrographic examination showed to be glass with phenocrysts of olivine. Similar glass samples were taken *in situ* in an exposure a little north of the northernmost gneiss window, (fig. 2). The diabase is fine to medium grained and in hand specimen can easily be mistaken for a normal diabase. The graphitic xenoliths found here and there show that the dike is of the same type as the Uivfaq and Kitdlît dikes. There are occasional small amygdules filled with hisingerite and little accessoric phyrrhotite can be seen. Although searched carefully for, no iron was found, but the reason could be the same as for the Kitdlît dike, where iron was only found on the shore where no lichen grows.

The dike can be followed in good exposures across the plateau to the wall of rock beside the first gneiss window. There is no sign of the dike in the gneiss, and because of the cover of moraine the dike cannot even be seen in the ridge between the two windows, but north of the second window it outcrops again. It is vertical and 8 m wide. Because of the good exposure in the gneiss window it can definitely be stated that the dike does not cut the gneiss.

At Kitdlît the gneiss is well exposed between the end of the Kitdlît dike and the basalt wall.

Since the Kitdlît dike disappeared at a low angle thrust of fault in the gneiss, and since the two dikes are very similar in petrography and content of xenoliths, it can be concluded that the Kitdlît dike has its extension toward the north as the plateau dike, but only cutting the basalt beds.

Imagining the whole gneiss area exposed covered by basalt beds, the low angle thrust will have its trend in the contact between the gneiss and the plateau basalt. Intruding from beneath, the joint giving space for the diabase, ends abruptly at the thrust, but the intruding magma was allowed to penetrate the basalt beds northwards. Jointing in the basalt above the gneiss is to be expected because the basalt pile will contract relative to the ridge during cooling.

Petrographic examination of the graphitic xenoliths has shown that the mineral paragenesis of these is as in the Kitdlît dike, *i.e.* spinel-corundum-sillimanite-cordierite-plagioclase.

In conclusion it can be said that all field relations suggest that the Kitdlît and Plateau dikes are identical, the latter being an extension of the former.

The field relations are unequivocal and it is very difficult to imagine the basalt magma having been in contact with any carbonrich cretaceous sediments, which in fact are not found exposed in western Disko.

The Y-dike

A small dike called the Y-dike, which is an apophysis of the Kitdlît dike, is shown on fig. 1. The petrographical and chemical composition of this dike is rather peculiar.

The dike is exposed in several places, and at one place it is less than 25 m from the trend of the Kitdlît dike. Going from west to east the dike is first located in the middle of a broad valley. Later it is exposed along the southern side of the escarpment. The strike is east-west, and the dip could not be measured. Total length of exposures is 400 m.

In the easternmost exposures some small-scale faulting seems to have occurred, the exposures being somewhat displaced.

It can be seen in the outcrops that the dike changes in mineralogical composition along the strike. Near the Kitdlît dike the rock is fine-grained, grey on weathered surfaces, otherwise dark greenish, with yellow-green serpentine identifiable. Towards the east a green mica becomes still more frequent, and at certain exposured locality becomes dominant. The mineral may be a chlorite (*cf.* beneath), and may earlier have been believed to be talc, as this mineral is mentioned from Fortunebay by STEENSTRUP and is described as such in BØGGILD (1953). When present in large amounts, it gives the rock a schistose appearance, the chlorite flakes being parallel.

A few veins up to a few centimetres wide with actinolite are occasionally present, and in a bleached zone in the rock near the actinolite, pyrrhotite and small black grains, later identified as hercynite, can be identified.

The dike rock appeared to be very peculiar, and a few chemical and petrographical results will be given here.

Near the Kitdlît dike the microscopic examination revealed that the rock is composed of an unidentified mineral (which may be a new mineral), olivine, serpentine, actinolitic hornblende with accessory pyrrhotite and hercynite. The modal composition has been provisionally determined but the result is rather uncertain. This is because of the similarity between hornblende, olivine and the unidentified mineral, which has pleochroism faint green, colourless, and faint brownish, respectively, and because of the heterogenous structure, *i.e.* rounded grains in a network of serpentine.

Modal composition of rocks from the Y-dike:

Table I

	vol. °/₀ Y1	vol. °/₀ Y2
Unknown	33	chlorite 28
olivine	18	30
hornblende	13	6
serpentine	29	31
pyrrhotite / hercynite	7	4
mica	+	

Y1 is from the westernmost exposure near the trend of the Kitdlît dike and Y2 originates from the eastern part of the dike where it meets an escarpment.

As mentioned above, this mineral is not found in the easternmost outcrop, where instead a green mica, probably a chlorite, is found. The transition between the two rock types is poorly exposed, and it is therefore uncertain whether there is a gradual transition. The modal composition of this rock is shown in Table I. As for the other modal analysis the result must only be regarded as tentative.

The chemical composition of both roch types has been determined. The result are presented in Table II.

Table II

SiO_2	Y1	Y4 (with chlorite)	
SiO_2	38.9	38.4	XRFA
Al_2O_3	3.7	2.8	XRFA
Fe_2O_3	11.2	10.7	XRFA, AA
FeO	5.3		Titr.
CaO	1.0	0.7	XRFA
MgO	35.5	36.8	AA
Na_2O	0.5	0.5	AA
K_2O	2.5	0.8	AA
Cr_2O_3	0.5	n.det.	Spectr.
TiO_2	0.7	n.det.	Calor.
SO_3	0.1	n.det.	Titr.
Loss. on ign.	8.6	6.7	1200°
Sum	103.2	96.8	

For Y4 only total iron as Fe_2O_3 has been determined.

Especially remarkable are the high water content and the high K_2O/Na_2O ratio. As described above, no felsic minerals were found in the rock, and the texture gives no indication as of the existence of a crystallizing melt. On the other hand, the texture is not that of a metamorphic mafic rock such as a peridotite. The two rocks analyzed have as seen from the table almost the same composition, and it is most likely that they have been derived from each other by thermal metamorphosis.

Since the dike is an apophysis of the Kitdlît dike, and since nothing similar was found elsewhere during mapping of south-western Disko, it would seem logical to consider it together with the hybrid dikes carrying graphite xenoliths and native iron.

It would be interesting to examine the reaction products between the rock with the chemical composition shown in Table II and a basalt magma at an appropriate temperature and pressure. On the other hand, it is very difficult to handle the oxide system in question, which comprises SiO_2-Al_2O_3-FeO/Fe_2O_3, MgO and CaO. From investigations in silicate systems related to this case, it could be expected that MgO will diffuse into the basalt from rock fragments of the composition of the Y-dike and a diffusion of CaO from the basalt into the xenoliths (CaO is a rather mobile component in silicate systems). Assuming that Fe_2O_3 and Al_2O_3 partly follows CaO, the result might be, depending on local conditions in the magma, pyrometamorphic minerals like those found in xenoliths from Uivfaq, Kitdlît and Igdlukúnguaq (*cf.* below) *i.e.* spinel, corundum, sillimanite, cordierite and anorthite.

This is not a proof of the origin of the xenolitic material in the hybrid rocks, but a suggestion for a future working model.

In conclusion it can be said that the Y-dike has very peculiar mineral paragenesis and chemical composition. Further mineralogical and chemical investigations are necessary. The dike may have originated from the hybridisation of basalt and an unknown rock, of which traces are found in the xenoliths in the dikes already described and in the Igdlukúnguaq dike, which will be discussed in the following section.

The Igdlukúnguaq dike

This dike is well known and often mentioned in papers concerning the telluric iron in the Disko-Nûgssuaq area. It is mentioned in several papers by Steenstrup, Löfquist & Benedicks (1940), and Vaasjoki (1965). Pauly (1958) has published a comprehensive treatise on the pyrrhotite mineralisation found here. Besides discussing the paragenitic relationship in general, he discusses the significance of the occurrence for the origin of the telluric iron, *e.g.* at Uivfaq.

None of these authors have shown any great interest in the silicates occurring in the dike rock. It was therefore surprising to find xenoliths in the southernmost exposure.

PAULY (1958) gives a review of the exposures, and visiting the locality in 1970, I could only confirm the general observations made by him.

There are five exposures. Three of these, in one of which the pyrrhotite mineralisation is situated, are located close together along a distance of 355 m. The strike is ca. N30°W and dip 85°W. The hanging wall is exposed showing a slightly hardened or baked sandstone at the contact. In CÖSTER's description (1929) two dips are stated, 85°E and 85°W, but judging by the way the dike is shown on the topographic map the westerly dip must be the true dip. Otherwise some tectonic disturbances must have occurred. This will be discussed below.

In hand specimen the rock is a diorite, with very little mineralisation outside the pyrrhotite lump. With the naked eye not only pyrrhotite but also magnetite and siderite in vesicles in a size of up to a few millimetres can be seen. The magnetite occurs as small octahedra on the walls of the vesicles.

There are two other exposures 350 m southeast of the other three and they occur along a distance of 200 m. The strike of these two is the same as for the other three but the dip cannot be measured. As seen from the topographic map drawn by CÖSTER (1929) it is impossible to connect the two groups of outcrops with a common strike; if they belong to the same dike, it must either be folded or a fault has offset the dike with a strike slip of 150 m. Both strikes are in accordance with the topography as read from CÖSTER's map.

The doubt about which interpretation is right is further accentuated by the fact that the two groups of outcrops are petrographically very different. This is already apparent in hand specimen. From north to south the composition even changes considerably.

At the northern end the exposure shows a dorite-like rock, which was confirmed by petrographic examination. Here and there a few hisingerite amygdules and pyrrhotite grains are present. Going southwards the diorite changes to a rock confusingly similar in hand specimen to a sandstone. The rock is slightly layered, the grain size varying from layer to layer. Rusty areas reflect the presence of siderite. Petrographic examination revealed the rock to be composed of dioritic and glassy layers.

At the southernmost outcrop true graphitic xenoliths occur. The outcrop consists of a rather loose rock, called "deeply weathered" by CÖSTER. It is superficially like a sandstone. It is a little rusty and some green coating, probably malachite, is present here and there. Several

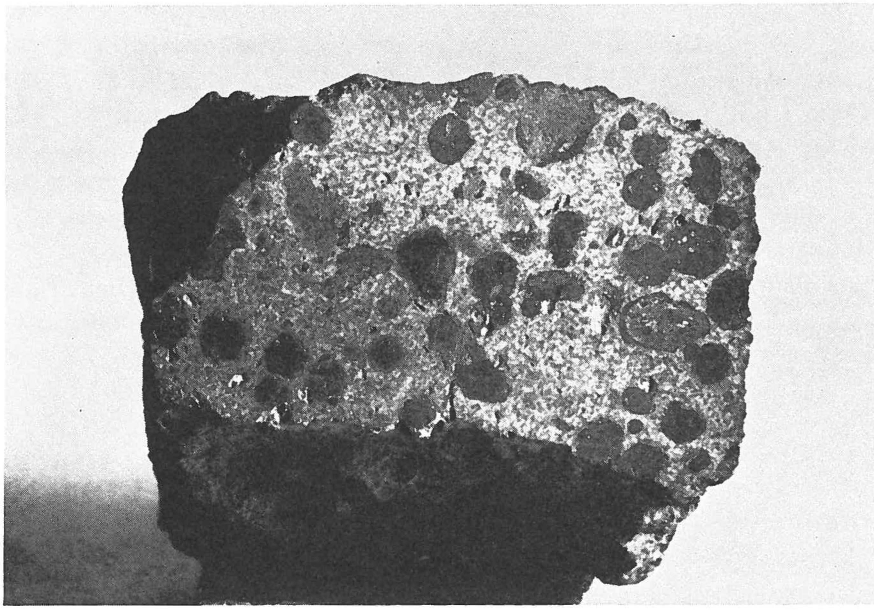

Fig. 5. A cut through the rock rich in spheroidal graphitic xenoliths from Igdlukúnguaq on East Disko. Height of cut about 4 cm.

graphitic xenoliths of different sizes were found in the rock. At some places the rock looks like a conglomerate (see fig. 5). The size ranges from 3–4 cm to less than half a centimetre. The form of the xenoliths is mostly elliptical or spheriodal. The graphite content varies greatly.

In the diorite interstitial to the plagioclase laths is seen a characteristic isotropic green or brown matter (also seen in the Uivfaq dike rock). Occasional small xenoliths (millimetre size) composed of basic plagioclase, some with a little sillimanite and spinel, are present. In the hybrid rock the interlayered glass carries phenocrysts of plagioclase and clinopyroxene and unidentified rather long thin needles. The dioritic layers can be very coarse-grained, and glass occurs in the interstices between the plagioclase laths. Siderite is common throughout. The graphitic xenoliths are set in a dioritic rock as described above and they proved to be a chaotic mixture of different mineral parageneses. Graphite is almost always present. Veins or pockets with dioritic material are frequent in the xenoliths. Plagioclase is always present together with one or more of the following minerals: Red spinel, corundum, sillimanite, and cordierite. Saphirine has not been found, though expected. An orthopyroxene is present in the xenoliths, whereas the clinopyroxenes are restricted to the pockets and veins. Glass, both as inclusions and as interstitial fillings, is frequent.

In conclusion it can be said that the Igdlukúnguaq dike, at least with respect to the southernmost outcrops, has a striking similarity to the Kitdlît and Uivfaq dikes. All have a northerly strike and westerly dip, even if they intrude basalt, gneiss and sandstone, respectively. The diorite is mainly composed of basic plagioclase, a pigeonitic and an augitic pyroxene with a little olivine. All the dikes carry an interstitial matter of undetermined composition with ilmeniteprisms. Xenoliths of very varied mineralogical composition are found in all three dikes. The minerals found in the xenoliths are plagioclase, graphite, orthopyroxene, corundum, red spinel, sillimanite and cordierite, locally mixed with dioritic matter and glass.

Opaque Minerals - Petrographic notes

In the preceding paragraphs it has been necessary to use some petrographic results to classify the rocks and their xenoliths. Because of the simultaneous occurrence of native iron and the xenoliths I have found it useful to present the following petrographic notes on the opaque minerals. Apart from the big boulders of iron and pyrrhotite found at Uivfaq and Igdlukúnguaq, respectively, the opaque minerals are true accessories.

Much has been published about the native iron from Uivfaq, of which the most will be found in the references. Petrographical description with respect to the composition and structure of the native iron is found in LÖFQUIST & BENEDICKS (1940), PAULY (1969), and DAUBREÉ (1877).

The iron from Uivfaq is white cast iron, and because of its high carbon content it would be called overeutectic. In both the iron boulders and the single grains in basalt the microscopic examination shows coarse cohenite, very irregular and often fringing the grains, with an interstitial pearlite. In addition, plates or needles of cohenite are visible in the pearlite in the boulders. When the iron was first described by NORDENSKIÖLD, it was probably the cohenite which gave the impression of widmannstättschen etch figures. The type of structures is shown on figure 6. In the light of the Fe-C diagram the cooling history was a slow cooling through the temperature field of the molten basalt, *i.e.* around 1200°, at which temperature preeutectic cohenite crystallized. The subsequent cooling must have been rather fast giving way to formation of finely lamellated pearlite.

Pyrrhotite is sometimes found as inclusions in the iron grains, but mostly it is found near the boundaries of the iron grains, situated in the silicate pockets (a textural feature much better developed in samples from Kitdlît). Farther away from the iron prismatic ilmenite follows the

Fig. 6. Structure of the iron from Uivfaq found disseminated in basalt. × 80, unetched specimen. White: Cohenite, grey: Pearlite, black: Silicates and pores.

pyrrhotite and in the centre of the silicate pockets magnetite is sometimes visible.

Several iron samples from Kitdlît have been examined. The structure consists of plate- or worm-like cohenite set in a ferrite matrix, the difference between the samples being difference in amount of cohenite. The amount can vary from nil to about 20 $^0/_0$. Examples are shown on figs 7 and 8. According to the texture the iron is a carbon steel, either under- or over-eutectoid.

Since pearlite structure is missing, it is likely that the cooling has been so slow that carbon segregated in the coarse grained structure observed (VHN of the ferrite was found to be 170 kp/cm/, as a confirmation that the steel is unhardened).

In the samples from Kitdlît the pyrrhotite occurs as inclusions in the ferrite and along the crystal boundaries as shown on figs 7 and 9. Ilmenite

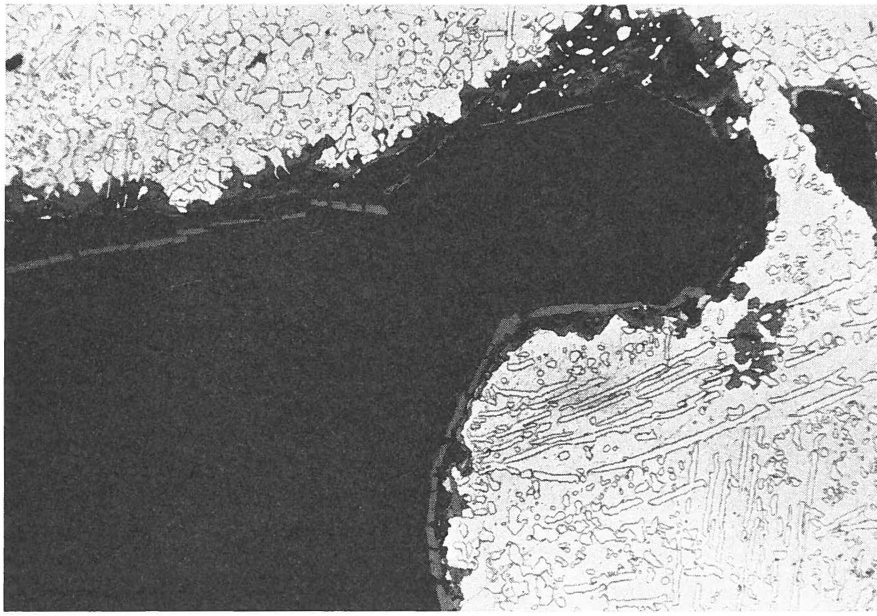

Fig. 7. Etched polished section of iron from Kitdlît. The cohenite lamellas are distinctly seen. Along the rim of the ferrite grain a lining of ilmenite crystals is seen. The small grey crystals between this lining and the ferrite is pyrrhotite. × 100.

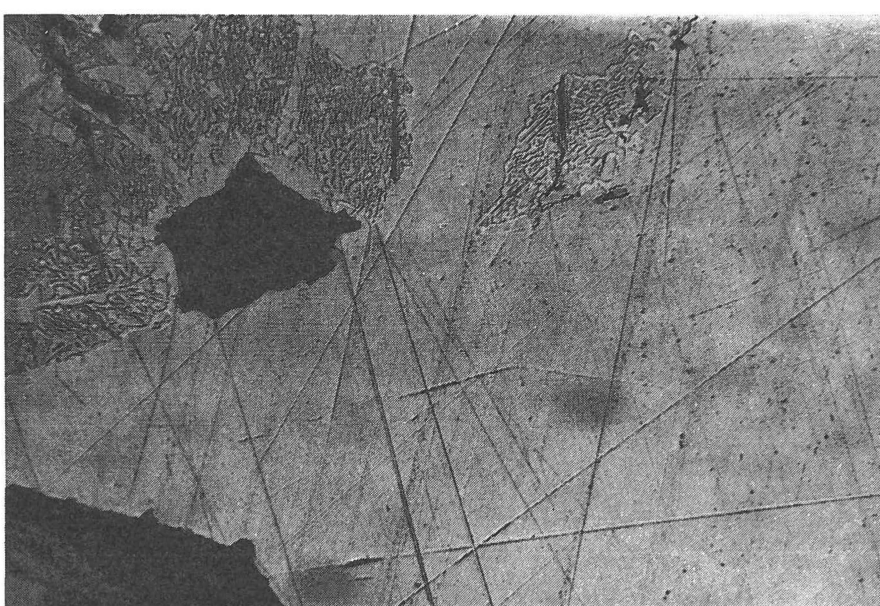

Fig. 8. Etched polished section of iron from Kitdlît. A few areas with worm-like cohenite in an otherwise carbon-poor ferrite. × 100.

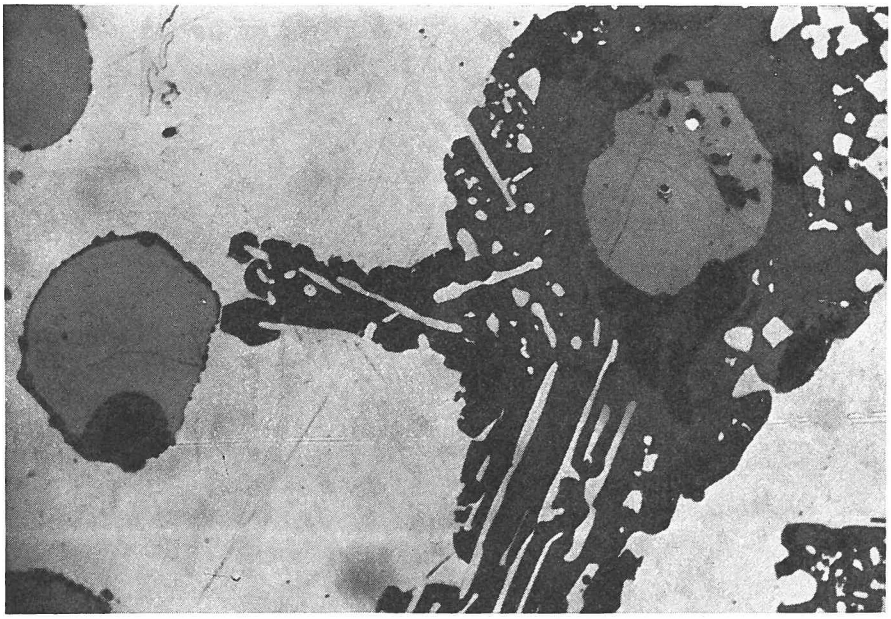

Fig. 9. Unetched polished section of iron from Kitdlît. The grey spheroidal grains are pyrrhotite, and the surrounding ferrite is more or less oxidized, by which the cohenite lamellas are exposed very well. × 200.

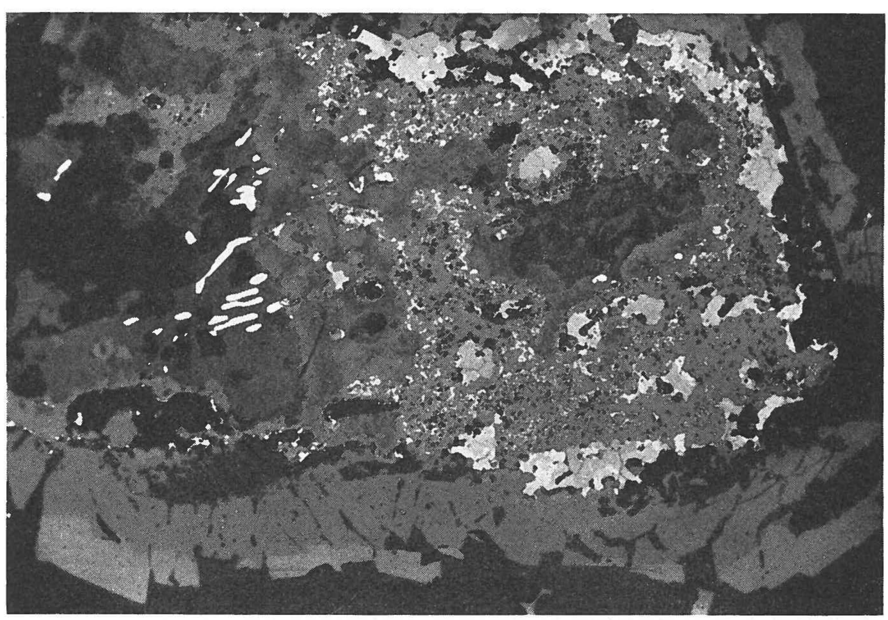

Fig. 10. Zonar grain from Kitdlît. Polished section × 80. The white worm-like grains are cohenite left untouched in the otherwise oxidized ferrite grain. The ferrite is surrounded by a partly oxidized pyrrhotite with pentlandite exsolutions. A zonar ilmenite surrounds the whole grain.

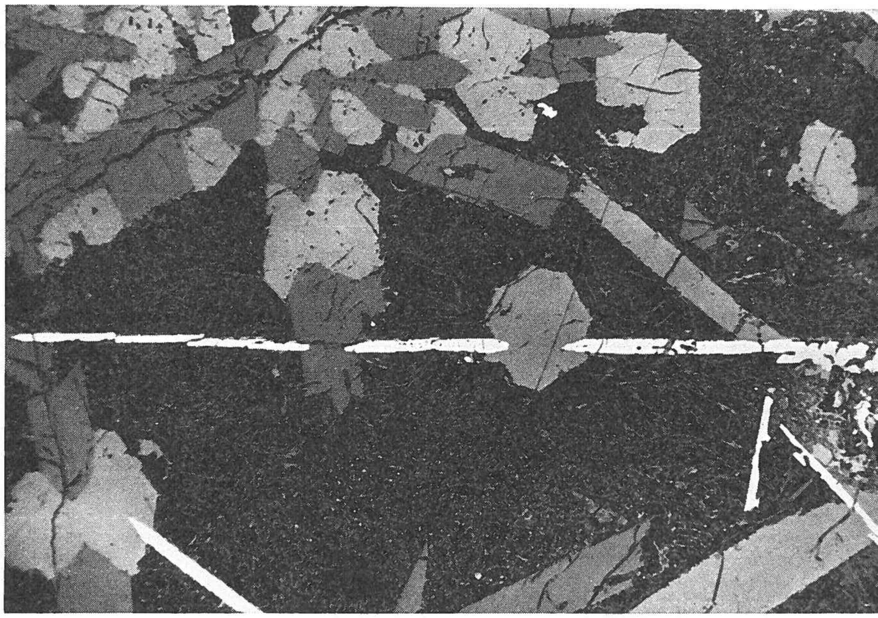

Fig. 11. Ilmenite plates on the interstices of the Kitdlît diabase. Medium grey is clinopyroxen, and dark grey plagioclase. × 100.

prisms aligned along the boundary of the ferrite can also be seen. Pyrrhotite, ilmenite, and rarely magnetite occur in the diorite, too.

A few grains with partly oxidized iron completely surrounded by pyrrhotite were found. The pyrrhotite itself is oxidized to magnetite. The whole grain is again surrounded by idiomorphic ilmenite, in places with a little magnetite. Small schlieren and crack fillings of pyrite are visible near one of the pyrrhotite-iron grains. An example is shown on fig. 10, where even the surrounding ilmenite is zonar.

In the diorite both at Uivfaq and Kitdlît ilmenite is always found more or less as prisms in the interstice between the plagioclase laths (Fig. 11). The rest of the interstitial area is mainly glass. Small amygdules in the form of hemispheres with the plane side toward the silicates and filled with an unidentified radially crystallized mineral are often visible near the rim of ferrite and pyrhotite.

The texture no doubt gives the impression that pyrrhotite, magnetite, ilmenite, and pyrite crystallized very late. Regarding the ferrite, the textural relationship is often masked by the succeeding minerals. However, in some samples from Uivfaq, ferrite and hisingerite both fill interstices, the plagioclase sometimes protruding into the ferrite or the hisingerite (Fig. 12). The ferrite may thus have crystallized later than the plagioclase, or at least it may have crystallized contemporary with plagioclase.

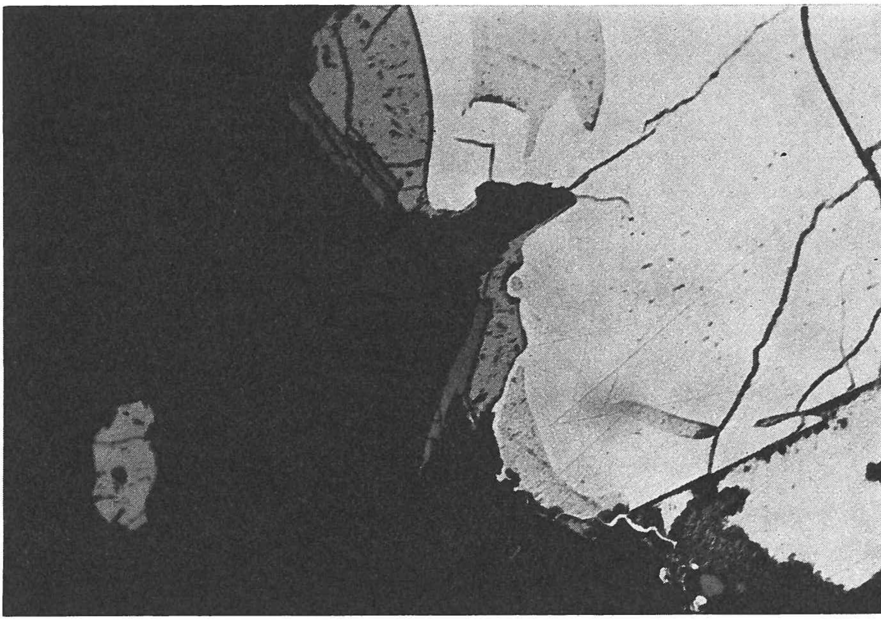

Fig. 12. Unetched sample of polished section from Uivfaq. × 200. White: Cohenite, and herein the dull areas are pearlite, medium grey: Pyrrhotite, dark grey: Ilmenite and black: Silicates. A plagioclase lath protrudes into the ferrite grain. The structural relationship between ferrite, pyrrhotite, and ilmenite is here well illustrated.

The zoning observed, ferrite-pyrrhotite-magnetite/ilmenite, points to a rising oxygen partial pressure in the cooling magma.

Pauly (1969) has mentioned a similar zoning in samples from Arsuk and Jernpynten, except that the ilmenite has not been found by him. He stresses the importance of the zoning.

Objections to the supratelluric theory

The so-called supratelluric theory, which assumes assimilation of carbon-rich shale by a basalt magma, was originally proposed by Steenstrup (1875) and Törnebohm (1878). Later Löfquist & Benedicks (1940) published a paper on the Uivfaq iron. Model experiments in the laboratory led them to consider that the supratelluric theory was confirmed, but they wrongly connected the Igdlukúnguak dike and the Uivfaq dike. They assumed the Uivfaq iron to have been formed by a reducing basalt magma, flowing round some large boulders of pyrrhotite. Melson & Switzer (1966) also discussed the origin and found confirmation of the theory.

The graphitic xenoliths are also discussed by these authors. They are mostly of the opinion that the xenoliths are derived from an aluminous shale. PAULY (1969) also favours the supratelluric theory. VAASJOKI (1965) suggest that the xenoliths have crystallized from an anorthositic magma. PEDERSEN (1969) concludes that magma was trapped at high levels in precambrian basement and cretaceous sediments, thus incorporating foreign rocks. Several conditions varying from magmachamber to magmachamber, such as degree of differentiation, composition of the wall rock, caused different rocks to be erupted. The occurrence of telluric iron is regarded as a special case of contamination by which the iron was formed during a natural reduction process. PEDERSEN (1969) also writes: "It has been confirmed that the well described "anorthit fels" inclusions are modified bituminous sediments".

The results from northern Disko reported by PEDERSEN (1969) are somewhat controversial to the results presented in this paper.

The objections to the supratelluric theory are in summary:-

1) The Uivfaq, the Kitdlît and the Igdlukúnguaq dikes are subparallel with northerly strike and steep westerly dip in spite of intruding basalt, gneiss or sandstone, respectively. This suggests a common tectonically origin for the three dikes.
2) The three dikes are petrographically similar and the graphitic xenoliths have similar mineral assemblages, and the relationship to the occurrences on northern Disko is evident. The similarity between the occurrences more than 100 km apart, is in contrast to the difference in geological and lithological surroundings.
3) The Kitdlît dike intruding a gneiss ridge along its axis, which is orientated nearly north-south in the central part of Disko, carries telluric iron and graphitic xenoliths. This observation is incompatible with the statement that basalt magma has assimilated bituminous shale. Consequently, the graphite and the iron must originate from the upper mantle or the basement.

The dike at Kitdlît, the Y-dike intruding the gneiss, has a chemical composition which is difficult to relate to sediments. The rock is mainly composed of magnesium and silicon; small amounts of aluminium, calcium and iron occur in addition. The water content is around 7 $^0/_0$. This dike must be considered together with the hybrid dikes of southern Disko, because of its occurrence as a branch of the Kitdlît dike.

The graphitic xenoliths provide a very interesting object for study. Besides the varying mineral assemblages, the xenoliths contain a lot of information showing many resorption and reaction phenomena and structural features.

The xenoliths may together with the Y-dike provide the clue to the origin of the hybridisation with basalt in the basement or in the upper mantle.

The supratelluric theory is attractive because it is simple. But the neighbourhood of bituminous shale (or coal) and basalt, carrying iron and graphitic xenoliths is not a proof of the theory. The neighbourhood might be due to an accident. On the other hand, very little evidence is available to prove the intratelluric theory, which assumes the native iron being formed during processes in the upper mantle (or in the basement). Thus a plausible theory is still missing.

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