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The Early Precambrian Gneisses of the Godthab District, West Greenland [and Discussion]

V. R. McGregor and B. J. Walton

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The early Precambrian gneisses of the Godthåb district, West Greenland

By V. R. McGregor
The Geological Survey of Greenland, Copenhagen, Denmark†

[Plates 4 to 6]

Intensely metamorphosed and deformed basic dykes, the Ameralik dykes, have been used to divide the amphibolite-facies gneisses of the Godthåb district into the Amîtsoq gneisses (older) and the Nûk gneisses. Metavolcanic and metasedimentary rocks (the Malene supracrustals), and stratiform meta-anorthosites are also present and are probably younger than the Amîtsoq gneisses, but are older than the Nûk gneisses.

The Amîtsoq gneisses contain abundant fragments of Ameralik dykes. They appear to have been derived from homogeneous granitic (s.l.) parents, but most of them have been intensely reworked before and/or after the intrusion of the Ameralik dykes and are now banded gneisses. They range from dioritic to granitic in composition and potassic varieties are common. Isotopic data indicate that the parent rocks of the gneisses were emplaced or metamorphosed about 3750 Ma ago.

Ameralik dykes are absent from the Nûk gneisses, which are the most abundant rocks in the area. These gneisses are derived from intrusive calc-alkaline parents, mainly tonalites and granodiorites, and represent a massive addition of granitic material to this level of the crust about 3080 Ma ago, after the first supracrustal rocks had been laid down.

Introduction

Early Precambrian rocks unaffected by major mid-Precambrian plutonic activity crop out on the west coast of Greenland between Ivigtut and Søndre Strømfjord (Pulvertaft 1968; Geological Survey of Greenland 1970; Bridgwater *et al.* 1972; figure 1 of this paper). The following features are characteristic of this part of the North Atlantic craton.

(*a*) The dominant rocks are quartzo-feldspathic gneisses. Many of the gneisses, perhaps even the majority of them appear to have been derived from granitic rocks by intense plutonic reworking. Large bodies of late relatively undeformed granitic rocks are not common.

(*b*) Amphibolite units, few of them more than a few kilometres thick and most of them much thinner, outline a complex pattern of multiple folding in the gneisses (see, for example, Berthelsen 1960; manuscript maps of many other areas are held by the Geological Survey of Greenland). Primary volcanic structures (pillow lavas, amygdales, agglomerate structures) are preserved here and there, but most of the rocks are now massive or banded amphibolites. Gneisses whose mineral compositions suggest a metasedimentary origin and, in a few places, thin marbles are associated with some of the amphibolites. Most of the amphibolites are presumed to be derived from basic volcanic rocks. Although some of the thickest amphibolite units contain less metamorphosed and less deformed rocks with greenschist facies mineral assemblages (Higgins & Bondesen 1966; Windley *et al.* 1966; Higgins 1968), there are no large, low-grade greenstone belts, such as are characteristic of many other early Precambrian cratons.

(*c*) All the rocks of the craton have mineral assemblages indicating metamorphism at least as high as amphibolite facies, except for the lower grade amphibolite-greenschist rocks mentioned above, rocks associated with late faults, and late dykes. In the northern part of the

† Present address: Atangmik, 3912 Sukkertoppen, Greenland, Denmark.

craton there are relatively large areas with granulite facies mineral assemblages (Geological Survey of Greenland, 1970).

(*d*) Basic complexes, most of them stratiform, characterized by calcic meta-anorthosites and meta-leucogabbros are present in a number of areas. They are highly attenuated and complexly folded together with the amphibolites and gneisses (Windley 1969).

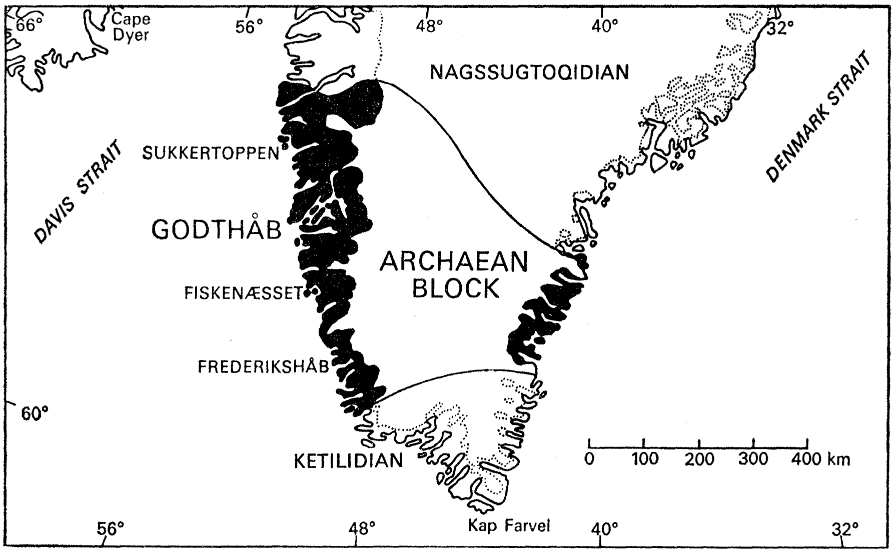


FIGURE 1. Geological sketch map of the southern part of Greenland, showing the boundaries of the early Precambrian craton and the location of the Godthåb district.

Some of the differences between the early Precambrian rocks of West Greenland and those of many other cratons, e.g. the Superior Province of Canada, the Rhodesian and Kaapvaal cratons of southern Africa, and the West Australian craton, may well be explainable in terms of a deeper level of erosion of the North Atlantic craton (Windley & Bridgwater 1971).

The Godthåb district is situated well within the boundaries of the craton. The town Godthåb, the administrative centre of Greenland, is separated from the open sea by an extensive 'skaergård' of low islands. East of the 'skaergård' there is a deeply dissected ice-sculptured highland, rising to peaks 1600 m high and cut by deep fiords, the largest of which are Godthåbsfjord and Ameralik. The former is a complex of interconnected fiords separated by large, high islands and reaches some 170 km in to the ice sheet. Excellent exposures are found within the splash zone along the coasts of the fiords and islands and on the mountains above a height of about 600 m. At lower altitudes the rocks are covered by a crust of lichens which obscures most of the fine details of the geology.

Regional geological mapping in the Godthåb district by the Geological Survey of Greenland between 1949 and 1953 (Noe-Nygaard & Ramberg 1961) yielded much information on the general geology of the area. The results have been summarized by Berthelsen & Noe-Nygaard (1965). The interpretation of the geology presented here is based on field work carried out by the present writer, while working with the Geological Survey of Greenland, during six summers between 1965 and 1971.

Establishment of the stratigraphy

The extremely complex geology of the Godthåb district is interpreted here in terms of a chronological hypothesis (table 1) which is consistent with all the major field relations observed and with the isotopic results obtained so far. The development of the hypothesis depended on the recognition of three important 'keys':

(*a*) *The Ameralik dykes*

Small bodies of homogeneous, medium-grained, black amphibolite are very abundant in some of the gneisses in the Godthåb district (figures 2 to 7, 9 and 11, plates 4 and 5). They were first noted along the coast of the outer part of Ameralik. Most of them have been strongly deformed and broken up and many have been migmatized by granitic veins. At favourable localities, where the rocks are least deformed, the amphibolites can be seen to have the form of dykes and to be discordant to their country rocks (figures 5 and 7, plates 4 and 5). As a working hypothesis it has been assumed that all the amphibolites of this type are derived from a swarm of basic dykes, but that most of them have been so intensely deformed, broken up and/or migmatized that direct evidence of their dyke origin has been destroyed. The name *Ameralik dykes* has been given to these amphibolites (McGregor 1968), even though the majority of them no longer retain a dyke form.

As the mapping progressed, it became apparent that the geology of the Godthåb district was made up of intercalated lithological units, some of which contained very abundant Ameralik dykes, while others contained none at all. The units that contain abundant Ameralik dykes are composed of quartzo-feldspathic gneisses that in some areas enclose enclaves of mainly basic material. The name *Amîtsoq gneisses* has been given to the rocks of these units (Oxford Isotope Geology Laboratory & McGregor 1971).

The lithological units from which Ameralik dykes are absent include the following:

(i) Relatively thin units of amphibolite, commonly banded, and associated gneisses with minerals (sillimanite, cordierite, staurolite, graphite) suggesting derivation from sedimentary parents. Pillow lava and agglomerate structures have been found in the amphibolites at one locality and green calc-silicate lenses and bands are common in them. It seems likely that most of these rocks are derived from supracrustal (sedimentary and volcanic) parents and they have been given the name *Malene supracrustals* (McGregor 1969). There is no evidence that the Malene supracrustals include rocks from more than one sequence of supracrustal rocks, but the possibility cannot be discounted.

(ii) Thick sheets of very calcic meta-anorthosite in the inner parts of Godthåbsfjord.

(iii) Abundant quartzo-feldspathic gneisses called the *Nûk gneisses* (Oxford Isotope Dating Laboratory & McGregor 1971). Nûk gneisses intrude and migmatize Amîtsoq gneisses, Malene supracrustals and meta-anorthosites. They commonly contain enclaves of amphibolite derived from the Malene supracrustals (figures 13, 14 and 16, plate 6).

(iv) Late granites and pegmatites.

(*b*) *Early structures obscured by deformation*

Most of the rocks in the Godthåb district have suffered very intense strain deformation: flattening and/or stretching. In most places this deformation was sufficiently intense to rotate all earlier structures until they became effectively parallel (cf. Watterson 1968). Many contacts that originally were discordant are now concordant. Rocks that originally were mesoscopically inhomogeneous, with different lithologies cutting or enclosed by one another, have been deformed into regularly and finely banded gneisses, amphibolites, etc.

(c) *Intrusive, granitic origin of the gneisses*

The intense deformation has erased or obscured many of the original features of the quartzo-feldspathic gneisses, but where for some reason the deformation has been weaker, there are many features that indicate that they have been derived from intrusive granitic rocks. There is more evidence of such an origin for the Nûk gneisses than for the Amîtsoq gneisses. Sharp, discordant contacts between gneisses and their country rocks are preserved in places, and discordant veins of gneiss penetrate out from the contacts. Sharply bounded enclaves that appear to have been rafted off by a magma are common in many places (figures 13, 14, plate 6). Where more than one phase of gneiss is present, the contacts between them can be seen to be discordant at favourable localities (figures 12, 13 and 15, plate 6). Many of the Nûk gneisses and some of the Amîtsoq gneisses are remarkably homogeneous on a mesoscopic scale (figures 7, 8, 12 and 15, plates 5 and 6). Most of the gneisses have, however, been so strongly deformed that direct evidence of an intrusive igneous origin has been destroyed (figures 10, 11 and 16). Such an origin is, however, inferred on the basis of comparison with the gneisses at localities where the deformation has been less intense and an intrusive origin is still relatively clear.

These 'keys' help to explain much of the geology of the Godthåb district and enable a stratigraphy to be built up. The intrusion of the Ameralik dykes and the intrusion of the parent rocks of the Nûk gneisses provide two time markers to which most of the other rocks can be related. A primary division is made between rocks cut by or containing Ameralik dykes (the Amîtsoq gneiss complex) and rocks from which the Ameralik dykes are absent. Of the latter the Nûk gneisses intrude the Amîtsoq gneisses, the Ameralik dykes, the Malene supracrustals and the meta-anorthosites and are clearly younger than all of these rocks.

Description of plate 4

Plate 4. Ameralik dykes and banded Amîtsoq gneisses.

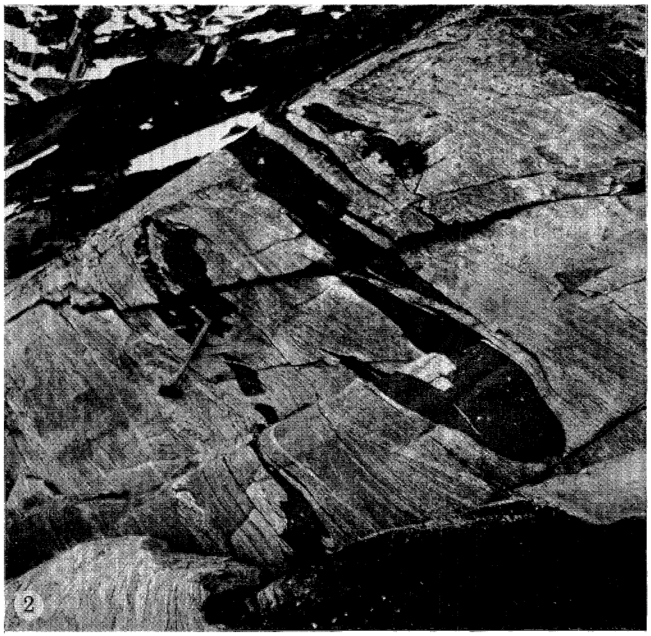
Figure 2. Typical folded and broken Ameralik dyke (amphibolite) enclosed in banded Amîtsoq gneiss, east of Serfarssuit, south coast of Godthåbsfjord. Note the homogeneous nature of the amphibolite and the presence in it of scattered small relic xenoliths of white anorthosite.

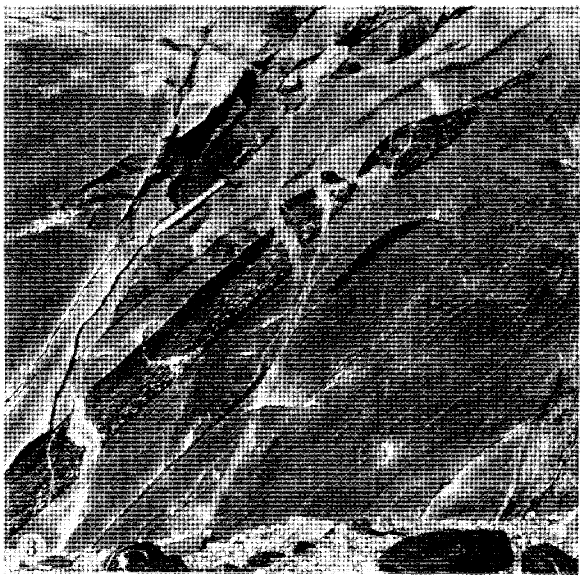
Figure 3. Deformed and broken Ameralik dyke in a raft of finely banded Amîtsoq gneiss just within the margin of the Qôrqut granite on the south coast of Storø, Godthåbsfjord. Deformed veins of granite extend in from the contact of the raft, visible below the hammer handle. The Ameralik dyke contains abundant, small, strongly deformed inclusions of anorthosite.

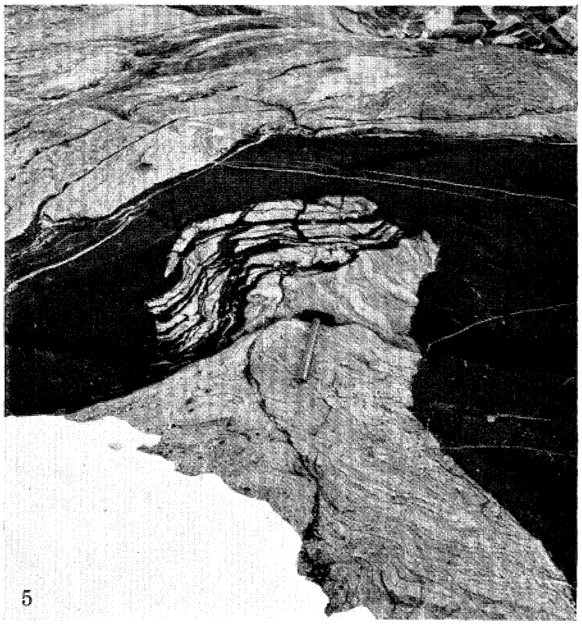
Figure 4. Strongly folded, thin Ameralik dyke cutting pegmatite-banded Amîtsoq gneiss, north coast of Ameralik east of Amîtsoq. The closed form of the fold is the result of differential stretching, perhaps superimposed on earlier, more normal folds. The pegmatite bands in the gneiss were formed before the basic dyke was intruded.

Figure 5. Little deformed, irregular Ameralik dyke cutting pegmatite-banded Amîtsoq gneiss, east of Hjortetakken. Most of the pegmatites in the gneiss are older than the intrusion of the basic dyke.

Figure 6. Folded Ameralik dyke in pegmatite-banded Amîtsoq gneiss, Amîtsoq, north coast of Ameralik. The pegmatite layers are younger than the basic dyke and are subparallel to the axial plane of the fold, suggesting that they were formed during the deformation that produced the fold. The basic dyke contains scattered anorthosite inclusions.







FIGURES 2 to 6. For legend see facing page.

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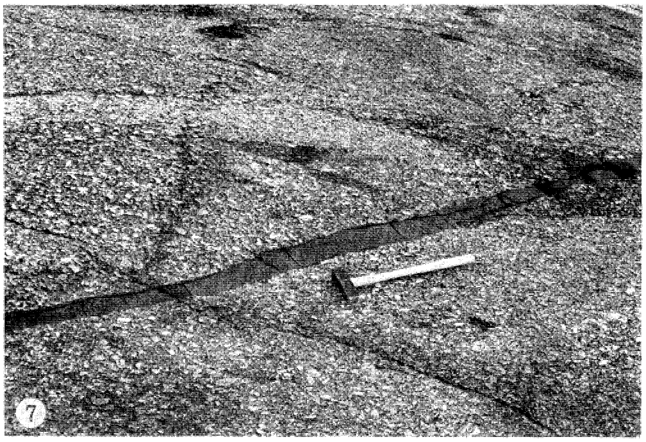


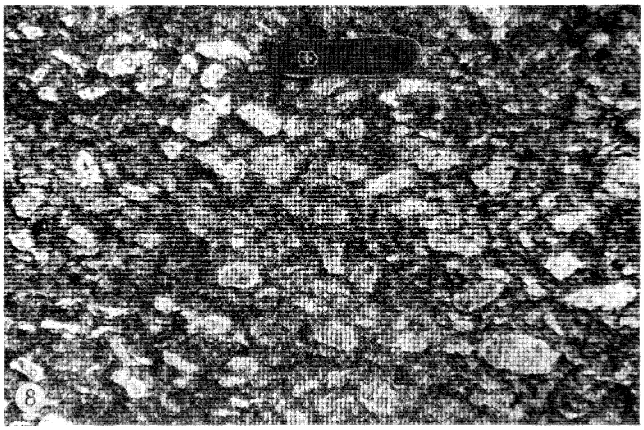


PLATE 2. Progressive break up of Ameralik dykes and accompanying deformation and metamorphic differentiation of the enclosing Amîtsoq gneisses, Kanajorssuit, south of the mouth of Ameralik. The photographs are taken from continuous coastal exposures over a distance of 100 to 200 m. The same changes occur over a few tens of metres across the strike.

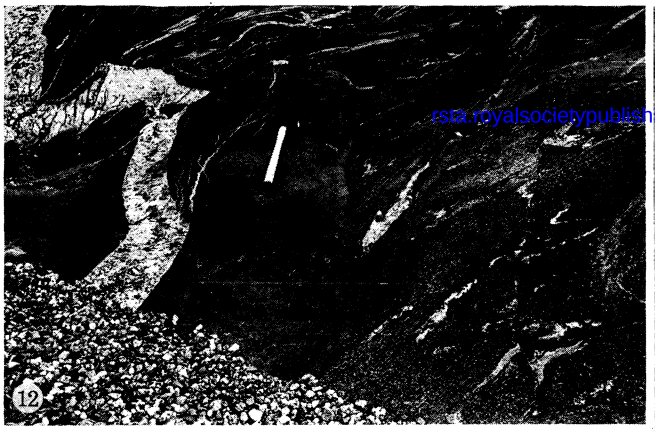
FIGURE 7. Little deformed, thin Ameralik dyke cutting dark augen gneiss derived from a porphyroblastic granodiorite. The feldspar megacrysts partly obscure basic schlieren and inclusions and appear to have grown after the granodiorite solidified.

FIGURE 8. Close-up of the texture of the same augen gneiss as in figure 7.

FIGURE 9. Deformed, but almost unbroken Ameralik dyke fraying out into thin apophyses. The homogenous gneiss is strongly deformed and small-folded and the original feldspar megacrysts have been streaked out into thin lenses.

FIGURE 10. Gneiss derived from the same parent as in figures 7 to 9, here more strongly deformed and with a fine lamination developed partly by intense attenuation of the original feldspar megacrysts and partly by metamorphic differentiation. Pegmatitic material has been segregated both in low-pressure patches (now deformed) and in more continuous thin layers. Nearby Ameralik dykes are moderately strongly broken up.

FIGURE 11. Intensely broken-up Ameralik dykes enclosed in banded gneisses derived from the same porphyroblastic granodiorite as in figure 7 and 8. Some of the pale bands are derived from pale granitic veins that cut the granodiorite.



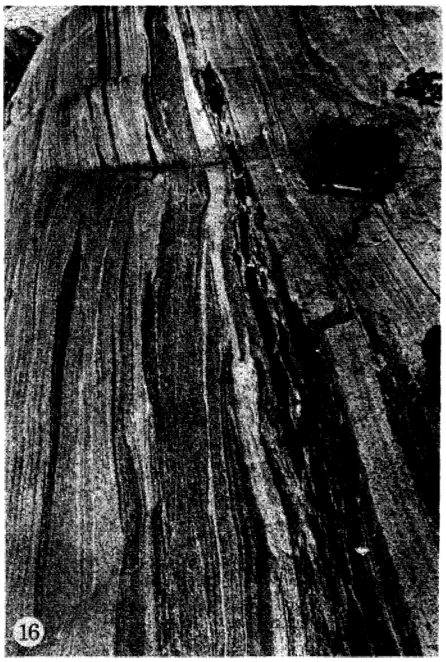


PLATE 3. Relatively little deformed Nûk gneisses showing intrusive field relations.

FIGURE 12. Earlier phase of Nûk gneiss, derived from a relatively coarse-grained parent, cut by a younger, fine-grained phase, south coast of Bjørneøen, Godthåbsfjord. The first phase was cut by pegmatitic veins and deformed before the second phase was intruded. Late, scarcely deformed pegmatites cut both gneisses. At nearby localities the same two gneiss lithologies are so strongly deformed that intrusive relations are no longer visible and the rocks have been changed into banded gneisses.

FIGURE 13. Probably the same two gneiss lithologies as in figure 12, at an exposure a few hundred metres away. The earlier phase contains sharply bounded, migmatized inclusions of amphibolite derived from nearby Malene supracrustals. The irregular form of the vein of the later phase is partly due to folding, but is partly original and suggests that the vein was intruded into very hot country rocks under conditions of stress.

FIGURE 14. Migmatized inclusions of banded green and black skarn-amphibolite, lithologically typical of the Malene supracrustals, south coast of Godthåbsfjord northwest of Lille Malene. The amphibolite is enclosed in rafts of an early phase of Nûk gneiss which are themselves enclosed in a younger, paler, more homogenous gneiss. A late granite dyke cuts all the earlier lithologies in the upper left part of the figure.

FIGURE 15. Intrusive relations between an early, dark, tonalitic Nûk gneiss and a younger, paler, granodioritic phase, south coast of Hundeøen, south of Godthåb. A few metres away the same lithologies are strongly deformed and concordant.

FIGURE 16. More strongly deformed Nûk gneisses, possibly the same lithologies as in figure 15, southwest of the centre of the town of Godthåb. The younger, paler phase contains strongly attenuated rafts of an earlier darker phase, which in turn contains broken-up fragments of Malene amphibolite.

In many parts of the Godthåb district, including much of the area shown on figure 17, units of Amîtsoq gneisses are interlayered with units of rocks with no Ameralik dykes. The Ameralik dykes were intruded as a very dense swarm and it is unthinkable that they could have intruded the Amîtsoq gneisses without having intruded the Malene supracrustals and the meta-anorthosites if these rocks had been in their present positions. Two explanations are possible:

(*a*) The Malene supracrustals and the meta-anorthosites were formed within the same area as the Amîtsoq gneisses, but are younger than the Ameralik dykes. The Amîtsoq gneiss complex may be a basement on which a cover of Malene supracrustals was laid down. Originally unconformable relations between them could be expected to have been obscured by later deformation, faulting and migmatization. Any basic dykes that might have intruded the basic volcanics of the Malene supracrustals would, because of the intense later deformation, now be massive, conformable or subconformable layers within the amphibolites and would not be obvious. It is conceivable, therefore, that the Ameralik dykes could be younger than or the same age as the Malene amphibolites. However, basic dykes are certainly absent from the associated metasedimentary gneisses and in terms of this explanation the Ameralik dykes must be older than the deposition of the sediments from which these gneisses are derived.

(*b*) The Amîtsoq gneisses and the Malene supracrustals were not formed in the same area and did not become interlayered until after the period of intrusion of the Ameralik dykes. The characteristic features of the Malene supracrustals are compatible with an origin on a thin, oceanic crust: the dominance of amphibolites derived from basic volcanic rocks, the presence of pillow lava structures, the presence of relatively thick units of quartz-cordierite gneisses, possibly derived from chemical precipitates, and the abundance of small bodies of rocks derived from dunites and harzburgites. It is possible that the Amîtsoq gneisses formed part of an area of continental crust, that the Malene supracrustals were laid down on an adjacent area of oceanic crust, and that the two were brought together by some form of plate movement and thrust into one another to give the present pile of thrust sheets.

The stratigraphic relations of the meta-anorthosites are not clear, but it seems possible that they were intruded as a sill or sills into the supracrustal rocks.

Amîtsoq gneisses

Amîtsoq gneisses probably make up rather less than half of the Godthåb district as a whole, but they are especially abundant south and southeast of the town of Godthåb and make up more than half of the relatively small area mapped since the division of the gneisses was begun (figure 17). The name Amîtsoq is taken from a locality on the north side of the outer part of Ameralik and means 'something without a skin' in Eskimo.

The Amîtsoq gneisses are dominantly pale quartzo-feldspathic gneisses that vary in composition from tonalitic to granitic. A small number (18) of samples of Amîtsoq gneisses from the area south of Godthåb have been examined in thin section and of these two-thirds contain more than 20 % potash feldspar and one-quarter more than 40 % potash feldspar. If these rocks are at all typical, then it appears that the Amîtsoq gneisses are richer in potash feldspar than the younger Nûk gneisses, at least within the area shown in figure 17.

Almost all of the Amîtsoq gneisses have been heavily reworked under plutonic conditions. The great majority of the Ameralik dykes are intensely deformed, broken up and migmatized and all of them have been completely recrystallized under high amphibolite facies conditions. It is clear that the gneisses that enclose the altered dykes must have been affected by the same processes after the intrusion of the dykes. At the scattered localities where the Ameralik dykes are less deformed and unmigmatized it is possible to gain an idea of the state of gneisses at the time of intrusion of the dykes.

At a number of such localities the little deformed Ameralik dykes cut homogeneous gneisses whose textures strongly suggest that they are orthogneisses derived from homogeneous granitic (s.l.) rocks. Some of these orthogneisses, for example in Praestefiord, a small branch of Ameralik, are rather fine-grained tonalitic rocks, similar in appearance to many of the younger Nûk gneisses, and contain many small, sharply bounded inclusions of basic rocks. On the coast south of the mouth of Ameralik and on the southeast corner of Qilángârssuit (Berthelsen 1955) there are coarse-grained, granitic and granodioritic augen gneisses containing abundant partly recrystallized megacrysts of potash feldspar (figures 7, 8). Discordant, intrusive relations have been preserved here and there between two gneiss phases or between gneisses and basic enclaves.

In a number of places it is possible to follow the progressive break-up of Ameralik dykes away from localities where they are little deformed and to observe the accompanying changes in the enclosing Amîtsoq gneisses. Figures 7 to 11, plate 5, show such a sequence at Kanajorssuit, south of the mouth of Ameralik. Where the Ameralik dykes are least deformed (figures 7, 8) the country rocks are relatively homogeneous, dark, augen gneisses with abundant feldspar megacrysts. The dark gneisses are cut by veins of paler gneiss (not shown in the figures). A few tens of metres away across the strike, but farther away along the coast, which is oblique to the strike, the Ameralik dykes have been completely broken up into strings of rounded fragments and the originally homogeneous gneisses have been changed into banded and finely laminated gneisses (figure 11). The banding (layering) is a result of the intense attenuation of the original gneisses, with the originally discordant veins of paler gneiss changed here to concordant pale bands in the laminated darker gneiss. The fine lamination of the darker bands is the result of streaking out of the original feldspar megacrysts accompanied by metamorphic differentiation, with segregation of the darker and lighter minerals into alternating laminae. Intermediate stages are seen in figures 9 and 10. The metamorphic differentiation produced both a very fine, close lamination and thicker, more continuous, subconcordant pegmatite layers within a darker matrix.

Figure 6 shows typical banded Amîtsoq gneisses at another locality on the north coast of Ameralik (figured by Ramberg 1956). Here again the banding consists of thin, subconcordant pegmatites in a darker matrix. The pegmatites are clearly later than a folded Ameralik dyke and the processes that formed them (migmatization or metamorphic differentiation) were accompanied by strong deformation. Evidence from these and other localities shows that the formation of banded gneisses of this type requires strong deformation under conditions where the components of feldspar and quartz are relatively mobile, i.e. under high amphibolite facies conditions within or approaching the field of anatexis.

Gneisses with pegmatitic bands like those shown in figures 4 to 6 are typical of the Amîtsoq gneisses over large areas. At some localities the dykes can be seen to have cut gneisses in which this type of banding was already present (figures 4, 5). It is thus clear that the processes that produced the banding of the Amîtsoq gneisses operated both before and after the intrusion of the Ameralik dykes.

In some areas the Amîtsoq gneisses contain rafts and inclusions of a variety of basic, ultrabasic and other rocks. Amphibolite, dioritic gneiss and hornblendite are common lithologies, especially in smaller inclusions. The texture, form, and field relations of some of the larger rafts, for example a body of dioritic gneiss on Qilángârssuit (Berthelsen 1955), suggests that they originated as igneous rocks intruded into the gneisses. Several of the larger rafts are clearly cut by and therefore older than the Ameralik dykes. Larger bodies of basic rocks within the Amîtsoq gneisses have been found only in the area around Narssaq, south of the mouth of Ameralik (figure 17), but may be more common in the middle section of Ameralik.

Other less common lithologies occur as inclusions in the Amîtsoq gneisses only. Enclaves of green and black rocks, composed mainly of hornblende and pale green clinopyroxene, have been found south of Godthåb especially around the southwest corner of Qilángârssuit. Other inclusions are composed of quartz and either pale green clinopyroxene or an association of magnetite, grunerite, deep green hornblende, iron-rich orthopyroxene and garnet. At least some of them are the products of intense silica penetration of banded ultramafic rocks. Other enclaves in the Amîtsoq gneisses that are composed of quartz and iron-rich minerals appear to have been derived from parents like a large, very elongated and very homogeneous raft in the gneisses southeast of Narssaq that is composed of quartz, magnetite, grunerite and pale green clinoamphibole. Both the form and the texture of this body strongly suggest that it was a dyke intruded into the gneisses.

Origin and significance of the Amîtsoq gneisses

Amîtsoq gneisses in a few areas can be seen to have been derived from igneous granitic (s.l.) rocks. The remainder of the gneisses have been so strongly reworked that direct field evidence of their origin has been destroyed. All, however, are lithologically similar to gneisses whose origin from igneous granitic rocks can be demonstrated in the field. At least some of the enclaves in the Amîtsoq gneisses appear to be derived from basic and ultrabasic rocks intruded into the Amîtsoq gneisses and reworked with them. No rocks whose lithology suggests a sedimentary or volcanic origin have been found within the Amîtsoq gneiss complex.

Whole rock Rb–Sr and Pb–Pb isotope measurements on rocks from the Amîtsoq gneiss complex have been published by the Oxford Isotope Geology Laboratory & McGregor (1971) and further work is in progress. Rb and Sr isotopes have been measured on more than fifty whole rock specimens of typical quartzo-feldspathic Amîtsoq gneisses from localities scattered over an area some 30 km across. Most of the specimens were carefully chosen from localities where the gneisses are least reworked. On a plot of $^{87}Sr/^{86}Sr$ against $^{87}Rb/^{86}Sr$ forty-two of these gneisses lie on or very close to a straight line that gives an isochron age of about 3750 Ma, indicating that the rocks were essentially isotopically homogeneous for strontium at this time. The gneisses are not significantly depleted in rubidium. Pb–Pb results on a smaller number of specimens suggest a period of massive uranium loss about 3600 Ma ago. The margin of error of the Rb–Sr and Pb–Pb isochron ages overlap.*

The Rb–Sr isochron age could be interpreted as the time of emplacement of a suite of isotopically homogeneous igneous granitic rocks from which the Amîtsoq gneisses were derived, or as the date of a period of high-grade metamorphism of the gneisses during which homogenization of strontium isotopes and loss of uranium occurred. The writer prefers the first

* A Rb–Sr whole rock isochon age of 3700 ± 140 Ma has recently been obtained on gneisses from the Isua area, 140 km northeast of Godthåb (Moorbath *et al.*, in press).

interpretation. The loss of uranium may have occurred under high-grade conditions that prevailed during or shortly after the period of emplacement of the granitic rocks.

The second interpretation requires a remarkable degree of homogenization of strontium isotopes over an area at least 30 km across in rocks at least some of which do not appear to have been migmatized or metasomatized since they were emplaced as homogeneous granites (s.l.).

Thus both the field evidence and the isotopic results are consistent with, but do not prove, an origin for the Amîtsoq gneiss complex as derived from a suite of intrusive, mainly granitic, rocks that were emplaced 3700–3800 Ma ago. They are the oldest terrestrial rocks whose age has been established so far. The recognition and dating of the Amîtsoq gneisses confirms that granitic rocks with apparently normal bulk compositions were present in the Earth's crust as early as this. It seems likely that they are older than the earliest supracrustal rocks and they may even be part of a primeval granitic crust.

The intrusion of the Ameralik dykes represents the first evidence of stable, although not necessarily cold, conditions in the Amîtsoq gneisses. In many places Ameralik dykes cut pegmatite-banded Amîtsoq gneisses and it is clear from this that the processes that produce such banding, i.e. strong deformation under conditions within or approaching the field of melting of granitic magmas, operated before the Ameralik dykes were intruded. Further work on the original nature of the rocks of the Amîtsoq gneiss complex and on conditions that prevailed before the intrusion of the Ameralik dykes will be made difficult by the fact that all of these rocks have been strongly metamorphosed and most of them have been deformed and migmatized after the Ameralik dykes were intruded.

Ameralik dykes

Ramberg (1956, Plate 4, Fig. 4) and Berthelsen (1955) noted the presence of bodies of amphibolite derived from basic dykes in the area south of Godthåb, but do not appear to have realized how abundant such amphibolites are over much of the Godthåb district in the rocks now called the Amîtsoq gneisses. This may be because only a very small proportion of the Ameralik dykes are still visibly discordant to their country rocks. Within most of the Amîtsoq gneisses Ameralik dykes occur every few metres or tens of metres. A particularly useful feature in identifying Ameralik dykes is the presence in a small proportion of them of small relic xenoliths of white anorthosite (figures 2, 3 and 6). Similar xenoliths have been noted in supracrustal amphibolites both north and south of the Godthåb district.

Almost all of the Ameralik dykes have suffered intense tectonic thinning. Most of the bodies that retain a dyke form are between a few tens of centimetres and several metres thick. Dykes 10 m or more thick have been noted, and there are several thicker, folded sheets of metadolerite that may belong to the association, e.g. the metadolerite sheet more than 150 m thick east of Ugpik (figure 17). One of the most characteristic features of the association over much of the Godthåb district is the abundance of very thin dykes (apophyses). In some areas, though, there are only few, relatively thick dykes.

Features such as very irregular contacts, genetic association with pegmatite or granite veins, irregular textural inhomogenity, or more intense deformation in dykes than in the enclosing gneisses, features which in the writer's experience are typical of basic dykes intruded into hot country rocks under conditions of plutonic activity, have not been found in the Ameralik dykes, and it is therefore assumed that they were intruded into relatively cool, (although not necessarily cold) stable country rocks.

The Ameralik dykes appear to have been derived from a very dense swarm of basic dykes, comparable to the younger Kangâmiut dyke swarm in the area around Søndre Strømfjord, north of the Godthåb district (Ramberg 1949.)

It is assumed that they were intruded within a relatively restricted period of time and that they represent a single major chronological event. A very small number of younger metamorphosed basic dykes have been noted, for example a single dyke cutting Nûk gneisses on Kuánĭnguit, northeast of Godthåb. Such dykes may well have been confused with Ameralik dykes in places.

Malene supracrustals

The Malene supracrustals comprise amphibolites and metasedimentary gneisses. Many of the units that can be traced in the field consist of amphibolite alone. In those units that contain both amphibolites and metasedimentary gneisses, the two occur separately and are not generally interlayered. Six lithologically distinct units of Malene supracrustals, separated by units of Amîtsoq gneisses, can be distinguished within the area mapped and are designated A (structurally lowest) to F (structurally highest) on figure 17. Unit D is the most conspicuous and extends for at least 70 km along the strike through Store Malene and the islands south of Godthåb. On the southeast corner of Bjørneøen (north of the area of figure 17) the amphibolites of this unit contain recognizable pillow lava and agglomerate structures.

Some of the supracrustal amphibolites are massive rocks, but most are banded and contain layers and drawn-out lenses of green rocks rich in calc-silicate minerals (diopside, epidote-group minerals, scapolite, sphene). Brown magnesian amphibolites containing anthophyllite or cummingtonite together with or instead of hornblende are present in some units. Some very homogeneous amphibolites have textures that suggest that they are derived from dolerites, probably sills.

The metasedimentary gneisses include pelitic and semi-pelitic gneisses that commonly contain sillimanite and, at a few localities, graphite. Gneisses composed mainly of quartz and cordierite, together with smaller amounts of sillimanite, pale brown mica, rhombic amphibole, and staurolite are prominent within unit D and form a sequence more than 100 m thick on islands south of the mapped area. Their field relations strongly suggest that they are the product of isochemical recrystallization and not of metasomatism. One specimen of a gneiss of this type was found to contain relic kyanite.

Ultramafic rocks

Pods and thin layers and lenses of ultramafic rocks derived from dunites, harzburgites and serpentinites are especially common within the supracrustal amphibolites, but are also found in other stratigraphic units, including the Amîtsoq gneisses. In some places they are concentrated along contacts between Malene amphibolites and Amîtsoq gneisses, contacts that are considered to have been major thrust planes (see below under Structure). It seems likely that most of them are younger than the Malene supracrustals and that they were emplaced along fault planes.

All of the ultramafic rocks have been recrystallized and now have amphibolite facies mineral assemblages. A very typical assemblage is olivine–orthopyroxene–tremolite–colourless chlorite.

Stratiform meta-anorthosites

Thick sheets of calcic meta-anorthosite are present at several localities in the Godthåb district (Windley 1969). They consist mainly of rather pure meta-anorthosite composed of calcic plagioclase with secondary clinozoisite and pale mica. More mafic rocks are rare, except in the anorthosite west of Qasigiánguit, on the south coast of Ameralik Anorthositic rocks appear to have been rather extensive in the inner parts of Ameralik and Godthåbsfjord, but they have been intensely migmatized by the intrusive granitic rocks from which the Nûk gneisses were derived and now occur as enclaves in Nûk gneisses.

The stratigraphic relations of the meta-anorthosites are not clear. Ameralik dykes are absent from those in Godthåbsfjord, but metamorphosed basic dykes that could conceivably be Ameralik dykes cut the one west of Qasigiánguit. Most of the meta-anorthosites have been heavily migmatized along their contacts by Nûk gneisses, but all are closely associated with supracrustal amphibolites. The evidence available at present is consistent with the hypothesis that they were intruded as sheets into the supracrustal rocks or along contacts between the supracrustal rocks and Amîtsoq gneisses.

Nûk gneisses

Nûk gneisses, quartzo-feldspathic gneisses from which Ameralik dykes are absent, make up more than half of the Godthåb district. Within the area shown in figure 17 they range in composition from dioritic to granitic, with tonalitic and granodioritic gneisses most common. Granitic gneisses are common in other areas.

Nûk gneisses occur as thin sheets of pale homogeneous gneiss, many of them still slightly discordant, within the Amîtsoq gneisses, Malene supracrustals and meta-anorthosites, as much thicker units intercalated with units of the older rocks, and as large, composite complexes. In all of these types of occurrence, they can be seen to be intrusive into their country rocks at favourable localities, where the deformation has not been too strong (plate 6).

A large, composite complex of Nûk gneisses crops out around and to the north, south and west of the town of Godthåb (Nûk in Eskimo). A small part of the complex is shown in figure 17. The oldest phases are dark, dioritic gneisses which in places can be seen to be derived from coarse-grained gabbroic rocks. The youngest rocks are bodies of very homogeneous granodioritic gneiss that occupy the cores of a row of elongated diapiric domes in the eastern part of the complex. The most common lithology is fine-grained, grey biotite gneiss of tonalitic composition. Over much of the complex several intrusive phases are present, the paler phases cutting the darker ones. Very elongated rafts and, in some areas, abundant small inclusions of supracrustal amphibolite are common. A unit of intensely migmatized Amîtsoq gneisses extends through the complex a few kilometres east of Godthåb. Rocks that probably belong to the same complex of Nûk gneisses crop out on the opposite side of Godthåbsfjord, west and north of Godthåb. Here, however, they have granulite facies mineral assemblages and contain much more dioritic and basic material, both as inclusions and as larger masses.

Thick sheets of mainly pale Nûk gneisses intruded into supracrustal rocks, mainly amphibolites, and folded with them form a characteristic outcrop pattern in parts of the Godthåb district (see, for example, Laurema 1964, Plate VI). It is conceivable that some Nûk gneisses might be derived from acidic volcanic rocks within the supracrustal sequence.

The Nûk gneisses display intrusive field relations to their country rocks and to one another wherever the later deformation has not been strong enough to have destroyed such relations. They are considered to be derived from a calc-alkaline intrusive suite intruded under conditions of regional stress. The earliest phases were gabbros, the main intrusive phases were tonalites and granodiorites that migmatized the older rocks including the earlier phases of the intrusive suite, and the last phases, at least in the area around Godthåb, were discrete plutons of granodiorite.

Thirteen Nûk gneisses from a small area north of Godthåb have given an excellent Rb–Sr whole isochron age of 3084 ± 46 Ma (Oxford Isotope Geology Laboratory & McGregor, in preparation). The specimens range from dioritic to granitic in composition and the earlier phases have been deformed before the latest phases were intruded (figures 12, 13). The metamorphic grade is relatively low in this area, possibly low to middle amphibolite facies, and it seems most likely that the isochron age gives the time of intrusion of the parent rocks of the gneisses rather than the time of a later metamorphism. The fact that such a range of lithologies lie on a single isochron supports the idea that they are derived from a co-genitic intrusive suite.

The Nûk gneisses are the most abundant rocks in the Godthåb district and their intrusion represented a massive addition of granitic rocks to this level of the crust about 3080 Ma ago.

Late granites and pegmatites

A complex body of relatively fine-grained biotite granite 50 km long and as much as 18 km wide occupies the centre of the Godthåb district, between Godthåbsfjord and Ameralik. This pluton, called the *Qôrqut granite*, is elongated parallel to the regional NNE structural trend and the southern part occupies the core of an anticline plunging to the SSW.

Two or more phases, differing from one another only in their content of biotite, are present at most localities. The older, darker phases are weakly deformed (figure 3) and foliated by parallelism of biotite grains. Along some sections of the contact of the pluton the country rocks are intensely migmatized and partly made over to granite. Rafts of partly granitized country rocks are common in the southern part of the pluton. Undeformed granite and pegmatite dykes, most of them gently dipping, cut the country rocks around the granite and are extremely abundant in the roof zone.

The Qôrqut granite appears to have been essentially an intrusive body, although its emplacement was accompanied by extensive granitization (remelting) of the country rocks. The strong elongation of the pluton parallel to the axes of the latest folds in the area and the foliated nature of the earlier phases suggests that it was intruded at the end of a period of regional deformation, perhaps over a deep NNE-trending zone of weakness.

Scarcely deformed pegmatite dykes are common in much of the eastern part of the Godthåb district and are assumed to be related to the plutonic activity that formed the Qôrqut granite. Along the west coast of the main arm of Godthåbsfjord their emplacement appears to have been associated with the retrogression of the country rocks from granulite facies to amphibolite facies.

Late basic dykes

Post-tectonic dolerite dykes, probably roughly comparable in age to the Kangâmiut dykes to the north (Ramberg 1949), are less common in the Godthåb district than in many other parts of the craton. They appear to have been intruded under high greenschist facies conditions, in the same general period that major wrench faults, for example the Kobbefjord Fault (figure 17), were active. They may not be very much younger than the Qôrqut granite.

Thin east–west trending Tertiary dykes (Bridgwater 1970) with basic to intermediate, rather alkaline, compositions have been found in the area around the mouth of Ameralik. Most of them are strongly zoned and contain carbonate and zeolite-filled amygdales. Xenoliths of rocks tentatively identified as granulite facies gneisses have been found in some of them.

Table 1. Tentative chronology of the Godthåb district

(The relative positions of several of the items in the chronology are uncertain: items (2) and (3) may be synchronous, item (5) may have preceded item (4), metamorphism under granulite facies conditions, item (8), may have postdated or outlasted item (9).)

(1) Plutonic development of a complex of dominantly quartzo-feldspathic gneisses (*Amîtsoq gneisses*) involving emplacement of granites, granodiorites and tonalites; intrusion of small bodies of basic and ultramafic rocks; strong deformation and migmatization under high-grade conditions that transformed most of the rocks into banded gneisses. Massive loss of uranium and homogenization of strontium isotopes 3600 to 3800 Ma ago, possibly during the emplacement of the granitic rocks, possibly during later high-grade metamorphism.

(2) Intrustion of an abundant swarm of basic dykes (*Ameralik dykes*) under non-plutonic conditions.

(3) Extrusion and deposition of basic lavas, including pillow lavas, and clastic and possibly also chemical sediments (*Malene supracrustals*).

(4) Major thrusting, producing a pile of alternation sheets of Amîtsoq gneisses and Malene supracrustals. Emplacement of ultramafic rocks (dunites and harzburgites), probably along the thrust planes. Partial serpentinization of the ultramafic rocks under greenschist facies conditions.

(5) Emplacement of stratiform anorthosites, probably as a sill or sills intruded into the supracrustal rocks or along their contacts.

(6) Intrusion of a major syntectonic suite of calc-alkaline rocks (gabbros, tonalites, granodiorites, granites; the parent rocks of the *Nûk gneisses*) as large complexes, sills and minor dykes. These rocks were isotopically homogeneous for strontium 3080 Ma ago. Migmatization of Amîtsoq gneisses and Malene supracrustals.

(7) Intense deformation producing several phases of folds, including earlier overturned folds and, as the latest phase, open, NNE–trending folds. Migmatization accompanying deformation.

(8) High-grade metamorphism outlasting the deformation of (7) and reaching granulite facies in the north-western part of the area. Emplacement of small bodies of diorite and granitic dykes in the granulite facies area.

(9) Strong stretching deformation in the area around Godthåb.

(10) Formation of the Qôrqut granite, weak regional deformation, and widespread emplacement of pegmatites. Retrogression of part of the granulite facies area to amphibolite facies. Retention of argon in mica and hornblende from 2700 to 2500 Ma ago.

(11) Intrusion of dolerite dykes, wrench faulting and local recrystallization under greenschist facies conditions.

(12) Intrusion of Tertiary basic and intermediate dykes.

Structure

Those parts of the Godthåb district that are not mainly Nûk gneisses or Qôrqut granite are made up of an intensely folded pile of alternating units of Amîtsoq gneisses, Malene supracrustals, Nûk gneisses, and in places, meta-anorthosites. The piling up of alternating units of Amîtsoq gneisses and Malene supracrustals is attributed to a major episode of thrusting, comparable to the thrusting of wedges of Lewisian basement up into the cover of Moine sediments at the margin of the Caledonian fold belt in western Scotland (Sutton & Watson 1962). Six lithologically distinct units of supracrustal rocks, each overlain by a unit of Amîtsoq gneisses, are recognized in the area shown in figure 17.

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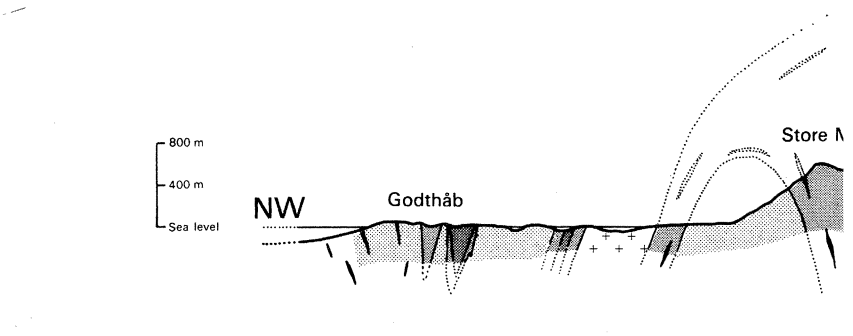

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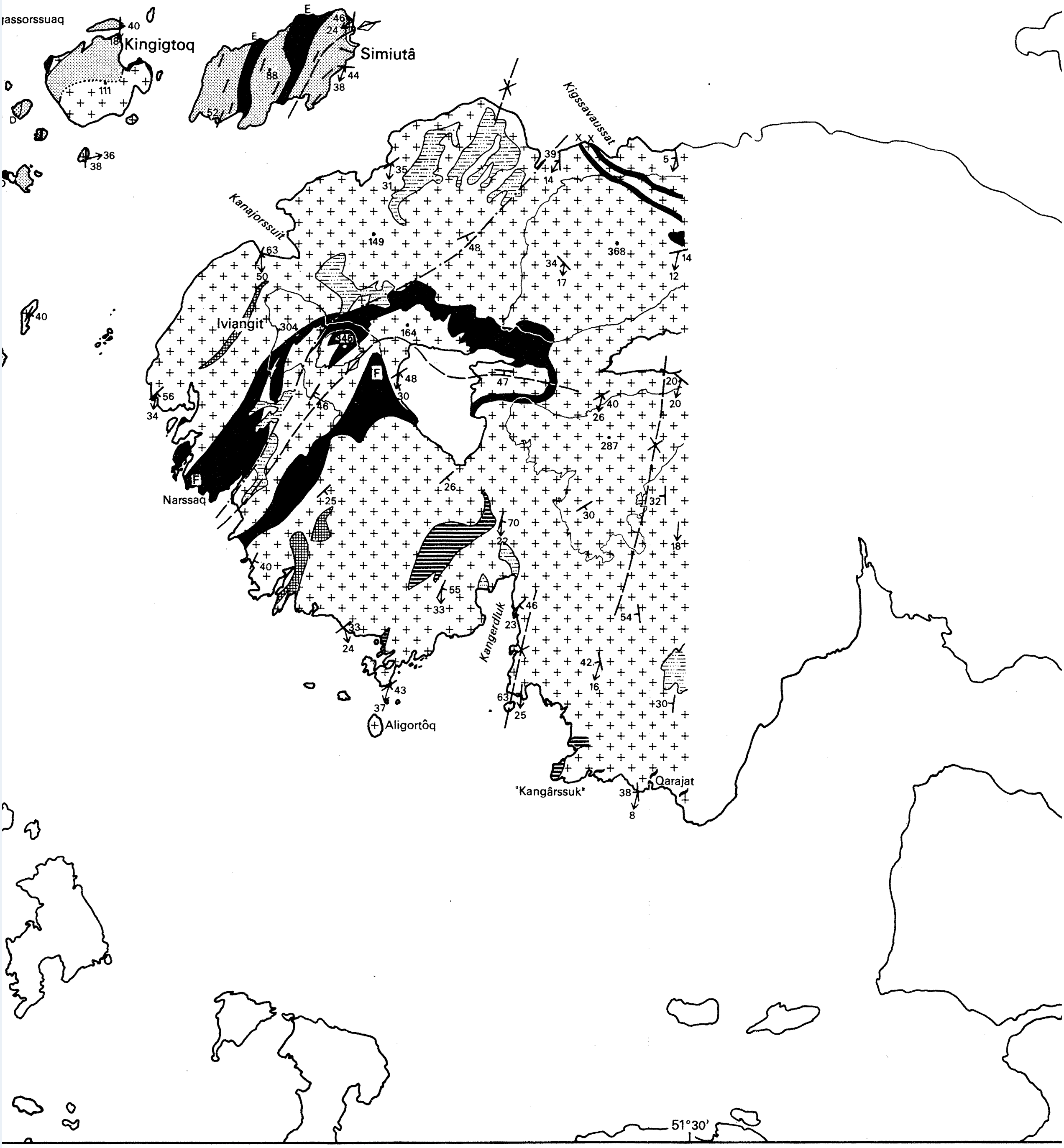

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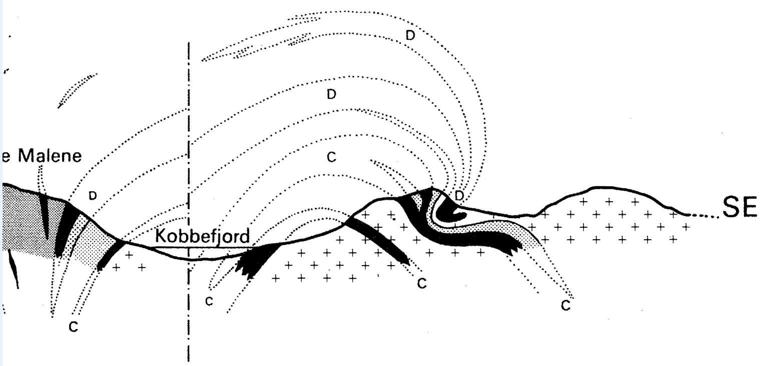

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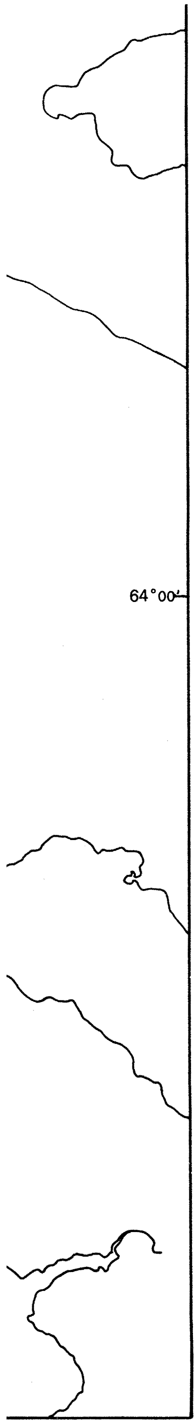

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FIGURE 17. Geological map of the area south and east of Godthåb, with one cross-section. Th

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S SECTION

The scale of the cross-section is the same as that of the map and there is no vertical exaggeration.

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This interpretation implies that many of the contacts between Amîtsoq gneisses and Malene supracrustals must originally have been thrust planes. Evidence of their original nature has been obliterated by intense deformation, metamorphic recrystallization and the emplacement of pegmatites. The location of many small bodies of ultramafic rocks along such contacts suggests that many of these rocks were emplaced along thrust planes. Some of the sills of anorthosite and the granitic parents of the Nûk gneisses may have been intruded along the planes of weakness provided by thrust planes.

The pile of units of Amîtsoq gneisses, Malene supracrustals, meta-anorthosites and Nûk gneisses has been intensely folded. Several phases of folding were involved, the details of which have not yet been worked out. There was at least one early phase of recumbent folding which in the area east of Godthåb appears to have had a movement direction from east to west (figure 17, cross-section). Many of the resulting folds are extremely attenuated. The last major phase of folding produced rather open folds trending NNE. The apparently simple pattern of outcrops in the northern part of the mapped area suggests that the earlier fold phases may have had the same NNE trend, at least in this area.

Along the eastern part of the complex of Nûk gneisses that extends through Godthåb the late, homogeneous, granodioritic gneisses rose diapirically, arching their country rocks into a line of *en echelon* domes and anticlines.

The last major phase of deformation involved intense stretching of the rocks around and south of Godthåb and produced very regular strikes and a linear fabric that plunges very constantly to the SSW at angles of up to 35°. A strong linear fabric plunging in the same direction has been found in many places southeast of Godthåb, but has not been found north of the mapped area or in the granulite facies area west of Godthåbsfjord. This stretching deformation may be later than the granulite facies metamorphism.

Some deformation, perhaps open folding, appears to have accompanied the early stages of formation of the Qôrqut granite.

Metamorphism

With the exception of post-tectonic basic dykes and rocks retrogressed near faults, all the rocks of the Godthåb district have amphibolite facies or granulite facies mineral assemblages.

Bearing in mind the complex plutonic history of the area (see table 1), it can safely be assumed that most of the rocks have been subjected to a number of phases of high-grade metamorphism. High-grade, probably amphibolite facies metamorphism, with conditions at or near those required for anatexis must have accompanied the conversion of the parents rocks of the Amîtsoq gneisses to banded gneisses, both before and after the intrusion of the Ameralik dykes. The intrusion of the granitic suite that later became the Nûk gneisses must also have been accompanied by high-grade metamorphism, again probably under amphibolite facies conditions. The present amphibolite and granulite facies mineral assemblages appear to have crystallized during metamorphism that accompanied and outlasted the last major phases of deformation.

Granulite facies rocks make up most of the Nordland peninsula, west of Godthåbsfjord (Noe-Nyggard & Ramberg 1961). Berthelsen (1960) showed that the granulite facies metamorphism at Tovqussap nunâ, just north of Nordland, was preceded by a complex history of deformation and outlasted the last phases of regional folding. Farther south too, in the Godthåb district, the granulite facies metamorphism outlasted deformation.

The granulite facies area is bordered by amphibolite facies rocks that appear to have been retrogressed from granulite facies. These apparently retrogressed rocks are very extensive north and northeast of Nordland (Lauerma 1964), but in the south, around the town of Godthåb, they form a strip no more than 10 km wide. Around the southeastern margin of the granulite facies area the retrogression appears to have been associated with the emplacement of undeformed pegmatite dykes that may well be the same age as the Qôrqut granite to the east.

In the remainder of the Godthåb district the rocks have amphibolite facies mineral assemblages. To the south, at the mouth of Buksefjord (Noe-Nygaard & Ramberg 1961), there are small areas of granulite facies rocks and in some other parts of the area there is evidence that the rocks have previously been at higher grades, approaching or even reaching granulite facies grade, for example on the island of Qilángârssuit (Berthelsen 1955) and south of the middle of Ameralik. There is no evidence that the main part of the amphibolite facies area has ever been at higher metamorphic grade.

Cordierite is a characteristic mineral in the metasedimentary gneisses, and this suggests that pressures were relatively low during the last metamorphism. Relic kyanite in one gneiss suggests earlier higher pressure conditions.

Regional setting of the Godthåb gneisses

In terms of broad geological features (the predominance of quartzo-feldspathic gneisses, abundant thin units of supracrustal amphibolites, presence of stratiform meta-anorthosites, complex multiple folding, high metamorphic grade) the Godthåb district is typical of the early Precambrian craton in West Greenland. However direct correlation of the stratigraphic units recognized in the Godthåb district with similar rocks in other parts of the craton is not yet possible.

Amîtsoq gneisses have now been recognized within an area that extends from the head of Godthåbsfiord as far south as the fishing station of Faeringehavn, a distance of about 180 km. Along the coast for at least 130 km south of Faeringehavn the majority of the gneisses are lithologically and stratigraphically similar to the Nûk gneisses, and Amîtsoq gneisses may well be completely absent. So far no concerted search has been made for Amîtsoq gneisses outside of these areas. It seems reasonable to expect that rocks equivalent to the Amîtsoq gneisses are present in other parts of West Greenland. Such rocks would be very difficult to recognize in the field without the help of the Ameralik dykes.

Bridgwater & Gormsen (1969) have noted the presence of very extensive agmatitic gneisses in the craton in southeast Greenland which they regard as older than supracrustal rocks that are comparable to the Malene supracrustals. These agmatitic gneisses may well be stratigraphically equivalent to the Amîtsoq gneisses.

Quartzo-feldspathic gneisses that are similar in lithology and field relations to the Nûk gneisses appear to be the most abundant rocks over much of the craton in West Greenland. Many have features that indicate that they are derived from granitic rocks which intruded supracrustal amphibolites lithologically very similar to those of the Malene supracrustals. Much more isotope work will be required before it can be established whether many of these gneisses are the same age as the Nûk gneisses and to what extent they and the Nûk gneisses are of subcrustal derivation. At present one can only suggest that the intrusion of the granitic rocks from which these gneisses are derived may have been responsible for a very considerable thickening of this part of the Earth's crust about 3100 Ma ago

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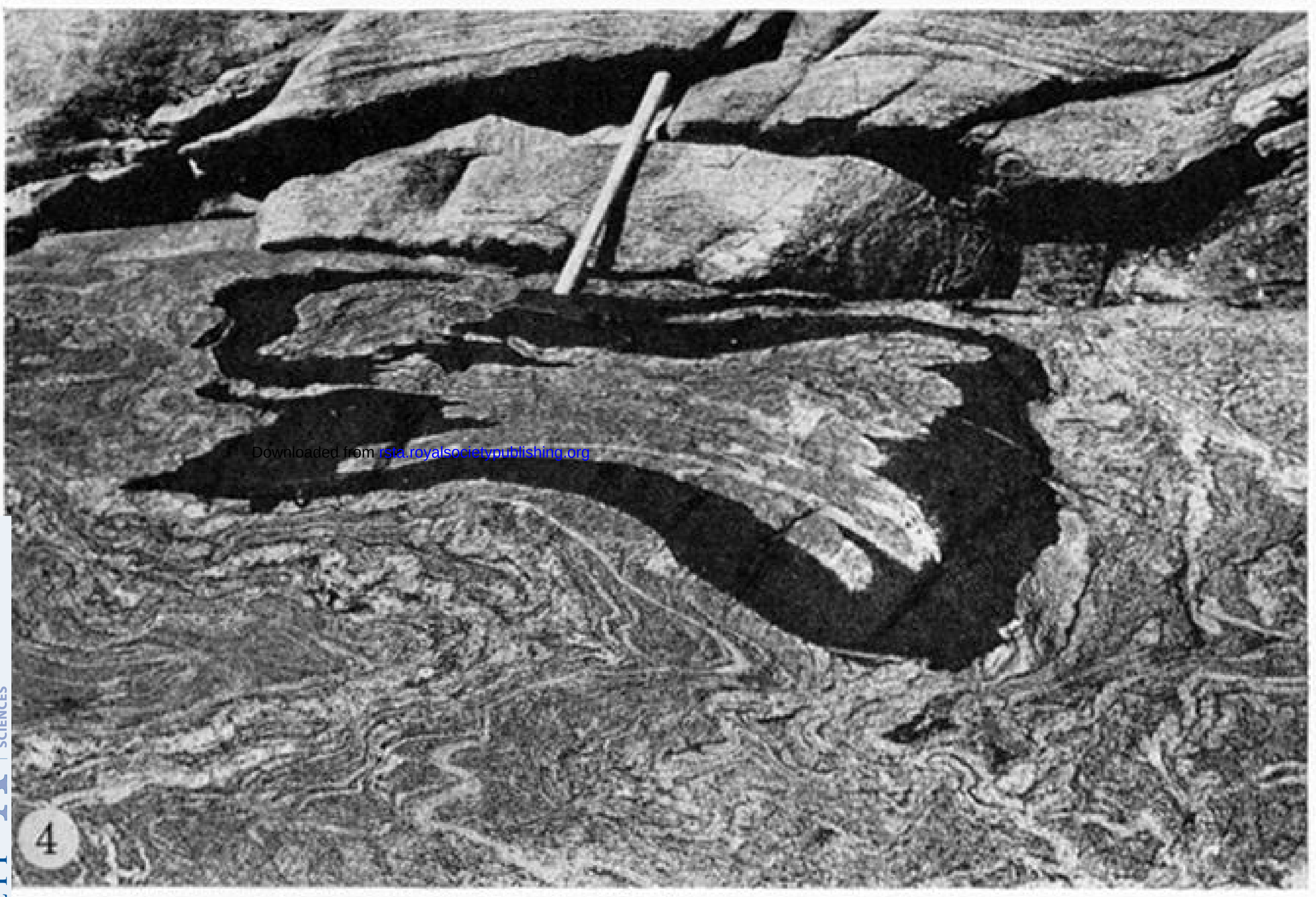
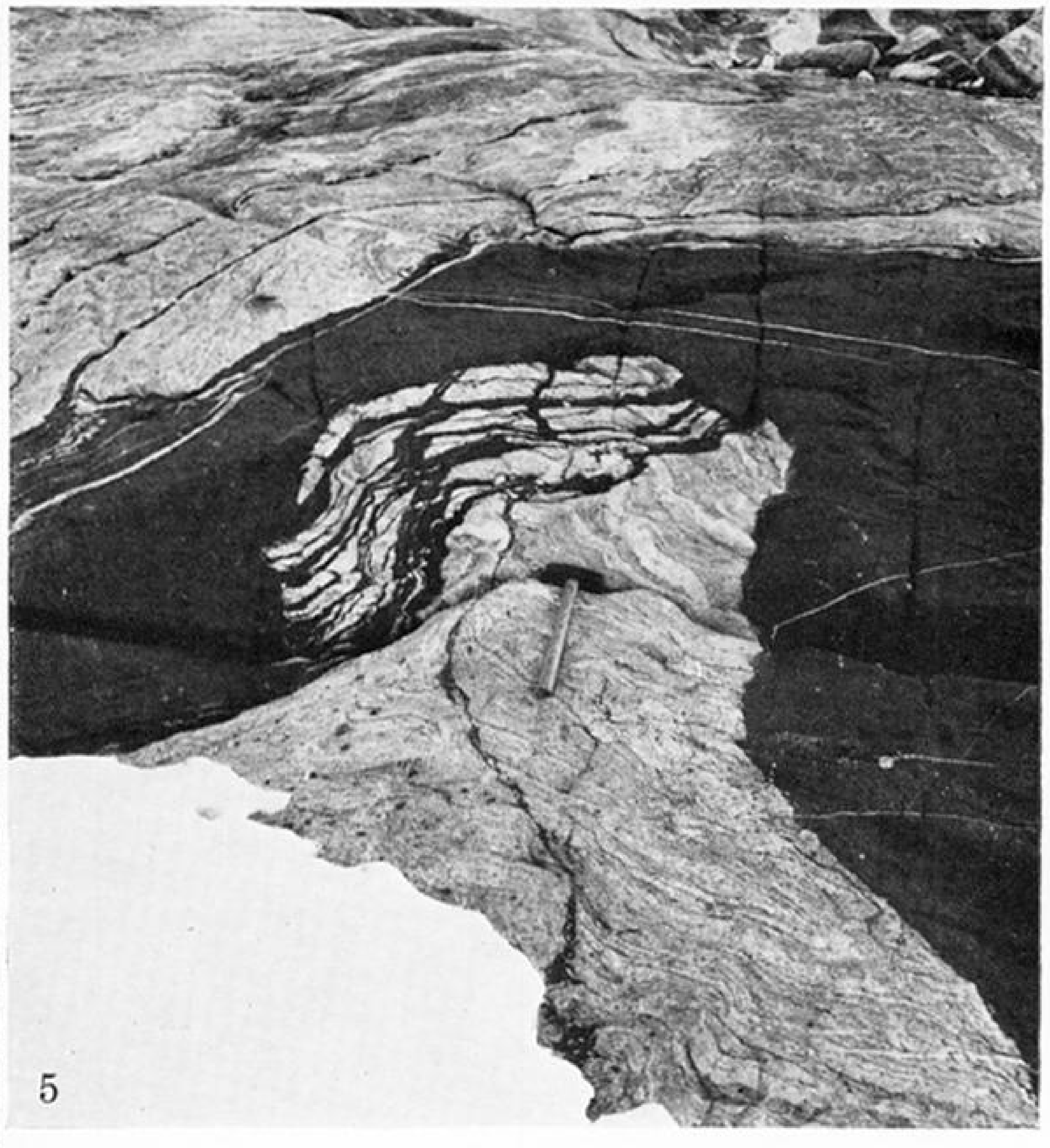
Discussion

Dr B. J. Walton (*Department of Chemistry and Geology, Portsmouth Polytechnic*) said that it might be possible to correlate the sequence of events in the eastern part of the Fiskenaesset region, north of Bjørnesund, West Greenland, with that in the Godthåb district. In this area the stratiform meta-anorthosites are well developed and were emplaced mainly in supracrustals. Gneisses can be distinguished which contain inclusions of the meta-anorthosites preserving a relict igneous stratigraphy. These could be equivalent to the Nûk gneisses, and there are other gneisses structurally below and above the meta-anorthosites, in which these inclusions have not been found, which might therefore be equivalent to the Amîtsoq gneisses.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES





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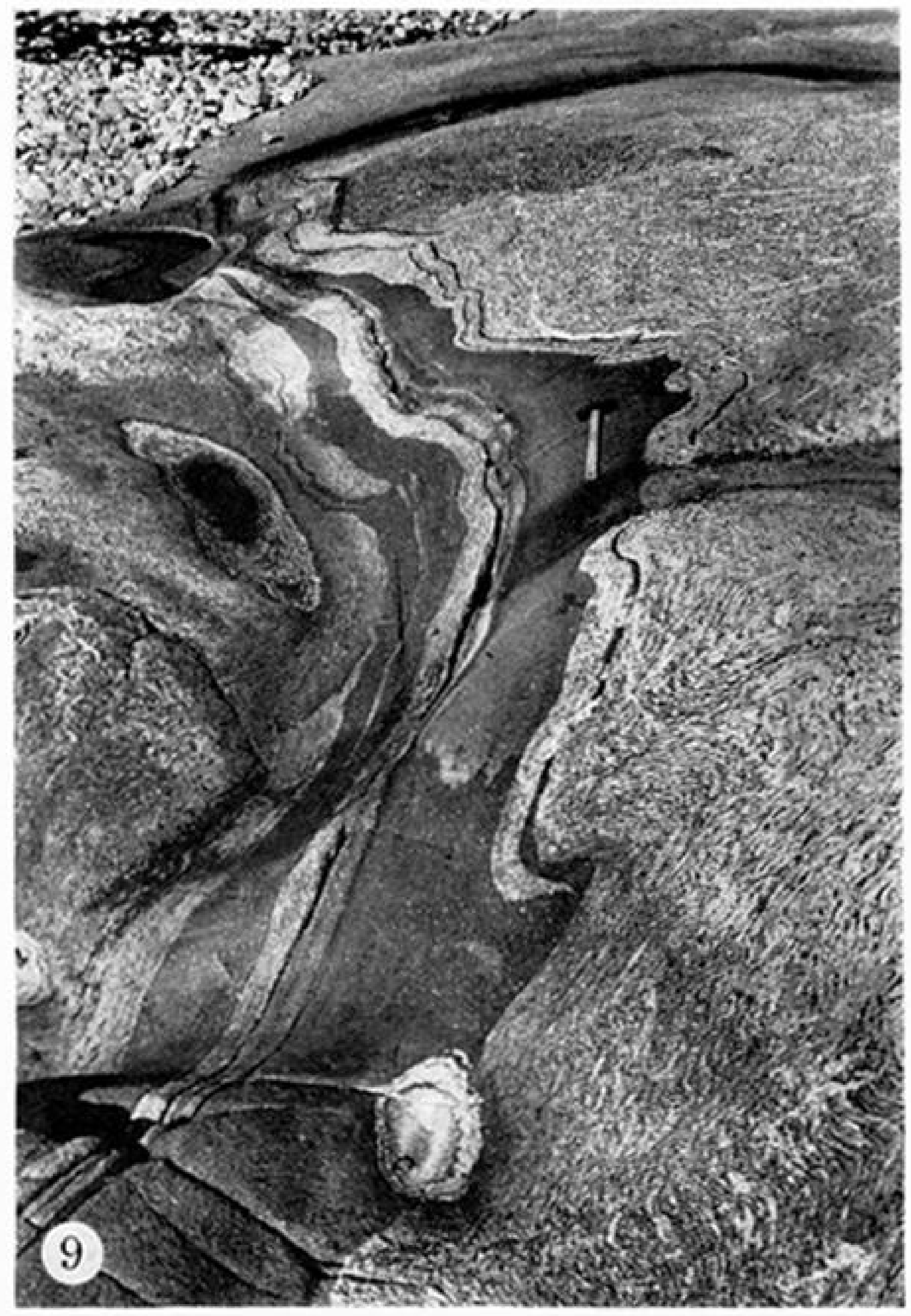
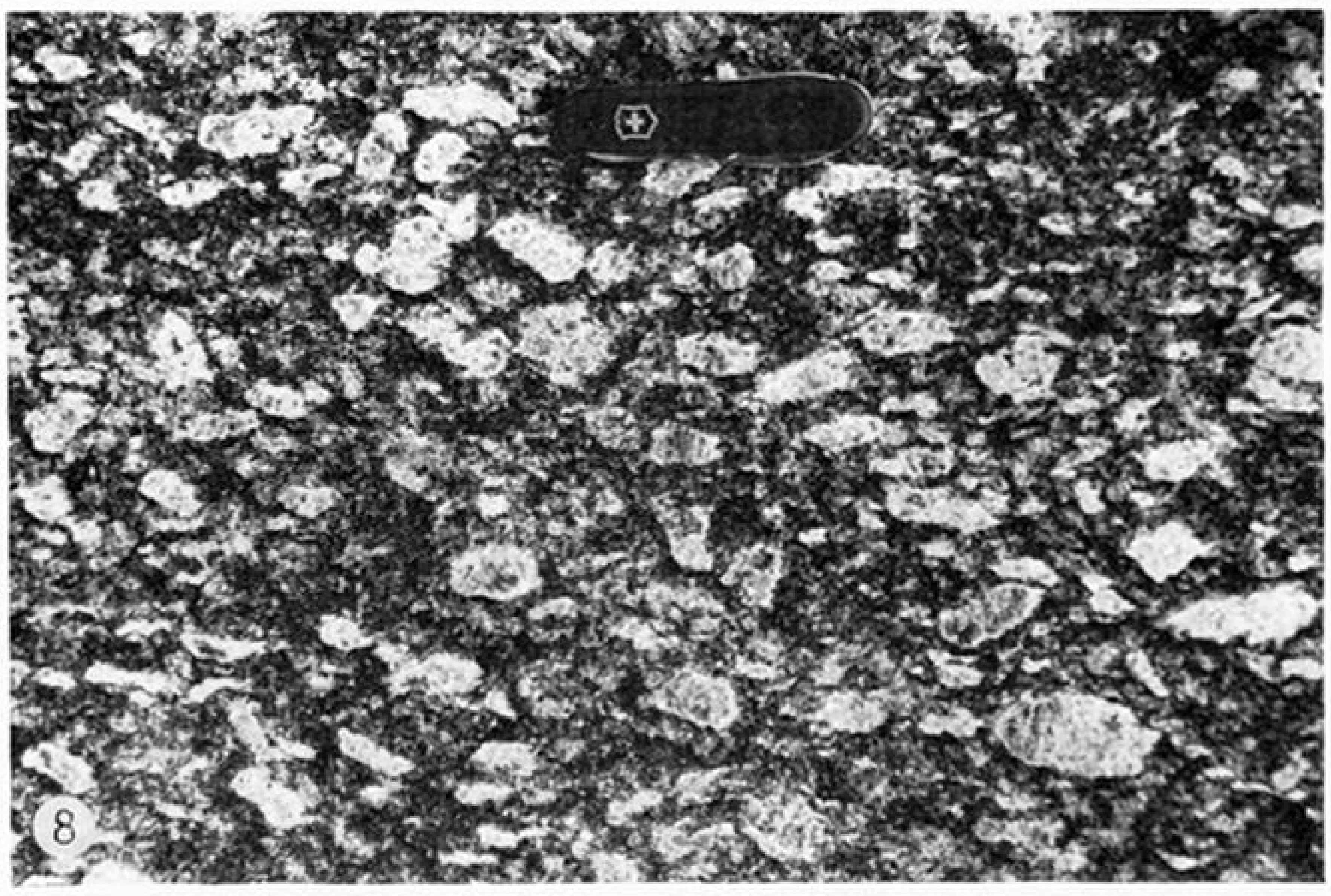
FIGURES 2 to 6. For legend see facing page.





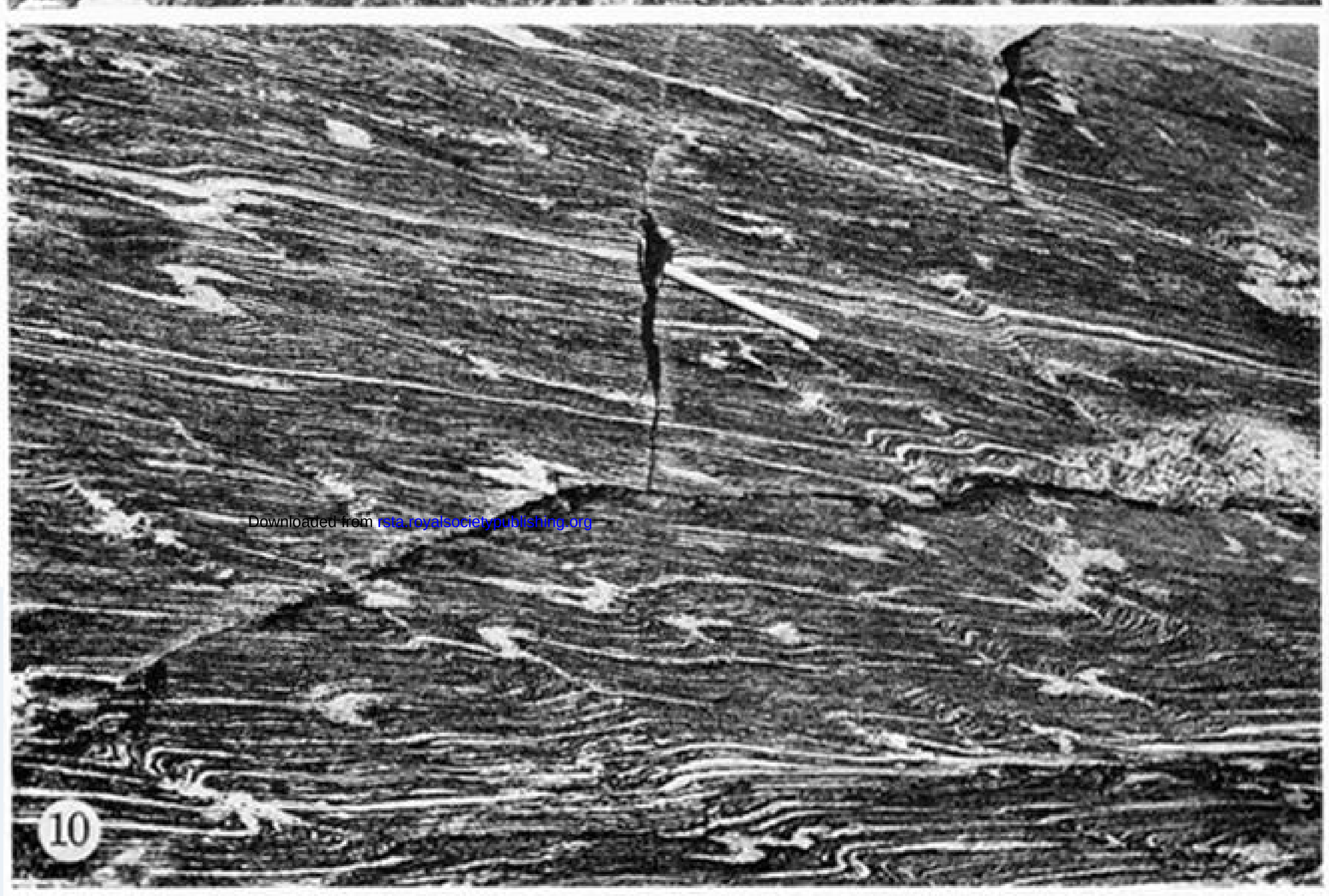


Plate 2. Progressive break up of Ameralik dykes and accompanying deformation and metamorphic differentiation of the enclosing Amîtsoq gneisses, Kanajorssuit, south of the mouth of Ameralik. The photographs are taken from continuous coastal exposures over a distance of 100 to 200 m. The same changes occur over a few tens of metres across the strike.

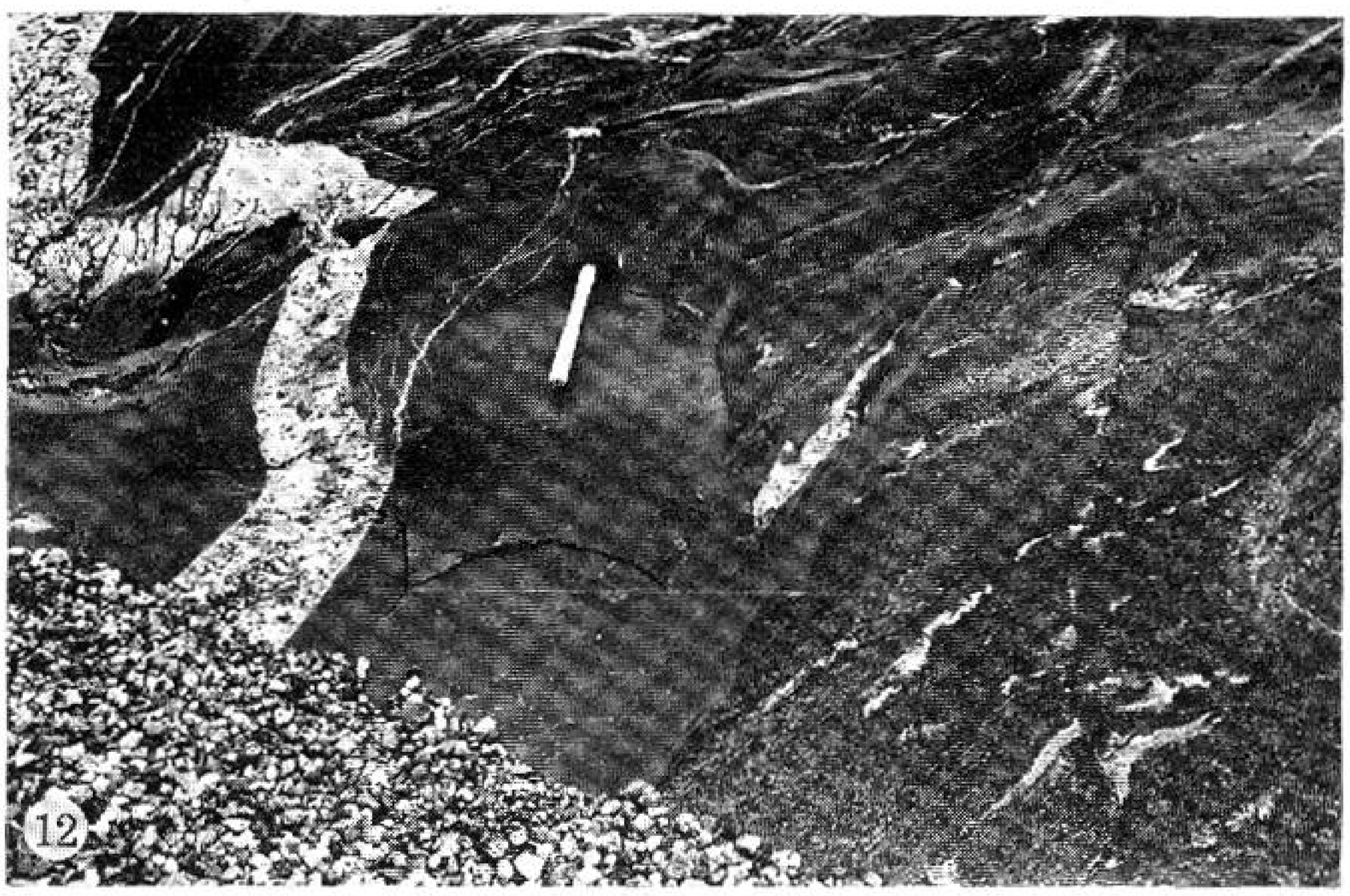
Figure 7. Little deformed, thin Ameralik dyke cutting dark augen gneiss derived from a porphyroblastic granodiorite. The feldspar megacrysts partly obscure basic schlieren and inclusions and appear to have grown after the granodiorite solidified.

Figure 8. Close-up of the texture of the same augen gneiss as in figure 7.

Figure 9. Deformed, but almost unbroken Ameralik dyke fraying out into thin apophyses. The homogenous gneiss is strongly deformed and small-folded and the original feldspar megacrysts have been streaked out into thin lenses.

Figure 10. Gneiss derived from the same parent as in figures 7 to 9, here more strongly deformed and with a fine lamination developed partly by intense attenuation of the original feldspar megacrysts and partly by metamorphic differentiation. Pegmatitic material has been segregated both in low-pressure patches (now deformed) and in more continuous thin layers. Nearby Ameralik dykes are moderately strongly broken up.

Figure 11. Intensely broken-up Ameralik dykes enclosed in banded gneisses derived from the same porphyroblastic granodiorite as in figure 7 and 8. Some of the pale bands are derived from pale granitic veins that cut the granodiorite.



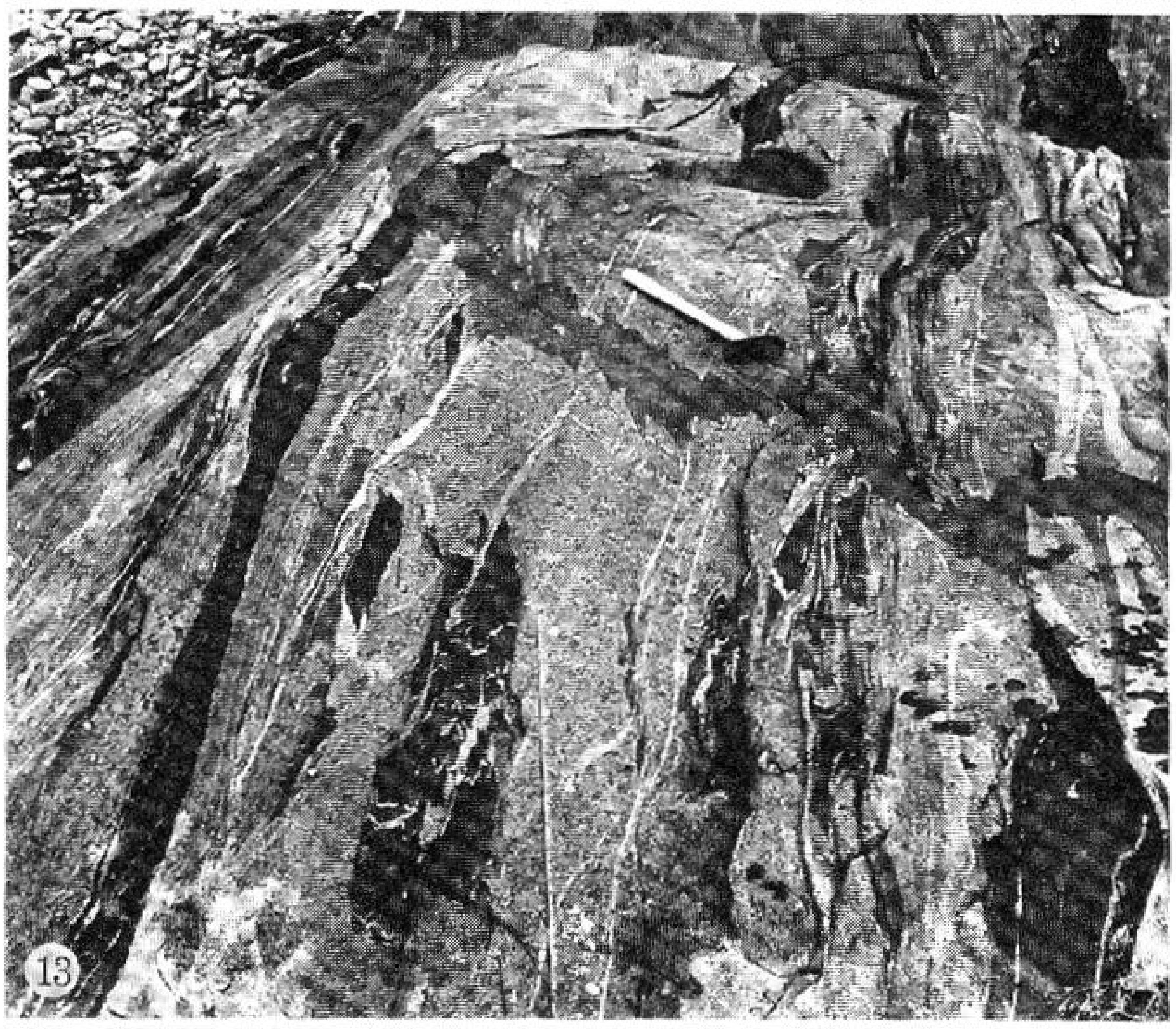


Plate 3. Relatively little deformed Nûk gneisses showing intrusive field relations.

Figure 12. Earlier phase of Nûk gneiss, derived from a relatively coarse-grained parent, cut by a younger, fine-grained phase, south coast of Bjørneøen, Godthåbsfjord. The first phase was cut by pegmatitic veins and deformed before the second phase was intruded. Late, scarcely deformed pegmatites cut both gneisses. At nearby localities the same two gneiss lithologies are so strongly deformed that intrusive relations are no longer visible and the rocks have been changed into banded gneisses.

Figure 13. Probably the same two gneiss lithologies as in figure 12, at an exposure a few hundred metres away. The earlier phase contains sharply bounded, migmatized inclusions of amphibolite derived from nearby Malene supracrustals. The irregular form of the vein of the later phase is partly due to folding, but is partly original and suggests that the vein was intruded into very hot country rocks under conditions of stress.

Figure 14. Migmatized inclusions of banded green and black skarn-amphibolite, lithologically typical of the Malene supracrustals, south coast of Godthåbsfjord northwest of Lille Malene. The amphibolite is enclosed in rafts of an early phase of Nûk gneiss which are themselves enclosed in a younger, paler, more homogenous gneiss. A late granite dyke cuts all the earlier lithologies in the upper left part of the figure.

Figure 15. Intrusive relations between an early, dark, tonalitic Nûk gneiss and a younger, paler, granodioritic phase, south coast of Hundeøen, south of Godthåb. A few metres away the same lithologies are strongly deformed and concordant.

Figure 16. More strongly deformed Nûk gneisses, possibly the same lithologies as in figure 15, southwest of the centre of the town of Godthåb. The younger, paler phase contains strongly attenuated rafts of an earlier darker phase, which in turn contains broken-up fragments of Malene amphibolite.

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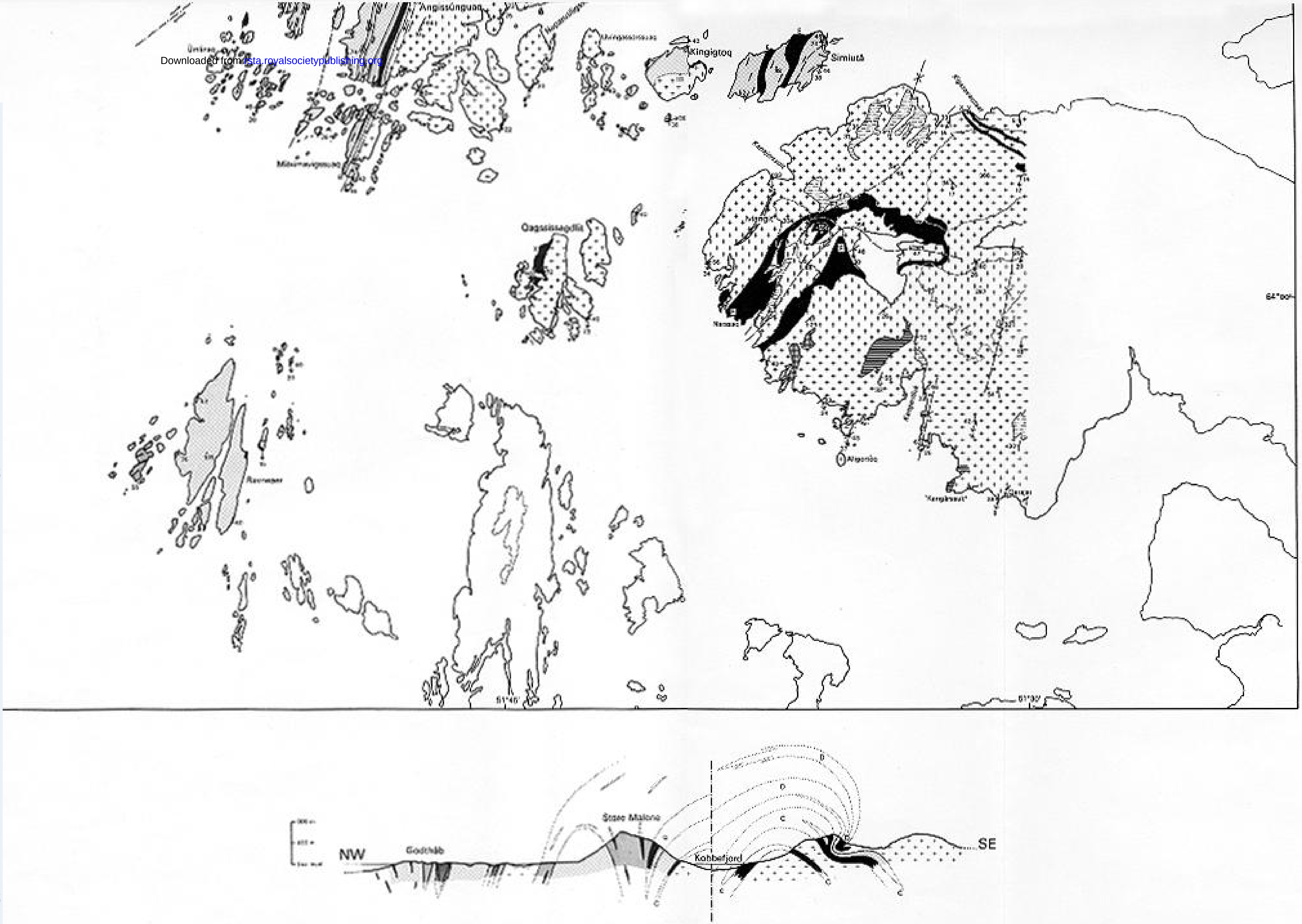

FIGURE 17. Geological map of the area south and east of Godthåb, with one cross-section. The scale of the cross-section is the same as that of the map and there is no vertical exaggeration.