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GRØNLANDS GEOLOGISKE UNDERSØGELSE
BULLETIN No. 85

THE IGALIKO NEPHELINE SYENITE COMPLEX

GENERAL DESCRIPTION

BY

C. H. EMELEUS AND W. T. HARRY

WITH 37 FIGURES AND 1 TABLE IN THE TEXT,
AND 4 PLATES

KØBENHAVN
BIANCO LUNOS BOGTRYKKERI A/S
1970

GRØNLANDS GEOLOGISKE UNDERSØGELSE

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Abstract

The Igaliko Nepheline Syenite Complex is in the Julianehåb District of Southern Greenland, at about 61°N and 45°W. The syenites and related rocks cover an area of about 450 square kilometres in the country between Tunugdliarfik and Igaliko Fjord on the west, and the Inland Ice to the east.

The Complex belongs to the group of Precambrian igneous intrusions, comprising the Gardar Igneous Province, exposed in the country around Ivigtut and Julianehåb. The Complex comprises four distinct intrusive centres, termed, in order of decreasing age, the Motzfeldt Centre, the North Qôroq Centre, the South Qôroq Centre and the Igdlerfigssalik Centre. With these are associated a number of small satellitic syenites which generally pre-date the rocks of the main centres of activity and numerous alkali trachyte and Big Feldspar Dykes, which, for the most part, belong to the regional Mid-Gardar swarms. The satellitic syenites and the three earlier syenite centres are earlier than the Mid-Gardar dykes swarms. Three members of the Igdlerfigssalik Centre are also earlier than the dykes but the four late intrusions in this centre cut the majority of the dykes.

Each centre is made up of several intrusive members; including satellitic intrusions, the Complex consists of 28 separate units as well as several small dyke-like bodies of syenogabbro and alkali gabbro. Within each centre the individual intrusions have arcuate, steep-sided outcrops with discordant, intrusive relations towards earlier members although, occasionally, there is evidence that petrographically and texturally distinct syenites were intruded at only short intervals thus possibly representing rapid pulses of magma from the same source. The mineralogy of the syenites is usually simple: perthitic alkali feldspar, nepheline and alkali pyroxene are the dominant minerals; these are accompanied by fayalitic olivine, alkali amphibole, biotite, magnetite-rich opaques, analcite, natrolite and apatite. Pegmatites are not numerous but the Complex does contain the celebrated Narssârssuk pegmatite which lies within the outer member of the later group of syenites in the Igdlerfigssalik Centre. Except where locally contaminated by assimilation of country rocks, the Igaliko syenites are all nepheline bearing; the commonest type is foyaite. The quartz syenite – alkali gabbro intrusive of Klokken, about 5 km south of the Complex, is not regarded as a satellite.

Igneous layering and mineral lamination are common internal structures in the syenites. These generally define concentric, inward-dipping structures within individual intrusions; the frequency with which the well-developed internal structures in one syenite may be sharply truncated by a later syenite indicates that, in some instances, an appreciable amount of time must have elapsed between successive intrusions. The structures found in the Igaliko syenites are identical with those described from other layered alkaline, basic and ultrabasic intrusions.

Igneous activity within the Complex began at least as early as the Mid-Gardar. Syenites of the earliest centre intrude sediments, agglomerates and lavas belonging to the Eriksfjord Formation and also cut a dolerite dyke which may belong to the

relatively early Gardar dyke swarm. The early Østfjordsdal Syenite (pre-South Qôroq Centre) cuts a small swarm of nepheline porphyry dykes.

The dykes of the Mid-Gardar swarms maintain their regional WSW–ENE strike throughout most of the Complex except near Qôroq where there is a marked swing into a more northerly direction.

Two major sinistral faults, striking ESE and east-west, displace the earlier centres of the Complex and the dykes. The faults are members of a regional set developed throughout southern Greenland. Since no alkaline dyke cuts the younger of the two faults, it is considered likely that the 2 km sinistral transcurrent movement of this fault post-dates the late syenites in the Igdlerfigssalik Centre; the late syenites are cut by a number of alkaline dykes petrographically identical with those displaced by the sinistral faults. Thus, the latest syenites at Igaliko may be of slightly earlier date than the later members of the Ilímaussaq Intrusion and the Central Complex of Tugtutôq, although still belonging to the Late-Gardar group of intrusions.

CONTENTS

PREFACE

William T. Harry died suddenly in June 1964. At that time we had almost completed our field investigations of the Igaliko nepheline syenites; the details of the succession within the Complex had been worked out and a start had been made on the petrography and mineralogy. It had been our intention to present as complete as possible an account of the Complex in a single publication; however, with Harry's death the situation altered so that the decision was taken to complete and publish a general account of the geology to accompany the geological map (Plate 4), rather than wait for the length of time that would inevitably elapse before supporting chemical, mineralogical and petrographic data became available.

In preparing this account I have drawn freely on Harry's field notes and on the joint reports which we submitted to the Geological Survey of Greenland on the completion of each season's work. The field work was either carried out together or else with much subsequent consultation when we did not map from the same camps; consequently, the conclusions reached regarding sequences of intrusion, age relations, etc., are always the results of our joint efforts. In dealing with the North Qôroq Centre (Chapter IV c) I have relied almost entirely on notes prepared and specimens collected by Harry; apart from a brief visit which I paid in 1966, and some earlier work where the centre adjoins the South Qôroq Centre, the field investigation of this ground was carried out by Harry.

Since the field work was largely carried out jointly, I feel that it is only appropriate that this account should appear under joint authorship, particularly as it is mainly concerned with work done prior to 1964. However, since I have prepared the material for publication I must accept responsibility for errors or omissions that have arisen at this stage.

I should like to record my gratitude for the help which I have received from Mrs D. Harry, and from the late Professor C. F. Davidson and other members of the staff of the Department of Geology of St. Andrews University. In particular, Professor Davidson generously placed at my disposal the large collection of thin sections of Igaliko rocks prepared in his Department, and Mrs Harry kindly gave me the numerous reprints assembled by her husband in preparation for our joint work on Igaliko.

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March, 1968

ACKNOWLEDGEMENT

I should like to express my thanks to the many people who enabled us to carry out our investigations of the Igaliko Complex. I am especially grateful to the Director of Grønlands Geologiske Undersøgelse (the Geological Survey of Greenland, GGU), K. ELLITSGAARD-RASMUSSEN, for placing the facilities of the Survey at our disposal, and for permission to publish this paper. Our work in the mountains of Igaliko would have been impossible had it not been for the skill and patience of the Royal Danish Air Force pilots operating the GGU helicopters; to them we owe a considerable debt of gratitude. Skipper M. POULSEN's skilful navigation of the ship "N. V. Ussing" enabled us to complete our work on the difficult shores of Qôroq and Tunugdliarfik within the space of one week of perfect weather during July 1962. Our work profited immensely from discussions with other members of GGU: Dr H. MICHEELSEN kindly placed at our disposal the preliminary results of mapping he carried out around the Narssârssuk pegmatite locality, Dr J. ALLAART, Dr B. WALTON and Mr S. ANDERSEN have discussed with us problems common to our adjoining areas. Through the kindness of Mr K. ELLITSGAARD-RASMUSSEN, Mr J. BONDAM, Dr J. FERGUSON and Mr J. HANSEN, we were enabled to see something of the work in progress on the related intrusions of Klokken and Ilímaussaq. Willing assistance was rendered in the field by E. SCHOU JENSEN, J. FRIDERICHSEN, K. THAMDRUP, K. BINZER, F. LARSEN BADSE and L. BUTTY.

In Great Britain, laboratory facilities were provided by the universities of St. Andrews and Durham. My thanks are due to Dr K. C. DUNHAM for his help and encouragement, and to Mr C. CHAPLIN and Mr G. WILSON and other members of the technical staff at Durham for the preparation of many thin sections and assistance with photography.

I am most grateful to Dr B. G. J. UPTON and to my wife for comment on, and discussion of this paper.

I. INTRODUCTION

Since N. V. Ussing's (1912) classic account of the geology of the country around Julianehåb, it has been known that there is a very large area of nepheline syenite to the east of Tunugdliarfik and the village of Igaliko; the presence of some syenite in this ground was, of course, well known to other geologists who visited the area during the nineteenth century.

In 1958 Grønlands Geologiske Undersøgelse (the Geological Survey of Greenland, GGU) commenced systematic mapping of the country between the southern limits of the Ivigtut area (Berthelsen, 1952) and the eastern boundary of Nunarssuit (Harry & Pulvertaft, 1963), and Kap Farvel at the southern tip of Greenland. When we had completed the field investigations of our areas in Nunarssuit and near Ivigtut it was decided that we should jointly undertake the survey of the Igaliko syenites. Accordingly, field work began in 1961 and was continued through the two succeeding field seasons. After the death of W. T. Harry in 1964 it became necessary to check certain points of the field mapping, so a further brief visit was made in 1966. With the completion of the primary field mapping the results were compiled into a single map covering almost all the syenites in the Igaliko area (Plate 4). The purpose of the present account is to provide a general description of the geology to accompany the map, and to give an outline of the petrography of the rocks comprising the Complex; more detailed accounts of aspects of the petrology are in preparation.

The Igaliko nepheline syenites form a group of high, barren mountains rising to a general level of between 1300 and 1800 metres (fig. 1). The ground is deeply dissected by fjords and steep-sided, ice-eroded valleys; in some instances glaciers still occupy the valley floors (fig. 2) and cling to the steep north-facing sides of the mountains (fig. 1). The general configuration of much of the ground is that of a deeply dissected shallow dome (fig. 2) with an elevation of about 1450 metres.

There is great variation in the ease with which access may be obtained to different parts of the Complex. The western parts near Narssarssuaq, Igaliko and Tunugdliarfik present little difficulty but the northern and eastern parts are remote and inaccessible. While it is pos-

Fig. 1. The northern side of the Igdlerfigssalik massif viewed across Qôroq from the North Qôroq Centre. The high peaks are formed by the syenite SI. 5. The entrance to "Gieseckes Dal" is situated in the left middle distance. Note the extensive glacial deposits on the lower slopes of the mountains. (Photo: C.H.E., GGU).

sible to reach most of Complex on foot, any serious investigations of the ground north of "Gieseckes Dal" should only be undertaken by a well-equipped party of at least four or five persons. The remainder of the area could be visited by smaller groups but it must be remembered that, even here, the terrain is rough, and the area virtually uninhabited and only occasionally visited by fishermen who come to Qôroq and "Gieseckes Dal", and by Greenlanders herding sheep near Østfjordsdal and along the western edges of the mountains.

Helicopter transport was used extensively during our investigations, except in 1966 when this was not available. Using small Bell-Augusta helicopters, it was possible to establish camps at many places that could not otherwise have been reached in the time at our disposal. Initially, we worked from the same camp sites but in 1962 and 1963 separate camps were established, contact being maintained every two weeks or so when camp sites were changed. The only major departures from this method of working were in 1962 when we both mapped the shores of Qôroq and Tunugdliarfik, using the motor cutter "Ussing" as our base, and in 1962 and 1963 when we joined forces at the end of each season to map the complicated ground between Tunugdliarfik and Igaliko Fjord.

Details of some of the routes through the complex, and related matters, are given in the Appendix (Chapter IX).

Fig. 2. Motzfeldt Sø and the mountains near the NE. edge of the Motzfeldt Centre. The peaks have a very uniform level at about 1500 m. (Photo: C.H.E., GGU).

Earlier visitors commented forcibly on the bad weather and the attentions of the mosquitoes (*e.g.* Ussing, 1912, p. 227). Over most of the Complex the insects have ceased to be a serious nuisance, their disappearance apparently coinciding with the introduction of large numbers of sheep. The weather remains unreliable, the violent föhn winds that afflicted Ussing are still a serious hindrance, especially where reliance is placed on helicopter transport. While working on this Complex we lost about one-quarter of the total time in the field through the effects of bad weather; this was fairly equally divided between periods of torrential rain, and föhn winds. Snowstorms may be encountered at any time during the summer months, especially over the high ground away from the fjords. The spells of fine weather may be marred by fog: towards evening, a thick blanket creeps in from Julianehåb Bugt, this may persist far into the following day, enveloping ground up to 1000 metres altitude, leaving only the peaks standing clear in the sunshine. Fog is particularly prevalent near Tunugdliarfik and Igaliko Fjord.

Exposure is generally good within the nepheline syenites, although valley floors may be covered by glacial deposits (fig. 1) and some hillsides have extensive and spectacular scree aprons on their lower slopes (fig. 36a). There is little vegetation on the syenites over an altitude of about 500 metres, except on the Narssarssuaq peninsula; the rocks crumble to give a mobile covering of gravel and coarse sand, making it difficult for plants to obtain a foothold.

II. PREVIOUS INVESTIGATIONS

The Igaliko area was visited by GIESECKE during each of his two excursions to the Julianehåb District (GIESECKE, 1910, pp. 36–37 & pp. 216–218). On both occasions he visited the settlement of Igaliko and sailed into Qôroq, exploring the side valley (now named "Geiseckes Dal") and viewing Qôrqup sermia. During the later visit, GIESECKE and people from Igaliko sailed to the SE arm of Igaliko Fjord where they went ashore and gained a vantage point from which a view of the sand flats in Østfjordsdal was obtained; at the same time mention is made of the fact that an inland lake is situated to the east of Qôroq so GIESECKE was aware of the existence of Motzfeldt Sø although it is unlikely that he actually saw or visited this lake. The salmon river in "Gieseckes Dal" is correctly placed as originating from the inland sea. GIESECKE made a few notes on the rocks of the area; the sandstones and porphyries at Igaliko and granite at Qôroq are mentioned. The sandstone and porphyry dykes at Igaliko appear to have attracted the attention of most of the early geologists visiting the area, an account of the dykes was given by PINGEL (1843), they were subsequently collected by LAUBE (1873) and described petrographically by VRBA (1874, p. 106, plate 1 fig. 1).

The presence of a large area of nepheline syenite east of Igaliko and Tunugdliarfik was known from a relatively early stage in the geological and mineralogical investigation of southern Greenland (*e.g.* STEENSTRUP & KORNERUP, 1881; FLINK, 1898) but no attempt at geological mapping in any detail appears to have been made until the latter part of the 19th century and the early years of this century when N. V. USSING and O. BØGGILD mapped the syenites on the coast sections between Narssarssuaq and Qôroq, around "Flinks Dal", and between Qôroq, Igánaq and Qôrorssuaq, including the Igdlerfigssalik summit area (USSING, 1894; 1912, plate IV). USSING makes a clear distinction between the marginal syenites at Niaqornârssuk, Narssârssuk and Igánaq, which he grouped as Augite Syenite, and the remainder which he classified as nepheline syenite, much of which he found to be similar to foyaite. He termed the foyaites the Korok type, from their development around Qôroq; they are probably equivalent to the syenite SS. 5 (see page 49) of the South Qôroq Centre. Another type, characterised by thicker rectangular feldspars and interstitial nepheline, was also noted as erratics on Igánaq and in the valley east of the small peninsula Usuk (Ussing, 1912, plate IV); this type which he termed the Usuk type, is almost certainly the same as the syenite SI.5 of the Igdlerfigssalik Centre. Dykes of syenite porphyry and tinguaite were noted cutting the syenites west of Qôroq, near "Flinks Dal", in Qôrorssuaq and in the river south of Narssârssuk. At the last named locality the augite syenite is cut by a tinguaite dyke, containing milky-white areas which were identified as cordierite (Ussing, 1912, p. 250, but see this account, p. 91). Ussing investigated the contact relations of the syenites and described the zone of alteration exposed between Tunugdliarfik and Igánaq; he also mapped the adjoining country rocks, recording the faulting on Igánaq (Ussing, 1912, p. 264, fig. 24). The dykes were examined in some detail, several varieties were distinguished including diabases, monzonite porphyries, augite-syenite porphyries, hedrumites, and nepheline porphyries. The important observation was made that while the augite syenite and nepheline syenites were intruded by only a few dykes this was not the case with the country rocks where the dykes are extremely numerous, hence a large number of the dykes pre-date the syenites. This observation, based as it was by work carried out principally in the ground between Tunugdliarfik and Igaliko fjords, has been verified in the recent investigations (Plate 4).

The only widely known feature of the Igaliko Nepheline Syenites is the occurrence of a large variety of rare minerals at Narssârssuk. In 1888 the Greenlanders from Igaliko took Steenstrup to this locality, and since that time it has become famous for its wealth of rare minerals as well as the occurrence of well-crystallized aegirine, quartz, feldspar, etc. Amongst the accounts of the locality and its minerals those by Flink (1898) Flink, Bøggild & Winther (1899), Bøggild (1906), and Steenstrup (1909) may be mentioned. The details of the investigations at Narssârssuk to about 1900 are summarised by N. V. Ussing who also listed the minerals that had been found at Narssârssuk, comparing them with those known from the pegmatites of the Ilímaussaq Intrusion (Ussing, 1912, p. 244–249). Since the appearance of Ussing's account, the locality has continued to be visited by mineral collectors and mineralogists (Gordon, 1924, 1927) who have sampled extensively, often using explosives, with the result that the pegmatite area now resembles a desolate battlefield, pock-marked by small craters. Unfortunately, much of the early collecting and description was made solely from the standpoint of the presence of the new and rare minerals, little attention being paid to the mineral paragenesis. At the same time as the general mapping of the Igaliko Complex was in progress a thorough mapping and collecting of the pegmatite occurrence was undertaken by Dr H. Micheelsen of the University of Copenhagen.

Two notable contributions to the general geology of the Igaliko syenite area have appeared since USSING's account. The southern limit of the syenites was extended to Østfjordsdal by H. ØDUM who also discovered the Klokken Syenite on the southern side of the broad, gravel-covered flats of Østfjordsdal (ØDUM, 1927, Plate VII). He regarded this syenite as forming a part of the main Igaliko mass. ØDUM also demonstrated the presence of the marginal Augite Syenite (= SI. 4 of the Igdlerfigssalik Centre) for some distance south of Qôrorssuaq, on the northern side of Tavdlorutit. Immediately before World War II, the south of Greenland was visited by Professor C. E. WEGMANN who made an outstanding reconnaissance survey of the country south of the Frederikshåb District (WEGMANN, 1938). WEGMANN's field work on the Complex appears to have been concentrated on the coast section between Qôroq and Narssarssuaq (Kiagtût) and the valley at Narssarssuaq. He was particularly impressed by the number of dykes cutting the massif in this area, in marked contrast to USSING's observations based on exposures south of Tunugdliarfik. Some of the dykes were considered to be younger than the massif but many were thought to be older and transformed, being preserved during transformation of the pre-existing rocks to nepheline syenite (WEGMANN, 1938, p. 81). His interpretation was in accord with the largely transformationist migmatitic hypothesis advanced for the Ilímaussaq nepheline syenites (WEGMANN, 1938, p. 80). BONDAM (1955) followed this approach in his account of some alkali-trachyte dyke rocks from Narssarssuaq.

Since 1958, regional mapping by Grønlands Geologiske Undersøgelse has extended into the country around the Igaliko Complex. Numerous papers have appeared describing the results of this work; these are referred to in the main text, but may be briefly summarised here in so far as they relate to the nepheline syenite complex. The glacial features have been described by WEIDICK (1959, 1963) who also discovered syenite occurrences beyond the limits of the ground mapped by us (see p. 37). Work south of Igaliko Fjord by BERRANGÉ (1966) shows that the Gardar dyke swarm is present in the ground just south of the fjord. North of Narssarssuaq, WALTON (1965) has delimited the northern extent of the Gardar dykes and established a local chronology (WALTON, 1965, pp. 39–51, fig. 1). The western margin of the Motzfeld Centre syenites was fixed by WALTON during his mapping and the northern extension of the Narssarssuaq plug mapped. Recently, SCHARBERT (1966) has published details of chemical and X-ray studies on alkali feldspar from alkaline dykes including some from the Igaliko Complex. J. W. STEWART and V. POULSEN have mapped the sedimentary and extrusive rocks between the Igaliko Complex and Narssaq (POULSEN, 1964) as well as the numerous minor intrusions (STEWART, 1964).

III. COUNTRY ROCKS OF THE COMPLEX

(a) Pre-Gardar rocks

Members of the Ketilidian Julianehåb Granite suite form the majority of the country rocks to the nepheline syenites (ALLAART, 1964, Map. 1; Plate 1). They include diorites and granodiorites, which are generally massive though sometimes with a weak NE–SW, steeply-inclined foliation, and occasional amphibolitic lenses. Areas of strongly banded gneiss have been mapped near Fox Bay to the SW of the Complex, relics of well-banded gneiss occur as large xenoliths within the nepheline syenites of the Motzfeldt Centre (p. 30). On the NW margin of the Motzfeldt Centre, west of Qôroq and Qôrqup sermia, the syenites cut the outer members of a group of monzonites and diorites mapped by WALTON (1965) in Mellemlandet and in Johan Dahl Land. Petrographically similar rocks also pre-date the syenites on the northern margins of the Motzfeldt Centre and the North Motzfeldt syenites, they may constitute an eastern extension to the basic to intermediate pre-Gardar complex mapped by WALTON. In this area the pre-Gardar rocks are cut by a few well-defined amphibolite dykes (*e.g.* 58394*).

Large microcline and plagioclase crystals are frequently found in the country rock gneisses. These porphyroblasts were noted north of the Motzfeldt Centre and also in dioritic and granodioritic rocks on the north side of "Gieseckes Dal". There does not appear to be any connection between the development of these large feldspars and the syenite; they do not result from any fenitization processes. The Ketilidian rocks throughout the Julianehåb district are sporadically porphyritic or porphyroblastic, the development of the large feldspars is attributed to pre-Gardar events (*cf.* UPTON, 1962).

(b) Gardar supracrustal rocks (the Eriksfjord Formation)

Isolated areas of supracrustal rocks are found at several localities bordering the Igaliko syenites; as well, there are smaller masses included within the Complex (Plate 4). They form the eastern extension of the

*) The numbers 58394, etc., refer to the rock collections of the Geological Survey of Greenland.

sediments and volcanic rocks which occupy much of the ground between Tunugdliarfik and Bredefjord (Poulsen, 1964, Map 1; Plate 1).

Fairly extensive outcrops are found at Narssarssuaq, between Tungdliarfik and Igaliko Fjord, and at several localities on the margin of the Motzfeldt Centre (Plate 4). The first two have recently been described (Poulsen, 1964; Stewart, 1964). At Narssarssuaq, a thick series of basic lava flows and pyroclastic rocks overlies and is interbedded with clastic sediments. To the south, at Igánaq and Narssârssuk,

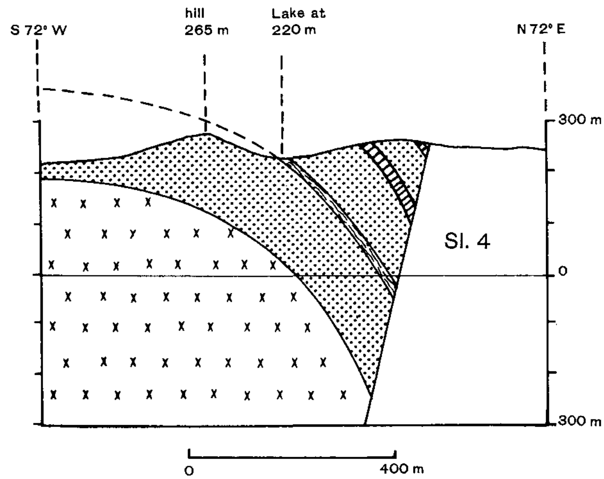

Fig. 3. Cross-section of the western margin of the Igdlerfigssalik Centre at Narssârssuk, showing the downwarping of country rocks towards the syenite SI. 4. (Symbols as on fig. 4.)

quartzitic sandstone and grits predominate but near the syenites thin basic layers are interbedded; they owe their preservation to the local development of steep dips towards the syenites (fig. 3). In this area there are occasional silty horizons in the sandstones; near Narssârssuk there is a thin magnetite-rich layer (63786).

The supracrustal rocks margining the Motzfeldt Centre were discovered during the recent mapping although their presence was suspected from loose fragments of breccia collected by K. Ellitsgaard-Rasmussen and J. Bondam during earlier reconnaissance work (21514). On the SW side of "Flinks Dal", sandstone, grit, volcanic breccia and thin basalt flows overlie Julianehåb Granite (fig. 4). The layers of volcanic breccia contain rounded, elongate areas of basalt up to 0.5 m in length. These have vesicular margins and resemble volcanic bombs (fig. 5). Within the syenites a few hundred metres to the NE, large masses of vesicular basalt with good flow structures dip steeply to the NE; these weather a dark green colour contrasting strongly with the syenite (fig.

11). On the SE side of "Flinks Dal" about 3 km ESE of the first locality, a small patch of coarse quartzite outcrops between snowfields at about 1700 m elevation. North of Motzfeldt Sø, on the NE margin of the Motzfeldt Centre there are two areas of supracrustal rocks. The more northerly of these consists of about 200 m of coarse, white sandstone,

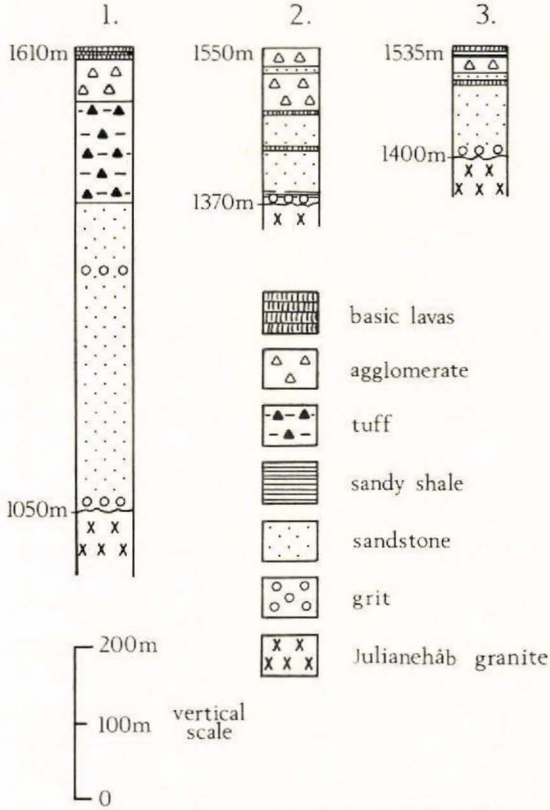

Fig. 4. Stratigraphic successions in the rocks of the Eriksfjord Formation margining the Motzfeldt Centre: 1. 1610 m mountain on the north side of Motzfeldt Sø. 2. 1550 m mountain about 3 km north of Motzfeldt Sø. 3. 1535 m mountain on the south-east side of the lower part of "Flinks Dal".

fine-grained ripple-marked chocolate-coloured sandstone with thin gritty partings, interbedded basalt flows, and breccias containing sedimentary and igeneous fragments. The clastic sediments, dominantly sandstones or grits, also contain thin layers of silty rocks and a conspicious chocolate coloured layer of mudstone with ripple marks and sun cracks. The sediments in this area have a general dip of about 15°SW. In another area, lying to the north of the 1610 m summit, a thicker series is preserved (fig. 4), consisting in the lower part of coarse grits and sandstones, often cross-bedded. Overlying these is a series of flinty, fine-bedded tuffaceous rocks, a coarse agglomerate containing basaltic and sedimentary fragments and, at the summit, a thin development of basic flows which have been metamorphosed by the adjacent syenites.

The sedimentary rocks north of Motzfeldt Sø are cut by two volcanic plugs (Plate 4). The northern plug is situated in a narrow gully near the margin of the sandstone outcrop. It measures approximately 70 m from north to south and 120 m from east to west. The plug consists of coarse agglomerate in which basalt fragments are dominant but with quartzite and Julianehåb Granite blocks present near the margins. Also included are blocks of carbonate-rich rock (58385). The country rock quartzite has been shattered and welded into a breccia for up to 2 m from the margin of the plug. There are also areas of well-bedded coarse green tuff (58381) within the coarse pyroclastic rocks. The pyroclastics are cut by irregular thin sheets of red trachyte (58383), while a trachytic sill (58384) at the northern margin of the plug thins rapidly to the north. The second plug is at 1300 m on the northern side of the 1610 m peak. It is about 100 m in diameter but the lower side is scree-covered. The plug is zoned with an outer member consisting of breccia of quartzite, basalt, and rare pieces of Julianehåb Granite, all in a fine-grained basic tuffaceous matrix. Within this zone there is a core of basaltic agglomerate (fig. 6) cut by a small central plug of unbrecciated dolerite (58392). Thin, irregular sheets of red-brown trachytic rock ramify through the breccias but none was found intruding the dolerite core.

1200 m north of the second plug the quartzites are altered in a highly irregular manner to white, milky vein-quartz with sporadic patches of pink feldspar. Over an area of about 20 metres diameter the irregular development of the vein-quartz resembles a breccia but closer examination showed that the alteration had taken place without appreciable disturbance of the quartzite (*cf.* Walker & Leedal, 1954 p. 214).

Supracrustal rocks, including basalt flows, agglomerates and white and grey quartzitic sandstones, are present at the east edge of the syenite NE of Motzfeld Sø and to the east of the East Motzfeldt Syenite; however, the succession is not known in detail.

In a subsequent section a description is given of large masses of altered basalt, agglomerate and Julianehåb Granite enclosed in the syenites of the Motzfeldt Centre. The more important inclusions are located immediately north and south of upper "Flinks Dal" but inclusions are also found at several other places. Flows of basalt inclined at a steep angle (50° N) form a large body in the syenite about 1 km NE of the main outcrop of supracrustals south of "Flinks Dal" (fig. 11) and another smaller body of altered basalt was found in syenite just north of the glacier at the NE corner of Motzfeldt Sø. Several small areas of

Fig. 5. Volcanic bombs in agglomerate. From a locality at 1510 m altitude on the south-east side of the lower part of "Flinks Dal" (= locality 3., fig. 4). Scale: coin about 4 cm diameter. (Photo: C.H.E., GGU.)

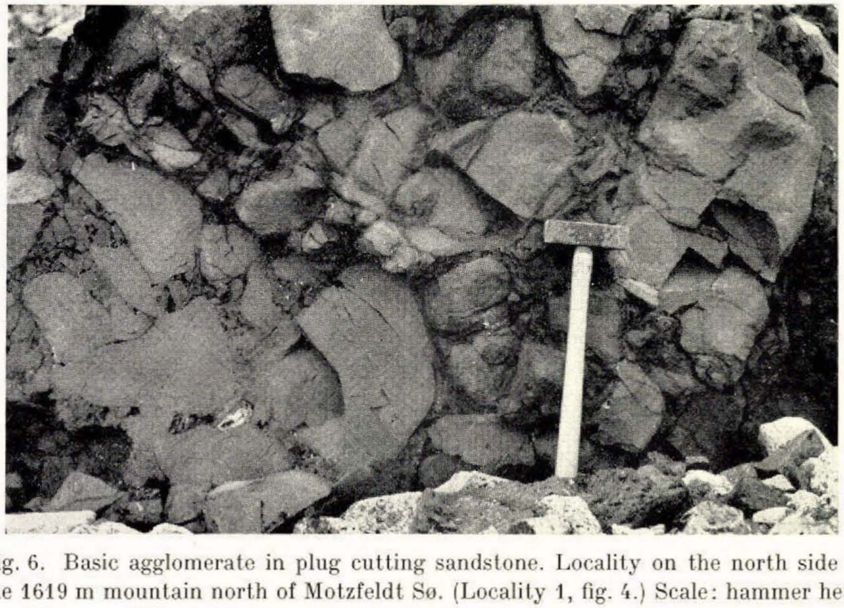

Fig. 6. Basic agglomerate in plug cutting sandstone. Locality on the north side of the 1619 m mountain north of Motzfeldt Sø. (Locality 1, fig. 4.) Scale: hammer head 15 cm long. (Photo: C.H.E., GGU.)

highly altered basic rock and sediments occupy low ground on the east side of the lakes in the central part of the Østfjordsdal Syenite.

A screen of quartzite was mapped along the NE margin of the Outer Foyaite (SN. 1) of the North Qôroq Centre, and at Narssârssuk xenoliths of coarse quartzite are intimately associated with the well known pegmatite.

It is evident from the distribution of the supracrustal rocks around the Igaliko Complex that there was once a widespread covering of sediments, pyroclastics and basic lavas, possibly extending well to the north and east of the areas mapped (SCHARBERT, 1963; POULSEN, 1964; WALTON, 1965). A considerable NW extension of the supracrustals is also indicated by occasional finds of lithologically-similar sedimentary fragments amongst the glacial debris at the edge of the Inland Ice between Igaliko and Arsuk Fjord, and even further north, in the Frederikshåb District (W. S. WATT, personal communication).

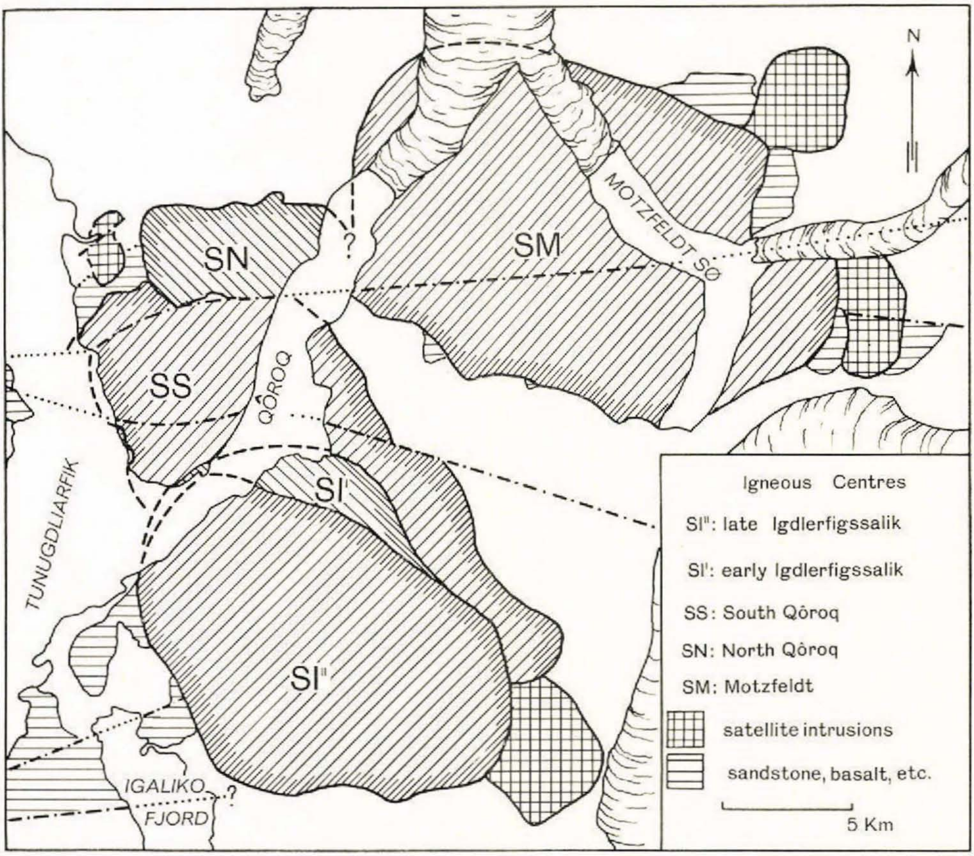

Fig. 7. Sketch map showing the igneous centres of the Igaliko Complex and the principal areas of supracrustal rocks adjoining the syenites.

IV. THE NEPHELINE SYENITES

(a) General

The Igaliko Nepheline Syenite Complex has four distinct centres and a number of small satellitic intrusions (fig. 7). Each of the centres consists of several nepheline syenite intrusions; associated with some of the centres there are small intrusions of syenogabbro and alkali gabbro. With the exception of the small quartz syenite–alkali gabbro intrusion of Klokken (Plate 1) all members of the Complex are undersaturated, nepheline-bearing rocks.

No radiometric dating has been carried out on rocks from the Igaliko Complex although data are available for the Ilímaussaq Intrusion and the alkaline igneous complex of Kûngnât (1020 m.y. and 1170 m.y.

respectively; Bridgwater, 1965). The Igaliko Complex probably spans a considerable part of the period of Gardar igneous activity (see Chapter VIII), the latest members being approximately equivalent in age to the Late-Gardar complexes of Kûngnât, Ilímaussaq and Nunarssuit, the earlier ones pre-dating the Mid-Gardar dyke swarms.

The criteria used to distinguish between the different syenites and to determine relative ages need not be reviewed in detail; they were those normally employed when mapping igneous complexes and included the development of fine-grain marginal facies and intrusive apophyses, and the presence of xenoliths or xenocrysts. Often, relative ages could be determined by the cross-cutting relationships of one syenite towards another, sometimes on a large scale but more often on a small scale (*e.g.* fig. 16). During the mapping it was frequently observed that individual intrusions maintained mineralogical and textural characteristics over very large areas of outcrop which proved a considerable aid in delimiting syenites.

One textural criterion for the presence of a contact proved exceptionally useful. Fine-grained, chill margins are not always developed at contacts; near the outer edge a younger syenite might become texturally extremely variable with irregular or rounded patches of coarsely crystalline or pegmatitic syenite set in a relatively fine-grained matrix. The coarse patches were often partially filled by analcite or natrolite in addition to the normal minerals of the syenite, and the mafic minerals zoned to more extreme, sodic varieties. Texturally, the patchy pegmatitic structure is similar to the drusy marginal facies found in certain high-level intrusions (*cf.* Richey, 1928); the difference being that whereas open cavities develop under high-level conditions, in the deeper-seated intrusions represented by the Igaliko syenites it was probably relatively difficult for open cavities to form, instead infilling by hydrous and low temperature minerals took place.

(b) The Motzfeldt Centre

(i) Introduction

The Centre covers an area of about 150 km², including the parts concealed beneath the glaciers and the waters of Qôroq and Motzfeldt Sø. Because of its relative inaccessibility this centre has received the least detailed investigation of any within the Igaliko Complex; until 1966 there were virtually no maps available and although the aerial photographs are good they do not cover the NE extremity of the centre.

Five nepheline syenite intrusions were distinguished. The relative ages have been established for the three oldest but are not completely known for the younger members: it appears likely that the two youngest

Fig. 8. Streaky textural banding in the marginal part of the syenite SM. 1 on the north shore of Qôroq, Motzfeldt Centre. Scale: hammer shaft about 35 cm long. (Photo: C.H.E., GGU.)

syenites should be represented by three intrusions (p. 34). The numerous alkali trachyte and other dykes cutting the centre are probably of appreciably later date but the small arcuate or dyke-like intrusions of syenogabbro and of alkali gabbro are considered to be part of the centre.

(ii) Syenite SM. 1

This syenite crops out in a broad arcuate zone on the outer part of the centre except on the southern margin where it is cut out by later members. The rock is a brown to red-brown highly feldspathic syenite with bladed alkali feldspars up to 3 cm in length. Other minerals include interstitial amphibole and alkali pyroxene, and small amounts of nepheline, generally in a highly altered condition. Coarsely feldspathic, amphibole-bearing pegmatitic patches are common with purple fluorite often a prominent constituent (63717). Near the external contact, the syenite is relatively fine-grained with a patchy development of small pegmatitic areas 10–15 cm in diameter. Texturally the rock resembles the young syenite SI. 6 of the Igdlerfigssalik Centre (fig. 26); a patchy, pegmatitic texture of this type is a very common feature of the marginal facies of syenites throughout the Complex.

The syenite contains few mappable internal structures. An example of weakly-developed mineral layering was found 2.5 km NNE of the foot of Qôrqup sermia; feldspar lamination occurs at a few localities, for example, on the west side of Qôroq about 3 km east of the 475 m lake. A strong, streaky banding is present in marginal syenite excellently exposed in fresh, ice-scoured slabs on the west shore of Qôroq about 1.5 km below the 1963 ice front of Qôrqup sermia (fig. 8). Here, the streaky banding is vertical or steeply inclined, parallel to the contact with the Julianehåb Granite. For the first 15 m from the contact the banding consists of alternating medium and fine-grained syenite both crowded with small pegmatitic patches some of which may be elongate parallel to the banding. There then follows a zone 30–40 m in width where the rock is almost gneissose in appearance: sinuous, 10–15 cm — wide bands of fine-grained, dark equigranular syenite (63771) alternate with bands of medium to fine-grained leucocratic syenite (63772) with occasional irregular pegmatitic patches. The gneissose zone passes gradually NE into a normal foyaite (63773) where there are only occasional streaks and ill-defined patches of a medium-grained syenite resembling the variety found nearest the outer margin. The structures probably owe their origin to flow of inhomogenous, partly crystalline syenite against the cold country rocks. The locality bears a strong similarity to the marginal member of a large Norwegian larvikite intrusion where the contact zone is exposed at Nevelunghavn (Oftedahl, 1960).

(iii) Syenite SM. 2

This syenite crops out east and west of the southern arm of Motzfeldt Sø. It is normally a dark grey, massive rock with euhedral tabular feldspars to 10×3 mm which increase in size in outcrops furthest from the contacts with older rocks. A vague feldspar parallelism was mapped at a few localities. Nepheline is found in white rectangular or anhedral crystals; alkali pyroxene and amphibole occur as highly anhedral areas. Rounded, ill-defined xenoliths of partially assimilated porphyry are common throughout the syenite. Pegmatite areas are very uncommon in this intrusion, nor are there any of the fine-grained sheets or dykes of microsyenite that commonly accompany other syenites.

(iv) Syenite SM. 3

This syenite crops out in a broad belt to the north of Motzfeldt Sø. It is also found as a narrow strip between SM. 1 and SM. 2 east of the lake, and in a small area at the SW extremity of the lake. It is a foyaite, with tabular feldspars 20×5 mm in cross-section, irregular areas of anhedral alkali pyroxene and amphibole up to 10 mm across, well-formed nephelines, and interstitial analcite and pink natrolite. Sporadic, radiating aggregates of aegirine needles are present. The rock may also contain occasional patches of deep brown biotite.

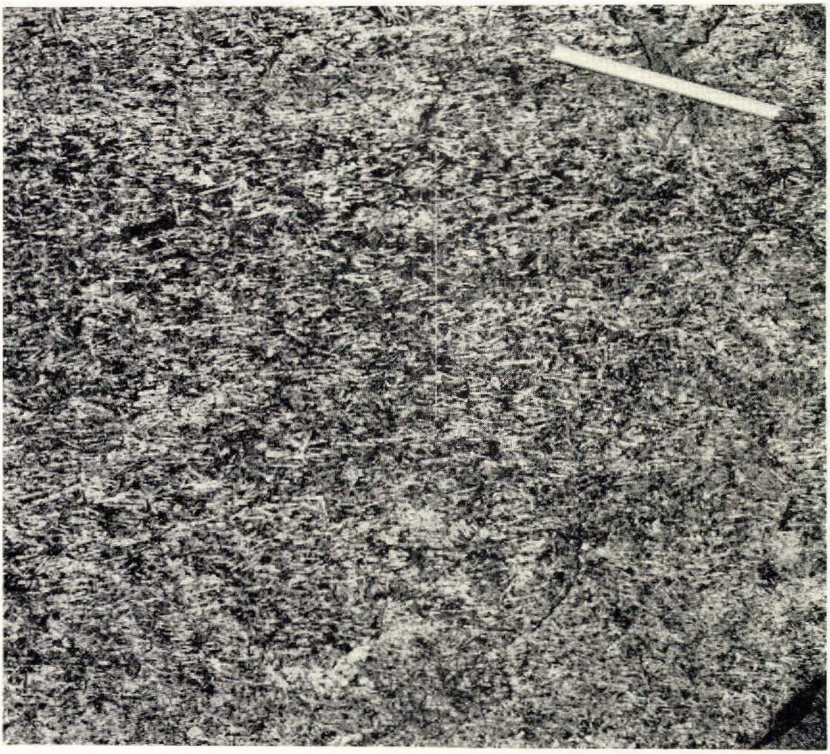

Fig. 9. Feldspar lamination in the syenite SM. 4, Motzfeldt Centre. From exposures about 6 km east-north-east of the foot of "Flinks Dal". Scale: pencil about 12 cm long. (Photo: C.H.E., GGU.)

The tabular crystals of alkali feldspar often show parallel alignment. This structure may be mapped for several tens of metres; in other instances the feldspar orientation is extremely variable suggesting a considerable amount of disturbance when the rock was in a partly crystalline condition. This feldspar lamination is the principal internal structure of SM. 3, it is generally steeply inclined with a direction of dip towards the centre of the arcuate outcrops. In addition, a small area of intense mafic banding was found in a stream section north of Motzfeldt Sø; this banding is concordant with associated feldspar lamination.

(v) Syenite SM. 4

The majority of the syenites between Motzfeldt Sø and Qôroq are included in this unit. The field evidence indicates that more than one intrusion is present, but SM. 4 is left as single unit and the anomalies resulting from this decision discussed subsequently (p. 34).

The coarser central facies of the syenite contains grey or cream coloured platy alkali feldspars 10–20 mm long and 3–5 mm thick, with

Fig. 10. Angular xenolith of coarse-grained syenite (SM. 1) in fine-grained syenite (SM. 4). At 730 m altitude in a stream section 1.5 km south of Inúnguarssuaq, Motzfeldt Centre. Scale: knife 12 cm long. (Photo: C.H.E., GGU.)

irregular crystals of red nepheline and dark green alkali pyroxene up to 5 mm in diameter. The feldspars are often well laminated (fig. 9). Weak mineral layering, concordant with the lamination, was recorded at a few localities. Close to the outer margins of the syenite the rock becomes very fine-grained with platy feldspars 2–3 mm long and 0.5 mm thick; the finest grained rocks (63730) occur where the syenite is chilled against the supracrustal succession east of "Flinks Dal".

The syenite SM. 4 is often xenolithic. Several classes of inclusion may be distinguished. Near the contacts with older syenites angular blocks and crystal fragments of the earlier syenites are enclosed in fine or medium grained SM. 4 (fig. 10). East of lower "Flinks Dal", angular blocks of little-altered quartzite, basalt and breccia occur in the syenite, some of the fragments reaching several hundreds of metres in length (fig. 11 a & b). Numerous rounded small, dark-coloured inclusions of porphyry up to 30 cm in diameter occur scattered throughout the syenite. At one locality, on glaciated slabs on the south side of the valley about 1 km east of the lake at 700 m altitude at the head of "Flinks Dal", the dark porphyry inclusions are drawn out into lens-like bodies elongated parallel to the local direction of feldspar lamination in the host syenite.

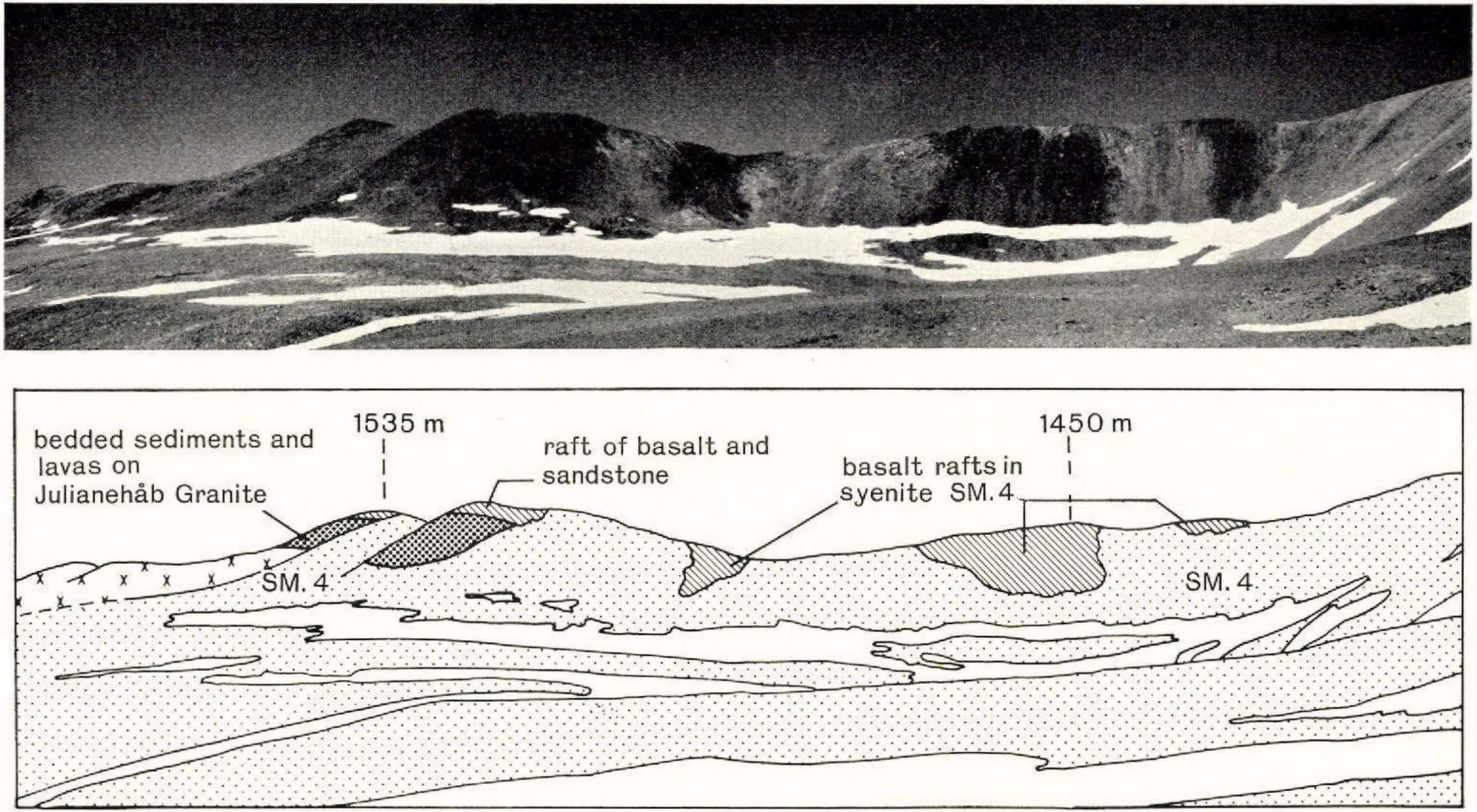

Fig. 11 a & b. Xenolithic masses of basalt and agglomerate enclosed in the margin of the syenite SM. 4 on the south-east side of the lower part of "Flinks Dal". (The 1535 m peak in the left of the photograph is locality 3 of fig. 4.) (Photo: C.H.E., GGU.)

(vi) Country-rock rafts in SM. 4

In addition to the xenoliths of earlier syenites and of dark-coloured porphyry, the syenite SM. 4 contains numerous large inclusions of microsyenite, porphyritic microsyenite, porphyries and porphyritic trachytes, and breccias composed of these rock-types in a microsyenitic or syenitic matrix. The principal outcrops of these inclusions form an arcuate belt about 4 km in length north of "Flinks Dal" where their dark weathering renders them conspicuous in the light-coloured syenite (fig. 12a). Other inclusions occur as elongate strips 2–3 km in length and several hundred metres thick on the south side of "Flinks Dal"; for the most part these are pale-weathering but on the NE side of the 1410 m mountain further dark-weathering inclusions are found. Inclusions of a breccia are very common in the syenite around the head of the shallow valley about 1.5 km north of the mountain Ivnârâ. Here, the fragments are angular, consisting of a variety of porphyries, microsyenites and porphyritic microsyenites (58034); they have slightly blurred outlines welded together by a microsyenitic matrix (fig. 12b) and the rock appears to have been thoroughly altered. Elsewhere in this valley the inclusions are mostly of a fine-grained trachytic rock which has a sheeted appearance due to the presence of irregularly-spaced layers of breccia up to 5 m thick separating layers of compact trachyte. Similar rocks were found high on the southern slopes of "Flinks Dal" near the 1410 m summit. At this locality, where the degree of metamorphism of the inclusions was less, the rocks were found to be closely comparable with the breccias and flow-banded lavas preserved in the supracrustal succession at the margins of the centre. These inclusions also resembled xenoliths found in the syenite SM. 1 close to the country rock near the NW side of the glacier flowing into the NE corner of Motzfeldt Sø.

The inclusions are usually extremely fine-grained, the dark colouration results from a fine impregnation by hematite. In section, a turbid alkali feldspar is the most abundant mineral, occurring as short laths or equigranular crystals; directional textures are uncommon in the inclusions. The feldspar is accompanied by finely-dispersed green to yellow-green aegirine, colourless to green mica, opaques including hematite, and often a patchy development of carbonate. The large feldspars of the porphyries are perthites, generally the crystals are turbid and dusted with sericite but their cores can be quite clear and apparently unaltered. Aggregates of bright green felted aegirine and of amphibole and biotite, may be after original mafic minerals. A few of the porphyritic inclusions contain altered phenocrysts of nepheline as well as alkali feldspar, nepheline may also be recognised in the groundmass (58015).

Fig. 12 a. General view of the syenite SM. 4 north of Ivnârâ, Motzfeldt Centre. Dark-weathering rafts of supracrustal rocks contrast with the light-coloured syenite. The dark lines on the right are alkaline dykes of the Mid-Gardar swarm.

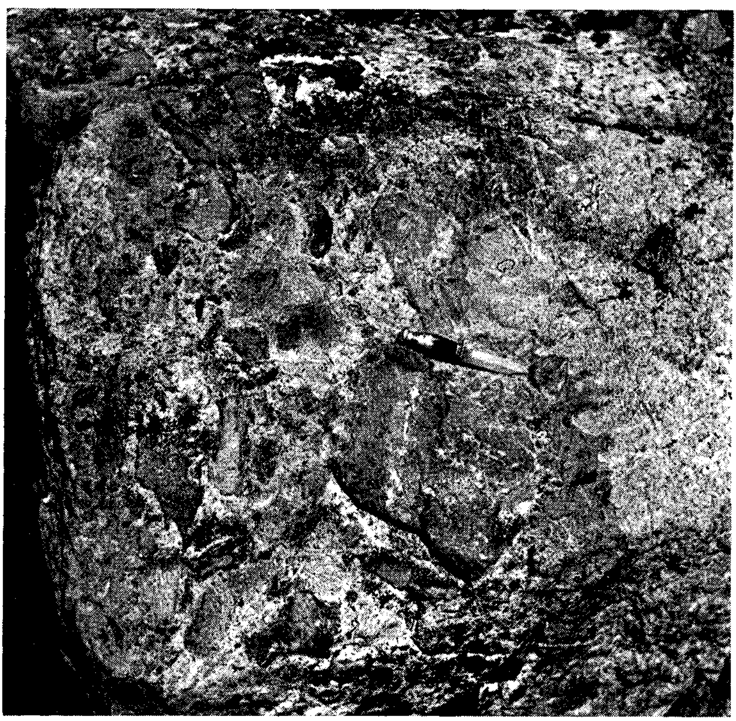

Fig. 12 b. Partially-digested supracrustal breccia xenolith in the syenite SM. 4. From the major supracrustal raft shown in the centre-distance of fig. 12 a. (Photos: C.H.E., GGU.)

A further group of large inclusions on the southern side of "Flinks Dal" consists of closely banded microsyenites, and mafic microsyenites. When these rocks were first seen they were thought to bear a resemblance to some of the green lujavrites of the Ilímaussaq Intrusion (USSING, 1912; FERGUSON, 1964). However, the resemblance is superficial; there is little similarity when the rocks are sectioned. The inclusions are made up of lath-like albite, a less well-formed alkali feldspar, acicular crystals of aegirine and opaque minerals, together with small amounts of sphene, leucoxene, rare aenigmatite, calcite, and pseudomorphs after original nepheline. The darker rocks are richest in opaques and alkali pyroxene. The feldspar laths sometimes show a distinct fluxion structure (58087). In the field, the banded structures may be complex; banding on the scale of several metres shows a good development of flat-lying fold structures.

These large inclusions may be interpreted in two ways: they may represent structurally complex trachytic intrusions, possibly the equivalents of the trachytic sheets seen north of Qôrqup sermia (p. 37), or they may be raft-like inclusions of gneiss that have been thoroughly soaked by, and recrystallized in the syenite SM. 4. On the evidence of the small and large scale banding, the fold-structures and the rapid fluctuations in composition an origin as gneiss inclusions is preferred; furthermore, they occur in close spatial association with large inclusions of undoubted supracrustal origin.

(vii) Syenite SM. 5

This coarse-grained syenite occupies about 8 km² of the central part of the high ground immediately south of Qôrqup sermia and the western end of Motzfeldt Sø. The syenite contains grey or red-grey rectangular alkali feldspars 3–5 cm long and 1–2 cm broad, prominent white crystals of nepheline to 3 cm in length and anhedral areas of mafic minerals 2–3 cm in diameter (58024). Coarser varieties, with feldspars as much as 5 cm in length, crop out on the slopes of "Flinks Dal" north of the lake at 700 m altitude. In the western part of SM. 5, close to SM. 4, the syenite becomes fine grained with poikilitic biotite entering as a prominent constituent (58020). The coarse-grained, normal syenite is similar in hand specimen to the syenite SI. 5 of the Igdlerfigssalik Centre.

Xenoliths are relatively common within the marginal SM. 5, they consist of trachytic and microsyenitic rocks, generally they are rounded and often intimately veined and partially assimilated by the enclosing syenite (58018). The fine-grained inclusions were probably derived from altered supracrustal material enclosed in the adjacent, earlier SM. 4.

There are few mappable internal structures in SM. 5. A small amount of feldspar lamination was found near the lake at 700 m altitude in

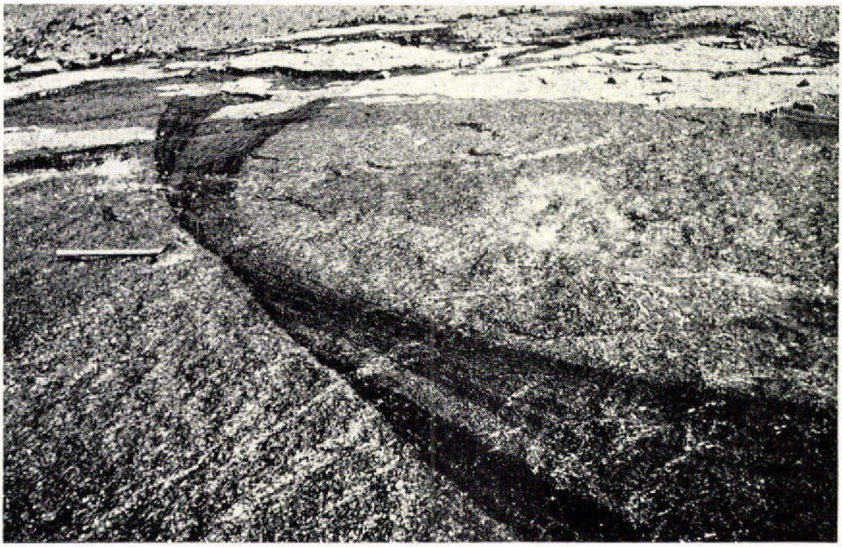

Fig. 13. Layered structures in the syenite SM. 5, Motzfeldt Centre. At about 1250 m elevation, south of Motzfeldt Sø. Scale: hammer shaft 35 cm long. (Photo: C.H.E., GGU.)

upper "Flinks Dal", in the same area there is also a weak development of mineral layering concordant with the lamination. Excellent mineral layering was found at one locality, in a stream exposure near the top of the cliff SW of Motzfeldt Sø, about 1 km SW of the foot of the eastern arm of Qôrqup sermia. The mafic bands have a lateral extent of about 70 m and occupy a zone about 30 m wide, striking at about 105° and dipping south at 70°. The individual bands are arcuate, they may coalesce and occasionally individual bands may have indications of younging towards the south (fig. 13). The mafic bands are about 1 cm thick and are separated by 3–4 cm of leucocratic syenite. Tabular feldspars up to 3 cm long are oriented with their length in the plane of the banding.

(viii) Age relationships of the syenites

The syenites SM. 1 and SM. 2:

The syenite SM. 2 is clearly younger than SM. 1 since xenoliths of SM. 1 are found in marginal SM. 2 east of Motzfeldt Sø and in the same area, veins of SM. 2 cut coarse-grained SM. 1.

The syenite SM. 3 and earlier intrusions:

East of Motzfeldt Sø, xenolithic masses of SM. 2 are enclosed by SM. 3. In the same area, SM. 3 forms the matrix to a zone of igneous breccia developed along the contact between SM. 1 and SM. 2 in the cliffs on the eastern side of the lake. To the north of the lake, the contact between SM. 3 and SM. 1 was found at a number of places. Near the junction, SM. 3 is fine-grained, with flow-banding parallel to the contact with coarse-grained SM. 1 while fine-grained veins from SM. 3 also cut the earlier syenite.

The syenite SM. 4 and earlier intrusions:

The contact between SM. 4 and the earlier syenite SM. 1 is sharp, SM. 4 is relatively fine-grained and contains angular fragments of SM. 1; a good locality for exposures of this contact is found in the stream section about 2 km SSW of Inúnguarssuaq. Less conclusive evidence of relative ages comes from the contact between SM. 4 and SM. 2 west of the southern arm of Motzfeldt Sø. Here, SM. 4 is fine-grained, laminated parallel to the contact with SM. 2, and a few veins of fine-grained syenites cutting SM. 2 are probably derived from SM. 4. The contact exposures of SM. 4 and SM. 2 on the lake shore section west of Motzfeldt Sø, 3.5 km NE of the 1370 m summit, show variable-textured SM. 4 in sharp contact with normal SM. 2.

An internal contact between the normal foyaite SM. 4 and a finer-grained variety was found on the north and NE sides of the amphitheatre-like line of mountains about 6.5 km ENE of the foot of "Flinks Dal"; the normal foyaite outcrops to the west, the finer-grained variety to the east.

The syenites SM. 5 and SM. 4:

The syenite SM. 5 was mapped only in contact with the syenites designated SM. 4. In the ground on the west of the SM. 5 outcrop there is good evidence that SM. 5 is younger than SM. 4 (p. 32). The reverse situation occurs about 1 km NE of the lake at 700 m altitude in upper "Flinks Dal". Here, SM. 5 is coarse-grained right up to the contact with SM. 4; at the junction xenoliths of coarse SM. 5 are quite common within the fine-grained foyaitic SM. 4 which evidently also chills against SM. 5. These relations, together with the evidence of an internal contact in SM. 4 south of "Flinks Dal", make it clear that the unit shown as SM. 4 on the map (Plate 4) should be subdivided: a nepheline syenite younger than SM. 5 must occupy the ground north of the eastern end of "Flinks Dal" and Motzfeldt Sø as well as a large part of the country south of the eastern part of upper "Flinks Dal".

(ix) Alkali-gabbro and syenogabbro intrusions

Several dyke-like outcrops of syenogabbro and alkali gabbro cut the syenites north and south of "Flinks Dal". At least two of these dykes are truncated by the major sinistral transcurrent fault in valley floor.

Alkali gabbro forms the broad dyke cutting the syenites SM. 4 and SM. 5 near the lake at 700 m in upper "Flinks Dal"; a continuation of this same dyke cuts the syenites SM. 1 and SM. 3 on the south side of the valley north of Motzfeldt Sø, about 1.7 km from the foot of Qôrqup sermia. Another broad dyke of alkali gabbro cuts syenite, mapped as SM. 4, about 2 km SE of the lake at 700 m in upper "Flinks Dal"; it is probable that there is only one major alkali gabbro dyke in the centre, off-set by faulting. In hand specimen the alkali gabbro is a dark coloured rock with dark grey or dull white plagioclase feldspars up to 3 cm in length, small granular olivine crystals, and conspicuous crystals of dark copper-coloured biotite. In section, other minerals present are titan-augite, interstitial alkali feldspar, stout prisms of apatite, and opaques. The plagioclase is strongly zoned from cores of labradorite to oligoclase rims mantled by alkali feldspar. Interstitial nepheline is usually present in small amounts (58109). The alkali gabbro dyke south of "Flinks Dal" was estimated to be 300 m wide, north of the valley it is about 200 m wide and north of Motzfeldt Sø the width is reduced to 40 m dying out completely 1.5 km from the lake.

Some facies of the alkali gabbro are highly porphyritic. The phenocrysts are large crystals of plagioclase, as much as 10 cm in length. The crystals may be euhedral though usually rounded, in some instances they appear to be broken (58050). The plagioclase crystals were most abundant on the southern margin of the dyke north of the 700 m lake where quantities could be hand-picked from the badly weathered gabbro matrix. Small anorthosite blocks were also noted in the gabbro at this locality (59117). A concentration of large plagioclase crystals was noted also towards the southern wall of the large alkali gabbro dyke SE of the 700 m lake.

Many of the large plagioclases appear to be xenocrysts. They closely resemble the xenocrysts found in the marginal dark facies of the syenite SI. 4 (p. 60) and in the complex contact zone between the syenites SI. 5 and SI. 7 east of Qôrorssuaq (p. 77).

Superficially, there is a similarity between hand specimens of the alkali gabbro and the syenogabbro. In section differences are at once apparent: the syenogabbro contains abundant cryptoperthitic alkali feldspar, sometimes as phenocrysts; plagioclase is scarce, the few crystals are probably of xenocrystic origin (58036). Interstitial nepheline is always present, this may also occur as blebs intergrown with alkali feldspar. The mafic minerals are a fayalitic olivine, pale brown or pale green clinopyroxene, deep red-brown biotite, opaques and stout prisms of apatite. A thin dyke of mafic syenite or syenogabbro cuts the syenite SM. 4 about 2.5 km SSW of the 700 m lake in upper "Flinks Dal" (Plate 4, marked D). Apart from this, all the syenogabbro intrusions in the centre are north of the "Flinks Dal" fault. The largest intrusion is in the form of an arcuate, dyke-like body cutting the syenite SM. 4 in a

4 km arc centred on Ivnârâ. Two much smaller syenogabbro dykes cut the younger SM. 4 on the south side of "Flinks Dal" between the lake at 700 m and Motzfeldt Sø.

While the syenogabbro intrusions are considered to be late members of the Motzfeldt Centre, it is possible that the thick alkali gabbro dyke, or dykes, may be of similar age to the giant dykes of gabbro discovered in Mellemlandet (Walton, 1965) and known elsewhere in the district. The correlation can be only very tentative; against it is the fact that the alkali gabbro dykes in the Motzfeldt Centre are thoroughly undersaturated nepheline-bearing rocks whereas the Mellemlandet dykes appear to be mildly alkaline gabbros from the descriptions by Walton (1965, p. 46) and from our specimens (63777–63780) where only a suggestion of nepheline was found (63779). In the Motzfeldt Centre both the syenogabbros and the alkali gabbros are cut by alkali trachyte dykes of the Mid-Gardar swarms.

(x) Satellitic intrusions near the Motzfeldt Centre

The North Motzfeldt syenites:

This small intrusive body has a diameter of about 4 km and is situated near the NE margin of the Motzfeldt Centre. There are two syenite intrusions: an early outer syenite NM. 1, and a later central one NM. 2. The syenite NM. 1 is equigranular, pale grey to white coloured, containing euhedral alkali feldspar 1–1.5 cm in length, small amounts of slightly altered nepheline and dark-coloured, interstitial amphibole (58352). This syenite is veined and brecciated by the finer grained marginal facies of syenite NM. 2. The syenite NM. 2 is characterised by the development of small, coarse-grained patches in a fine-grained matrix; the coarse areas contain idiomorphic feldspars to 5 cm long, interstitial dark amphibole, white nepheline and pinkish natrolite in very anhedral areas. The medium-grained rock between the patches is of similar mineralogy except that natrolite is absent (58368).

Although no exposure of the contact between the North Motzfeldt syenites and the syenite SM. 1 was found, it is clear from their overall field relations that SM. 1 is the later (Plate 4).

The ground occupied by the North Motzfeldt syenites is high but generally undulating. An exception to this is the prominent hill (1300 m) within NM. 2 which rises several hundreds of metres above the sea of boulders derived from the *in situ* disintegration of the syenites. This hill is made even more conspicuous by reason of its deep chocolate brown colour, contrasting strongly with the pale-weathering syenites. Most of the hill is made up of dark-coloured porphyritic trachytic rocks, trachytes, and breccias (58286), similar to the large inclusions in SM. 4 and almost certainly derived from supracrustal rocks that once overlaid the area.

The North Motzfeldt syenites are cut by alkali trachytes and Big Feldspar dykes of the Mid-Gardar swarm, and by a basic dyke, 10 m in width, containing numerous platy plagioclase crystals about 25×3 mm in cross section although occasionally as much as 10 cm long.

The East Motzfeldt syenite:

This intrusion has an outcrop about 5 km from north to south and 2 km from east to west. It is situated at the eastern margin of the Motzfeldt Centre. The typical rock consists of idiomorphic, rectangular alkali feldspar crystals 10×3 mm in cross section, interstitial nepheline (not obvious in hand specimen), and alkali amphibole (54234). The specimens collected are red coloured owing to finely disseminated hematite.

Since the intrusion was only discovered during the course of a brief helicopter visit it has not been possible to determine its field relations in any detail. The syenite contains little-altered xenoliths of basalt and agglomerate. Its relations with the Motzfeldt Centre are uncertain, but it is assumed to pre-date SM. 1. The western parts of the syenite are cut by sheets of a fine-grain microsyenite (54233), probably a dissected sill.

(xi) Late minor intrusions

Numerous sub-horizontal sheets of syenite, microsyenite and pegmatite cut SM. 1 and SM. 3 on the north side of Motzfeldt Sø. The sheets vary in thickness from 15 m to less than 1 m, and they form light-coloured layers in the darker syenites; they are so numerous and closely spaced that when first seen from the south side of the lake it was assumed that the mountains north of the lake consisted of gneiss cut by dykes.

The sheets vary in grain-size. Some have streaky dark and light bands of microsyenite with occasional pegmatitic schlieren pods, others are pegmatitic throughout, or they may be differentiated into coarser marginal zones with large amphibole and feldspar crystals and a centre of microsyenite (fig. 14). The microsyenites are highly sodic; bright yellow-green aegirine is common, sometimes accompanied by deep red-brown aenigmatite (63704). Similar flat-lying sheets occur in marginal exposures of SM. 1 on the NW side of Qôrqup, near the foot of Qôrqup sermia.

Many of the sheets are highly feldspathic; weathering of this type of sheet is responsible for the high proportion of coarsely feldspathic rock fragments in the frost-shattered debris mantling the high ground north of Motzfeldt Sø.

(xii) Geologfjeld syenite

Outcrops of syenite and gabbro were noted and collected by A. Weidick during glaciological work on the north side of Geologfjeld. The locality is about 5 km north of the margin of the Motzfeldt Centre

Fig. 14. Pegmatite sheets cutting the syenite SM. 1 north of Qôrqup sermia, Motzfeldt Centre. The coarse margins consist of aegirine-augite, nepheline and alkali feldspar. Scale: hammer shaft 25 cm long. (Photo: C.H.E., GGU.)

east of Qôrqup sermia. The material collected included a carbonatite (8216) and porphyritic trachytes (8215 A, 8218 A) from dykes, a larvikitic syenite (8217) and a partially serpentinised olivine augite rock (8215 B) consisting of well-formed olivines poikilitically enclosed by large plates of brown augite. The basic and syenitic rocks form low hummocky ground on the north side of Geologfjeld.

Loose boulders found in moraine in the lower part of Storeelv valley, NE of Qôrqup sermia, probably come from the same intrusion. These blocks include feldspathic gabbros (63706 A, B) with interstitial alkali feldspar and altered nepheline, a banded larvikitic syenite (63707 B) with mafic bands (63707 A) rich in purple-brown augite rimmed with overgrowths of bright green aegirine augite, together with euhedral nepheline, alkali feldspar, opaques, poikilitic brown amphibole, biotite and cancrinite.

Unfortunately, it did not prove possible to visit the Syenitknold area. However, from Dr Weidick's descriptions and samples, and from examining the aerial photographs, it appears probable that a large composite alkali-gabbro – syenite dyke crops out at Syenitknold, north of Geologfjeld. This may be related to the thick gabbroic dykes in Mellemlandet (Walton, 1965, p. 44, plate 2).

Fig. 15. Outward-dipping contact of the Motzfeldt Centre syenites (pale-coloured, on left) with dark-weathering country rocks. East of the lower end of Motzfeldt Sø. (Photo: C.H.E., GGU.)

(xiii) The external margins of the centre

The alteration of the country rocks surrounding the centre is very slight, in contrast to the complete reconstitution of inclusions within the syenites. Near the margins, the Julianehåb Granite becomes dull and lustreless, in section there is a decrease in the amount of quartz, and small needles and aggregates of green alkali pyroxene form along crystal boundaries. There is not extensive fenitization. Similarly, the supracrustal rocks do not show appreciable alteration.

Because of the high relief within the centre, from sea level to over 1700 m, the three-dimensional shape of many of the boundaries may be determined. The contacts with the country rocks are steep and outward dipping; this may be verified either side of the southern end of Motzfeldt Sø (fig. 15), north of the lake and Qôrqup sermia, and near the southern end of "Flinks Dal". The emplacement of the syenites appears to have taken place with a minimum of disturbance to the earlier rocks; flat-lying supracrustal rocks crop out right up to the syenite margins (fig. 11) with almost no signs of disturbance although rafts in the adjacent syenites may dip at high angles (Plate 4; fig. 11b). Faulting, possibly connected with syenite emplacement, was seen near the 1550 m mountain north of Motzfeldt Sø: several small normal faults cut the supracrustal rocks, downthrowing to the north, away from the syenites.

The present external contacts are wall-like; erosion has cut well below the level of the roof of the centre. The numerous large inclusions in the syenite SM. 4 almost certainly come from the roof zone. In detail, the margins of these inclusions may be highly irregular and even steep-sided; however, they are in the form of flat-lying rafts. When taken in conjunction with the undisturbed state of the country rocks, the shape of these rafts may provide a further clue to the method of emplacement of the syenites: similar features are displayed by other Gardar intrusions (p. 108).

The internal contacts between the different syenites intrusions are also steep, the emplacement of later syenites has been accomplished with the minimum of structural disturbance to the earlier intrusions; for example, there is an almost complete absence of crushing at the contacts.

(c) The North Qôroq Centre

(i) Introduction

The centre consists of five major intrusions, several of which develop variants, and a number of minor intrusions. The five syenites have arcuate outcrops centred on a focus near the western side of Qôroq. The centre is cut by dykes of the Mid-Gardar swarm, by syenites of the South Qôroq Centre, and it is faulted (Plate 4). It forms well exposed ground on the slightly dissected plateau between Qôroq and Narssarssuaq, and on the steep eastern hillsides of the Narssarssuaq valley. It is also well exposed in the rather inaccessible cliffs on the western side of Qôroq.

The nepheline syenites of this centre are mainly foyaites.

(ii) Syenite SN. 1, the Outer Foyaite

Two members have been recognised within this unit, an outer coarse-grained foyaite and an inner, medium-grained foyaite. These may be of different age and represent separate intrusions but no evidence adequate to support this view has been obtained. However, the inner foyaite is xenolithic in places, unlike the outer foyaite, and the latter diminishes in width towards the northern part of the centre, as if cut out by the inner foyaite.

The outer foyaite is usually a dull, altered-looking rock. It is coarse-grained with feldspars 20×2 mm, fayalitic olivine, interstitial areas of alkali pyroxene and alkali amphibole, and small nepheline crystals often altered to micaceous aggregates (gieseckite). Although the feldspar crystals are usually tabular, igneous lamination is relatively rare; likewise, mafic banding is not common. It is imperfectly developed in syenite to the west of the long lake at 550 m altitude, near the contact with the Julianehåb Granite. The inner foyaite is of finer-grain, the feldspars are 10×1 mm, accompanied by small, fresh nepheline crystals, fayalitic olivine, and interstitial alkali pyroxene and alkali amphibole. There is pronounced lamination of the tabular feldspars often accompanied by aligned lenticular xenoliths, or, occasionally, thin mafic bands. Xenoliths, which may be common, are mainly developed in outcrops west of the 2.3 km long lake at 550 m altitude; they include fine-grained micro-syenites and porphyries. Plastic deformation is common, which, combined with assimilation of the xenoliths, imparts a streaky appearance to the rocks.

(iii) The syenite SN. 2, the Leucocratic Syenite

The leucocratic syenite is massive, pink in colour, and often shows some affinity with the Porphyritic Syenite (SN. 4). Nepheline is not visible in the field, dark minerals tend to be subidiomorphic, and the feldspar crystals (up to 20×5 mm in size) which sometimes display a weak porphyritic tendency, are stoutly prismatic and randomly arranged. Lamination and mineral layering were not found. In section, the rock consists of anhedral areas of gieseckite after nepheline, perthitic alkali feldspar, euhedral biotite and pale green pyroxene, and highly interstitial alkali amphibole. Opaque minerals and apatite are common accessories.

(iv) The syenite SN. 3, the Altered Foyaite

The syenite is weakly porphyritic with randomly oriented feldspar crystals (15×2 mm) in a fine-grain grey or purple coloured groundmass containing highly anhedral dark areas. The matrix consists of perthitic alkali feldspar, nepheline, now largely pseudomorphed by gieseckite, opaques, and poikilitic alkali pyroxene, alkali amphibole and rare biotite. The rock is extremely brittle and so highly discoloured that its texture is largely obscured, however, there does not appear to be any apparent metamorphic recrystallization either in the hand specimen or thin section.

(v) The syenite SN. 4, the Porphyritic Syenite

The Porphyritic Syenite comprises a variety of massive rocks that pass gradually into one another in the field. They are linked by a tendency for the feldspars to be porphyritic and for the dark minerals to be granular rather than anhedral. Both features are most pronounced in the finer-grained rocks. Pegmatites, aplitic varieties, preferred orientation of minerals and mineral layering are absent. Xenoliths are rare. Small oval inclusions of a rock resembling the fine-grained marginal SN. 4 occur in marginal coarse SN. 4 to the west of the 608 m summit. Near its contact with earlier syenites the Porphyritic Syenite contains xenoliths of the earlier intrusions.

In its interior, the syenite is coarse-grained and contains stout rectangular perthitic feldspars up to 20×5 mm in size together with subidiomorphic dark minerals. These are relatively rare olivine, strongly zoned pyroxene with aegirine augite rims, alkali amphibole and biotite. Occasionally, small amounts of aenigmatite may be present (54193). Nepheline is present as anhedral areas or as cuspate inclusions within the large alkali feldspars; in either situation it is generally thoroughly altered. Towards the outer boundary the syenite SN. 4 becomes gradually finer-grained. This marginal phase occupies a belt up to 400 m; it includes strongly porphyritic syenites (54223) with stout idiomorphic grey feldspar phenocrysts 5 to 10 mm in length in a fine-grained, dark grey matrix of interlocking grains of perthite, altered nepheline, biotite and amphibole. A decrease in size and content of feldspar phenocrysts was noted for several metres up to the outer contact of SN. 4 west of the 608 m summit, also along the northern margin of the intrusion. There is a striking similarity in hand specimen between the marginal porphyries in SN. 4 and some dyke rocks that cut the centre.

At a few places along the outer boundary of the syenite SN. 4 there is a fine-grained aphyric rock with granular aegirine-augite and amphibole (52418) or else poikilitic areas of pyroxene and amphibole (54210), up to 5 mm in diameter. Such rocks are found invading the marginal phase of SN. 4, as for example 300 m N 15° W of the 608 m summit, and can occur at some distance from the margin of SN. 4, in the marginal phase. Probably there is no great difference in age between the aphyric rock and SN. 4; similar occurrences are known from other Gardar syenite intrusions.

(vi) The syenite SN. 5, the Inner Foyaite

Typically, the Inner Foyaite is a coarse-grained syenite containing perthitic alkali feldspar crystals 20×2 mm in size, interstitial areas of alkali pyroxene and alkali amphibole up to 10 mm in diameter and anhedral nepheline now largely altered to gieseckite and cancrinite. The rock is often grey coloured but may be reddened over extensive areas. It weathers readily to gravel, a common feature of the foyaitic members of the Igaliko Complex. Feldspar lamination is occasionally seen, mafic bands are very thin and extremely rare. The interior of the intrusion is uniformly of this type; aplites and pegmatites are negligible and xenoliths are lacking.

Some variation is found near the outer margin of SN. 5. Medium-grained foyaite is an important constituent; it is composed of 10 mm-long perthitic alkali feldspars, small euhedral nepheline crystals, needlelike aegirine and interstitial analcite and rare aenigmatite (54201). This rock is laminated more frequently than the coarse-grained variety, occasionally the lamination may be extreme (54198). The medium-grained variety is fairly extensively developed in the NW part of the intrusion where it forms arcuate outcrops within, and passing into coarse-grained foyaite. There is no good reason to believe that the medium-grained and coarse-grained foyaites are separate intrusions. They are intimately associated in excellent outcrops that yield no signs of age differences between them. Both can be seen to form veins in the Porphyritic Syenite SN. 4 and structurally they are disposed about a common centre. The differences may be largely the result of differing degrees of feldspar lamination.

Another type of SN. 5 is the highly variable rock described in the field by the term mélange. This is found in two elongate bodies, one extending west for approximately 2 km from the 747 m summit, the other west of the 658 m summit: they are shown as "Microsyenite (of various ages)" on Plate 4. The principal outcrop, near the 747 m summit, is an arcuate strip 50–100 metres thick at its northernmost limit, thinning towards both ends. It consists of a foyaite with innumerable lenses or impersistent foliae of fine-grained dark-grey rock which either resembles the aphyric outer contact phase of the syenite SN. 4, or contains small feldspar phenocrysts (10×1 mm) aligned parallel to the lengths of the lenses. The fine-grained component consists of perthitic alkali feldspar laths, sparse altered nepheline, and anhedral to poikilitic crystals of aegirine-augite, alkali amphibole and biotite. The lenses are up to 30 cm in length, a few centimetres thick and are well-defined. They appear to have undergone plastic deformation for they often display an undulating pattern, wrapping around the scattered xenoliths of SN. 4. The lenses make up at least half the mélange. The enclosing foyaite is medium to coarse-grained but not often quite so coarse-grained as the typical foyaite of SN. 5. There is generally good feldspar lamination concordant with the lenses and with the boundaries of the mélange area.

The mélange is seen to intrude the syenite SN. 4 but it appears to be an integral part of SN. 5.

The other body of mélange, near the northern margin of the SN. 5 intrusion, is essentially similar to the main outcrop but the dark component is a porphyry which weathers to small pits (54209).

Another variant of SN. 5 is a mafic foyaite forming small outcrops close to the contact with SN. 4 at several localities. The mafic constituents are red-brown biotite in discrete areas, aegirine, and aggregates of green to yellow green biotite. In one specimen (52413), the rock appeared to have been crushed and recrystallized, fractures in perthitic alkali feldspar were healed by clear albite, and long strips of calcite, cancrinite and albite cut through the mafic minerals.

Close to the contact with SN. 4 at the northern end of the outcrop, SN. 5 is highly variable. Coarse-grained foyaite contains dark, fine-grained areas unlike those in the mélange. These areas consist of white perthitic alkali feldspar phenocrysts up to 20 mm in length and abundant idiomorphic nepheline crystals 2–3 mm in diameter. The rest of this restricted development of variable rock has a considerable range in grain size and includes pegmatitic areas as much as a metre in diameter with randomly-oriented feldspars up to 5 cm in length. At the SW end of its outcrop, close to SN. 4, the syenite again becomes variable and shows banding that strikes at 120°, dipping SW at 20°. The banding results from the alternation of thin layers enriched in dark minerals with coarse-grained and fine-grained layers of foyaite several centimetres thick. In places SN. 5 is pegmatitic. Other variants here may result from reaction between SN. 5 and earlier SN. 4 (54206, 54204).

(vii) Age relationships

The syenite SN. 4 is clearly younger than SN. 1, SN. 2 and SN. 3 since it transgresses across their boundaries and develops an extensive fine-grained marginal phase against them. SN. 4 contains xenoliths of SN. 2 and SN. 3, sends an apophysis of its marginal phase along the SN. 2–SN. 3 boundary at a small lake 500 m east of the 830 m summit, and veins SN. 2; it also cuts sharply across the preferred orientation direction of SN. 1 on the west side of the long lake at 550 m altitude (fig. 16).

The age relationships between SN. 1, SN. 2 and SN. 3 were not conclusively established, but from their general disposition they seem to be numbered in order of intrusion. The contact of SN. 2 with SN. 3 was not seen. It may be exposed on the steep wall of Qôroq but it is concealed in the readily accessible ground. The contact between SN. 1 and SN. 2 is rather poorly exposed on the ridge leading to the 830 m summit. "Simultaneous" contacts or rapid passages were seen but in places SN. 2 becomes texturally variable, sometimes mafic, near the contact. No evidence that SN. 1 is younger than SN. 2 was obtained, the scanty data suggest in fact that it is the older of the two bodies. It develops no marginal phase against SN. 2.

There is abundant evidence that SN. 5 is younger than SN. 4. Innumerable veins of the coarse-grained and medium-grained foyaite cut SN. 4 which is enclosed in SN. 5 as numerous screens and xenoliths from a few centimetres to many metres in length. Even the mélange variant of SN. 5 contains xenoliths of SN. 4, and can be seen to intrude SN. 4. The outcrop of SN. 4 is cut to ribbons and in places breached

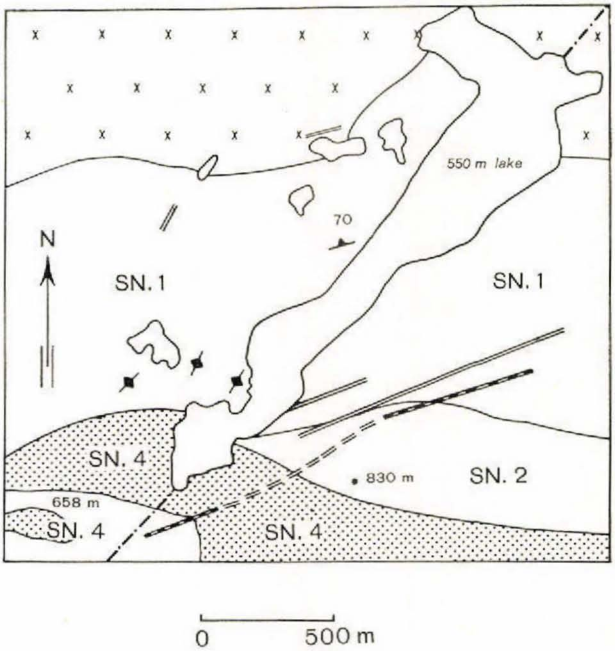

Fig. 16. Cross-cutting relationship of the syenite SN. 4 towards structures in SN. 1, North Qôroq Centre. (Cross symbol = Julianehåb Granite.)

by SN. 5, which intrudes SN. 1 north of the 608 m summit; this wholesale disruption of SN. 4 is most striking. Moreover, SN. 5 may form a local marginal modification at the contacts with SN. 4 and SN. 1, and comes into contact with different varieties of SN. 4. For instance, its northern margin lies largely against medium- or coarse-grained SN. 4 but followed westwards its cuts into fine-grained marginal varieties of the earlier intrusion.

All members of the North Qôroq Centre are cut by dykes of the Mid-Gardar swarm. Faulting also affects most members of this centre.

(viii) Structure of the centre

The syenites form outcrops with outer boundaries very roughly arcuate about a common centre that is now obliterated by the South Qôroq Centre. The outer margin of the centre, against the Julianehåb Granite and supracrustal rocks, is steep and outward-dipping: this can be seen clearly on the SE side of the Narssarssuaq valley near the abandoned hospital, and on the west wall of Qôroq about 3 km below the foot of Qôrqup sermia.

Although relatively poorly exposed there is evidence that the internal contacts are very steep; for example, in the outer contact of

SN. 4 at the south end of the lake at 550 m altitude, and the contact of SN. 5 against SN. 4 in the SSW valley south of the lake at 550 m.

The intrusions SN. 1, SN. 4 and SN. 5 are considered to have been originally steep-sided stocks. SN. 1 and SN. 4 were both cored-out by successively younger intrusions, and both of these and SN. 5 truncated by the later South Qôroq Centre.

(ix) The breccia plug

A small diatreme cuts the syenites SN. 1 and SN. 5 at their contact in exposures between two small lakes about 400 m north of the 608 m summit. The plug contains angular to sub-rounded blocks of the syenites SN. 1 and SN. 5 as much as 0.8 m in diameter, set in a fine-grained, dark green, iron-stained matrix. The matrix contains small rounded dark-coloured inclusions sometimes in such profusion that the rock appears almost pisolitic (87124); also present are dark rounded inclusions to 10 cm diameter, flakes and books of dark mica to 2 cm in diameter, and lustrous crystals and crystal fragments of titanaugite. The breccia plug is cut by a thin, irregular 5 cm-thick apophysis from a dark-coloured porphyritic trachyte dyke.

In section, the matrix is made of small patches of altered syenite in a groundmass consisting of phlogopitic mica, a few purple-brown titaniferous augite crystals, pseudomorphs in carbonate and opaques after olivine and also after small six-sided or square cross-sectioned minerals, and areas of calcite some of which is in the form of pseudomorphs after a lath-like mineral (59743). The matrix is identical in section to the matrix of the breccia plugs at Qagssiarssuk described by STEWART (1964); the pseudomorphs after olivine, perovskite and melilite first recognised by STEWART closely match those found in the breccia matrix of the North Qôroq diatreme.

(d) The South Qôroq Centre

(i) Introduction

This centre measures 23 km from NW to SE and nearly 10 km from NE to SW. The area now exposed is about 80 km², although this is evidently only a fraction of the original extent of the centre, much of which has been obliterated by the later Igdlerfigssalik Centre. The centre consists of five distinct nepheline syenites, in addition to which there are a number of minor intrusions of syenite, a small area of alkali gabbro and three satellitic nepheline syenites.

(ii) Syenite SS. 1

A small crescentic area of syenite at the SE extremity of the centre is considered to be the earliest member. The trend of the outer margin of this syenite, SS. 1, against the basement rocks and the earlier Østfjordsdal syenite is not greatly at variance with the trend of the contact of the later syenite SS. 2 with SS. 1, so it is reasonable to regard SS. 1 as a member of the South Qôroq Centre rather than as a satellitic intrusion.

The syenite is medium- to coarse-grained, there are abundant rectangular 30×10 mm alkali feldspar crystals, irregular interstitial areas of grey-green nepheline, anhedral dark green aegirine augite and small amounts of olivine, amphibole and opaques. The mafic minerals form complex aggregates of crystals. In some respects this syenite resembles the coarser facies of the Østfjordsdal syenite and the syenite SI. 5 of the Igdlerfigssalik Centre. Approaching the contact with the country rocks and the Østfjordsdal syenite, SS. 1 becomes much finer-grained with a patchy crystallization: coarse, pegmatitic areas a few centimetres in diameter are scattered throughout the rock which is otherwise of medium or fine grain.

The syenite is usually massive. However, weak feldspar lamination striking parallel to the outer contact is developed near the SE margin and also at several localities on the SE slopes of the spur from the 1800 m summit NW of SS. 1.

(iii) Syenite SS. 2

This syenite crops out extensively south of Narssarssuaq, on the NE side of "Gieseckes Dal", either side of "Flinks Dal" at the lower end of the valley, and to the SE on the slopes of the Agdlerulik mountain mass. It is a remarkably persistent type; syenite from any of these localities differs very little in the hand specimens, although a somewhat finer-grained variety is always present at the outer margins of the intrusion. The typical syenite is light grey coloured, composed of thin tabular crystals of perthitic alkali feldspar, measuring 10×1 mm, small grey or grey-green nepheline crystals, and aggregates of alkali pyroxene in irregular poikilitic patches about 10 mm in diameter. The poikilitic mafic minerals impart a characteristic spotted appearance to this syenite. The rock is massive, mineral layering and feldspar lamination are not present except at the margins where there may be strong alignment of the small, platy feldspars parallel to the contact. In the marginal facies, which passes imperceptibly into normal SS. 2, the grain size is very small; the feldspars are often only 3 mm in length and the poikilitic character of the mafics again very pronounced. The actual contact of

SS. 2 with earlier rocks is often very sharp regardless of whether the older rock is Julianehåb Granite, supracrustal rocks, or an earlier syenite.

The syenite SS. 2 is remarkably free from xenoliths. Only at one place, in the shore section on the east side of Tunugdliarfik, were inclusions found in any quantity. Near the north end of the submerged moraine at the entrance to Qôroq (Ussing, 1912, Pl. IV) there are xenoliths of a coarse-grained laminated foyaite, these were probably derived from the nearby Tunugdliarfik syenite. Small rounded mafic inclusions were found in SS. 2 in coastal exposures about 5 km SSE of the harbour at Narssarssuaq.

The syenite is remarkably free from pegmatitic or aplitic modifications. An area of pegmatite was found near the contact with supracrustal rocks about 2 km SE of Narssarssuaq airport.

(iv) Syenite SS. 3

This syenite is invariably separated from other earlier rocks by the syenite SS. 2 (Plate 4). It is a medium- to coarse-grained rock with bladed or tabular crystals of perthitic alkali feldspar up to 30×7 mm, smaller pink nepheline crystals, and highly irregular anhedral dark-green aegirine-augite. The rock is usually massive; mineral layering is rare, persistent feldspar lamination was found at a few places about 6 km SE of Narssarssuaq.

(v) Syenite SS. 4

The syenite SS. 4 is a light-grey rock of rather coarse grain, containing conspicuous rectangular crystals of alkali feldspar up to 15×5 mm. In darker grey varieties, the feldspar has a distinct schiller structure. In section, the feldspar is cryptoperthite, it is accompanied by small amounts of nepheline which occurs either as rounded blebs intergrown with the feldspar or as anhedral interstitial areas; the proportion of nepheline is very small. The mafic minerals occur as dark, irregular areas in hand specimen; in section these are seen to be made up of olivine, pale-lilac coloured augite, brown amphibole and small amounts of opaques and apatite. The syenite is a more basic variety than most in the centre; it has clear affinities with the lardalites and larvikites rather than foyaitic nepheline syenites.

Feldspar lamination was not observed in this intrusion but mineral layering is present; often it is extremely well developed. Some of the best exposures of layered rocks are found on the west side of Qôroq about 5 km NNE of Niaqornârssuk. Here, repeated thin mafic bands rich in olivine and pyroxene alternate with normal leucocratic syenite bands 10–20 cm thick. The steep to vertical banding is parallel to the

Fig. 17. Brecciated mafic layered structures in the syenite SS. 5, South Qôroq Centre. NW shore of Qôroq about 2 km NNE of Niaqornârssuk. Scale: hammer shaft 35 cm long. (Photo: C.H.E., GGU.)

contact with SS. 3. The mafic bands (e.g. 59671) are slightly finer-grained than the associated leucocratic syenite.

The syenite SS. 4 usually occupies a zone of variable thickness between the earlier syenite SS. 3 and the extensive outcrops of the foyaite, SS. 5. SS. 4 is, however, not always present between the east side of Qôroq, the lower part of "Flinks Dal" and the northern side of "Gieseckes Dal". SE of "Gieseckes Dal" it is once again present but only as a narrow strip a few hundred metres wide. On the west side of Qôroq, the exposures of SS. 4 at sea level are considerably narrower than those to the west, on the plateau, suggesting that the syenite has been partially cut out by SS. 5 (fig. 18).

(vi) Syenite SS. 5

Well-formed, tabular crystals of alkali feldspar are a characteristic feature of this syenite. The feldspars are up to 30×4 mm in size, commonly they display excellent lamination and invariably dominate the rock in hand specimen. They are accompanied by grey-green or white subhedral areas of nepheline, anhedral aggregates of alkali pyroxene and amphibole (sometimes together with olivine), opaques and apatite as accessories, and interstitial pink natrolite.

Small amounts of mafic mineral layering were found in this syenite; the layering is completely conformable with mineral lamination in the same rock except where the layered structures are brecciated. Here, the laminated structures wrap around the mafic layered blocks. Good examples of brecciated mineral layering were found in loose blocks on the west side of Qôroq, about 2 km NNE of Niaqornârssuk (fig. 17). The laminated and layered structures strike parallel to the outer margins of the syenite but they dip towards the centre of the intrusion, diverging sharply from the outward-dipping outer margins.

The present outcrop of SS. 5 is much modified by faulting and later intrusions. The most extensive outcrops are those west of Qôroq and on the east of the fjord near "Flinks Dal" and "Gieseckes Dal". Elsewhere, the actual outcrop is often limited because of later glacial deposits or scree but there are good exposures south of Agdlerulik. A very small but quite recognisable outcrop of SS. 5 is situated on the coast of Qôroq NW of Igánarssuánguaq (the 577 m hill); at this locality the syenite is cut by a thick alkali gabbro dyke striking slightly east of north.

(vii) Age relationships of the syenites

The syenites SS. 2 and SS. 1:

Towards the contact with SS. 1 the syenite SS. 2 becomes finer-grained with the mafic minerals forming poikilitic areas which impart a mossy appearance to the rock in hand specimen. SS. 2 is seen to cut and brecciate normal coarse-grained SS. 1 at an altitude of about 1000 m on the SE slopes of the Agdlerulik mountain mass. The contact is steep, with a southerly inclination.

The syenites SS. 3 and SS. 2:

Both syenites form distinct, mappable units. At a number of places, notably on the coast about 2 km west of Niaqornârssuk and on the plateau about 6 km SSE of Narssarssuaq, it was possible to see a complete gradation from one syenite to the other. The coarser-grained SS. 3 becomes progressively fine-grained towards SS. 2, there is a complete passage to normal SS. 2 over about 100 metres of continuous exposure at both places. From the central position of SS. 3 within SS. 2, together with the decrease in grain size towards SS. 2, the syenite SS. 3 is considered to be the later of the two; it is, however, evident that no great interval of time separated the two syenites, SS. 3 may well represent a later pulse of magma from the same source as SS. 2 (HARRY & RICHEY, 1963).

The syenites SS. 4 and SS. 3:

Close to SS. 3 the syenite SS. 4 is fine-grained and granular. The contact between the two syenites is sharp; in exposures at about 400 m elevation 1.5 km NW of Niaqornârssuk, angular blocks of the syenite SS. 3 up to 2 m in diameter, are enclosed in marginal SS. 4. SS. 4 is, therefore, younger than SS. 3 and intrusive towards it.

The syenites SS. 5 and SS. 4:

The relationship of these two syenites is similar to that of SS. 2 and SS. 3. Both are in the form of distinct mappable units, each retains its characteristic features to within quite a short distance of the other yet there were no definite intrusive features at their contact. There are, however, good grounds for regarding SS. 5 as the later syenite, if not a completely distinct intrusion. There is a slight reduction in the grain-size of SS. 5 towards SS. 4. This is particularly well seen on the west coast of Qôroq about 3 km NNE of Niaqornârssuk and on the plateau west of Qôroq where the fine-grained SS. 5 is also patchily pegmatitic next to SS. 4. West of Qôroq there is not complete parallelism between the outer and inner margins of SS. 4, the outer margin of SS. 4 is nearly vertical but the contact with SS. 5 dips north at a moderate angle with the result that the outcrop width of SS. 4 is much restricted in the low ground close to the fjord. East of Qôroq, the syenite SS. 5 is in direct contact with SS. 3, SS. 4 having been cut out completely in this area. Thus, it is clear from the field relations that SS. 5 is transgressive towards SS. 4 and must therefore be regarded as a separate, later intrusion, but, from the absence of xenoliths of SS. 4 in SS. 5, the lack of small-scale intrusive features, and the absence of a definite chill marginal zone to SS. 5 against SS. 4, the intrusion of SS. 5 probably took place shortly after SS. 4, before the earlier syenite had cooled completely but after it was essentially solid.

(viii) The outer margins of the centre

The earliest syenite, SS. 1, does not have a well exposed outer margin. Near the country rocks or the Østfjordsdal syenite it becomes much finer-grained, the development of the fine-grained marginal facies cuts across the boundary between the Østfjordsdal syenite and the Julianehåb Granite (Plate 4).

As mentioned earlier (p. 47) the syenite SS. 2 becomes fine-grained towards earlier rocks. It occasionally sends small veins into the country rocks, and sometimes encloses blocks derived from them. About 2.5 km

SE of Narssarssuaq airport fine-grain marginal SS. 2 is in contact with and intrudes different facies of the syenite SN. 1; further examples of the intrusive relation of SS. 2 towards this and other members of the North Qôroq Centre were seen near the 587 m summit and, further east, to the south of the 719 m summit. They demonstrate clearly that the North Qôroq Centre is of earlier date than the South Qôroq Centre.

Generally, the syenite SS. 2 produces little obvious alteration in earlier rocks at its outer margin. The outcrops of marginal SS. 2 against supracrustal rocks about 1.8 km SE of Narssarssuaq airport are an exception. Here, the more basic and calcareous (tuffaceous) rocks provide mineralogically-interesting hornfelses and the quartzites are altered to rocks rich in alkali pyroxene and alkali feldspar. The unusual degree of alteration may be connected with the presence of pegmatite in SS. 2, itself a somewhat unusual feature.

(ix) Minor intrusions associated with the centre

The alkali gabbro:

A thick dyke of alkali gabbro cuts the syenite SS. 5 near the south side of "Gieseckes Dal". It is well exposed on the SE coast of Qôroq, to the south it extends for about 150–200 metres before being cut off by the later, fine-grained marginal syenite SI. 2. The gabbro is a dense, dark-grey rock, it consists of plagioclase strongly zoned to margins of alkali feldspar; there is also interstitial nepheline and analcite. The mafic minerals are rounded olivines, anhedral violet-brown augite, granular opaques with red-brown biotite rims, and accessory apatite. Near the contact with SS. 5 there has been reaction with the earlier syenite resulting in an increase in biotite and alkali feldspar.

Porphyritic microsyenite sheets:

A series of steep-sided sheets of porphyritic microsyenite cut the syenite SS. 3 close to the contact with SS. 4 (Plate 4). The sheets are off-set by faulting. Although the sheets are present in SS. 3 close to SS. 4 none was found within the later syenites; they therefore pre-date SS. 4 or else they are off-shoots from the later syenite, an interpretation supported by the manner in which the sheets focus on the SS. 4 outcrop. The sheets are well laminated microsyenites. Platy crystals of perthitic alkali feldspar, to 1 cm long, are associated with subhedral nepheline partially replaced by cancrinite, sodalite, alkali pyroxene and biotite. The mafic minerals are generally anhedral and interstitial.

(x) Structure of the centre

The outer margins of the centre are well exposed south of Narssarssuaq, near "Flinks Dal", and "Gieseckes Dal", and in the vicinity

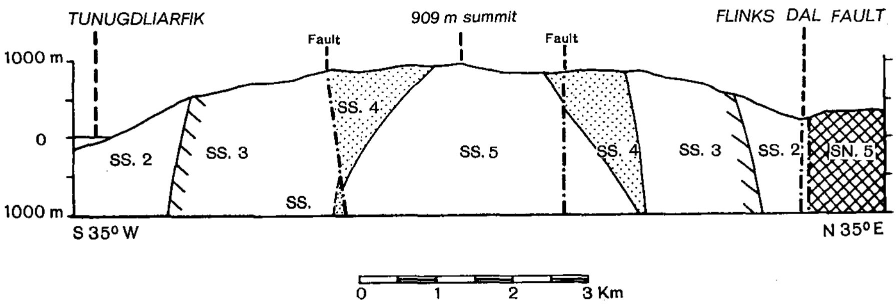

Fig. 18. Cross-section through the South Qôroq Centre from Tunugdliarfik to the North Qôroq Centre.

of Agdlerulik. Wherever the relief is sufficiently great, the contacts with earlier rocks are found to be steep and outward-dipping. Likewise, the internal contacts between the major members are steep and outward-dipping. Nowhere are there any indications of inward-dipping contacts nor of contacts with roof-like relationships towards earlier rocks although the junction of SS. 5 against SS. 4 may be at as low an angle as 40° west of Qôroq. Within several of the major intrusive units the presence of mineral lamination and layering provide indications of the operation of magmatic currents and of crystal settling with bottom accumulation of early-formed phases.

The centre consists of a series of steep-sided, elongate stock-like intrusions (Plate 4; fig. 18). The younger intrusions occupy successively more central positions within the centre, the emplacement of each major unit after SS. 2 resulting in the obliteration of a considerable part of the preceding unit, leaving the earlier units with outcrops that simulate thick ring-dykes but which are, in fact, cored-out stocks. The presence of internal structures in several of the syenites strongly suggests that these intrusions each underwent an appreciable amount of *in situ* differentiation before the emplacement of the later units.

(xi) Satellitic intrusions associated with the centre

The Narssarssuaq stock

A small, steep-sided intrusion of nepheline syenite cuts the quartzites, breccias and metabasalts of the Eriksfjord Formation at Narssarssuaq. This intrusion is of variable texture but most commonly it is a medium-grained, equigranular syenite (46285), purple-grey when fresh but more frequently weathered to a dull brown or red-brown colour. Xenoliths of a porphyritic fine-grained syenite occur sporadically. A somewhat similar porphyritic syenite cuts the plug in outcrops in the cliff face on the west of the 221 m hill. The area of syenite at Narssarssuaq is about 1.5×1 km. Another, similar syenite was found by B. J.

WALTON exposed over an area of about 1 km² on the north side of the river at Narssarssuaq. It is probable that these two areas of syenite are parts of the same stock, perhaps dextrally off-set by faulting along the line of the Narssarssuaq valley.

The syenite north of the Narssarssuaq river cuts Julianehåb Granite. It is cut by members of the regional trachytic dyke swarm; similar dykes were also observed cutting the stock at Narssarssuaq. It was not possible to determine the age relative to the syenites of the nearby South Qôroq Centre. From the altered condition of the Narssarssuaq stock it could be argued that it had been affected by the South Qôroq syenites; however, all that is certain is that the stock is later than the Eriksfjord Formation and earlier than the regional Mid-Gardar dyke swarm, including the Big Feldspar Dykes.

The Tunugdliarfik Syenite

This syenite forms a very small outcrop on the eastern shore of Tunugdliarfik about 3 km WNW of Niaqornârssuk (Plate 4). No contacts with older rocks were observed, the syenite is bounded by later SS. 2 syenite of the South Qôroq Centre and by the fjord. In the few outcrops visited, the syenite was found to be a laminated foyaite (58205) carrying small porphyry xenoliths in coastal exposures near the southern limit of its outcrop.

The Østfjordsdal Syenite

This syenite has an outcrop measuring approximately 5 km north–south and slightly less from east to west. It was nearly elliptical in outline prior to the intrusion of the later syenites. The syenite is medium- to coarse-grained, consisting of tabular alkali feldspar crystals about 30×10 mm in cross-section, grey-green nepheline up to 10 mm diameter, interstitial aggregates of well formed crystals and irregular areas of dark-green aegirine augite. Biotite is relatively abundant in a fine-grained marginal phase. Pegmatites are rare, one small area on the SW margin of the intrusion contains alkali pyroxene, purple fluorite, bipyramidal crystals of brown zircon, and alkali feldspar (52262).

In general, the syenite is uniform and free from signs of internal structures; however, near the contact with the Julianehåb Granite it develops feldspar lamination striking parallel to the contact. In the centre of the intrusion there is a suggestion of weak mineral layering. A medium-grained variety of the syenite outcrops in the ground close to several small lakes near the centre of the intrusion. This is a modification of the normal syenite developed around numerous inclusions of altered quartzite and biotite-rich basic rocks. The inclusions have probably been derived from supracrustal rocks; it is to be noted that they are situated just to the north of a line marking the eastern continuation of the southern boundary of the main outcrop of supracrustal rocks near Igaliko (Plates 1 & 4).

The Østfjordsdal syenite was intruded at a relatively early stage in the history of Gardar igneous activity in the Igaliko area. It is cut by the earliest syenite of the South Qôroq Centre, by the later Igdlerfigssalik Centre syenite SI. 6, and by trachytic and lamprophyric members of the regional dyke swarm. However, it is younger than a group of NE-striking trachyte dykes which outcrop in the Julianehåb Granite around its margins. These alkaline dykes include several nepheline porphyries containing well-formed alkali feldspar and nepheline phenocrysts up to 2 cm in length. These dykes are petrographucally similar to the Fox Bay group of nepheline porphyries described by Ussing (1912, p. 272). Thus, there is evidence that some of the trachytic dykes in this ground are members of an early Gardar dyke swarm. From the evidence of the altered quartzite and basalt inclusions, the syenite was intruded after the rocks of the Eriksfjord Formation were deposited.

(e) The Iĝdlerfiĝssalik Centre

(i) Introduction

The syenites of the Igdlerfissalik Centre form two groups separated by the alkali trachyte and basic dykes of the Mid-Gardar swarms (Plate 4). There are three early syenites, SI. 1, SI. 2, and SI. 3, these outcrop on the northern margins of the centre. The later part of the centre is made up of four major nepheline syenite intrusions, SI. 4, SI. 5, SI. 6 and SI. 7. Disregarding that part of the centre now concealed by Qôroq, the total area is about 140 km², of which about 25 km² is accounted for by the early syenites. The centre includes some of the highest ground within the Igaliko Complex (fig. 1); Igdlerfigssalik (1752 m) rises abruptly from the fjord in the west, to the east the group of mountains around Agdlerulik and to the south is of similar height. The relief is considerable: Qôroq cuts through the NW edge of the centre, "Gieseckes Dal" lies along the NE, and the deep valley of Qôrorssuaq provides a magnificent section through the heart of the centre. A large proportion of the high ground corresponds to the outcrop of the coarse-grained syenite SI. 5.

Although the deep dissection of the centre has made it possible to obtain a fairly good three-dimensional picture of this part of the Complex, much of the ground was too steep for detailed work, particularly in view of the crumbling nature of the weathered syenites. As a consequence, the mapping is sketchy at a number of places, most notably on the SE side of Qôroq, on the NE of Igdlerfigssalik, and the steep slopes of the mountains south of Qôrorssuaq.

(ii) Syenite SI. 1

The outcrop of this syenite is restricted to a narrow strip of ground between Tunugdliarfik and Niaqornârssuk, on the west side of Qôroq. The normal rock is a grey or dark-grey medium-grained syenite with rectangular-sectioned feldspars up to 20 × 5 mm, small, interstitial chalky-white areas of nepheline and lustrous copper-brown biotite. Darker variants of the syenite often contain feldspar with pronounced schiller. In section the feldspar is frequently patchily clouded, it also contains small blebs and cuspate areas of nepheline or altered nepheline. Occasionally, there are plagioclase xenocrysts (An 45–50); these have clouded cores and mantles of complexly-intergrown nepheline, alkali-feldspar and aegirine augite. These xenocrysts appear as chalky-white crystals in hand specimen, they may be zoned with white outer rims and dull black cores. The mafic minerals in SI. 1 are pale coloured augite, olivine (Fo 15), red-brown biotite which sometimes forms a mantle about opaque grains, brown amphibole and accessory apatite.

The syenite generally lacks obvious internal structures but close to its outer margins, where the rock becomes very fine-grained, there is good vertical or steep feldspar lamination parallel to the contact; this is accentuated by the presence of small feldspar phenocrysts aligned parallel to the groundmass feldspars.

A few dyke-like bodies of coarse pegmatite cut the syenite on slabs near the fjord about 560 m WSW of Niaqornârssuk. They contain alkali feldspar, nepheline, natrolite, and well-formed prisms of black alkali amphibole (58187). It is not known if these pegmatites are a late phase of SI. 1, or are related to one of the later syenites.

As will be seen, there are many points of similarity between SI. 1 and the dark marginal phase of the late syenite SI. 4 exposed near Narssârssuk, south of Tunugdliarfik. In particular, the dark-colouration of rock containing schillerized feldspars, the occurrence of partially-digested andesine xenocrysts and the development of a fine-grained, laminated, slightly-porphyritic marginal phase, are features common to both. It is certainly tempting to equate the two areas; indeed, this has been done by the earlier investigators (USSING, 1912, Pl. IV; ØDUM, 1928, Pl. VII). There are, however, serious objections to this otherwise attractive correlation. The syenite SI. 1 at Niaqornârssuk is clearly older than syenite classified as SI. 3 (fig. 19). From the exposures south of Igánarssuánguaq, it is known that SI. 3 pre-dates the syenite SI. 4; furthermore, there is the evidence of the relative ages of SI. 3, SI. 4 and the Mid-Gardar dykes. At Narssârssuk there is no evidence to separate the dark syenite from other members of the SI. 4 suite; these form a continuous series (p. 60).

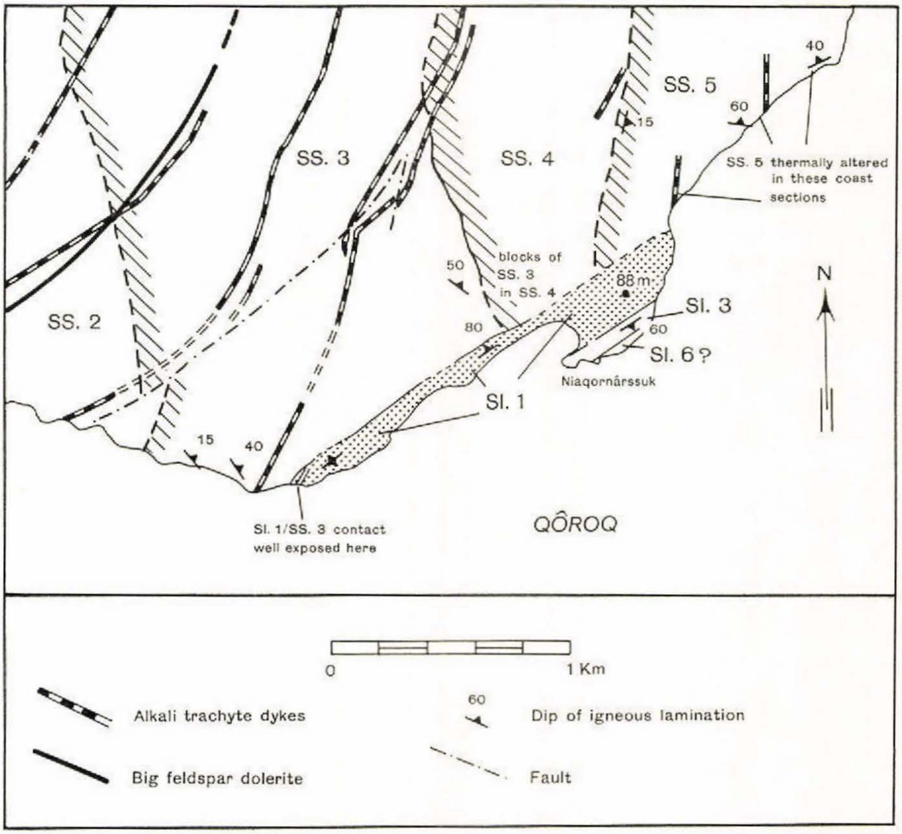

Fig. 19. Sketch map of the cross-cutting relationship of the syenite SI. 1, Igdlerfigssalik Centre, towards members of the South Qôroq Centre near Niaqornârssuk. (Outer margins of the South Qôroq syenites are shaded.)

(iii) Syenite SI. 2

This syenite forms most of the hill Igánarssuánguaq (577 m) and the lower slopes of "Gieseckes Dal" for 3 km to the east. It is typically an equigranular rock, with grain-size rarely exceeding 10 mm. Grey, perthitic alkali feldspar is accompanied by interstitial nepheline, which is not usually visible in hand-specimen unless the rock is slightly altered, and by aggregates of aegirine augite rimmed and partly replaced by alkali amphibole. A fine-grain variety of the syenite is exposed in a belt up to 50 m wide against the narrow strip of earlier SS. 5 and alkali gabbro exposed close to Qôroq. Internal structures are not common but well-developed feldspar lamination with mafic banding was found in a stream section about 1.2 km NE of Igdlerfigssalik summit (1752 m).

The contact between SI. 2 and SS. 5 is sharply intrusive, it transgresses the contact between SS. 5 and the alkali gabbro, and xenoliths of SS. 5 are present in the marginal SI. 2.

(iv) Syenite SI. 3

The outcrop of this syenite extends for over 12 km along the north side of the centre, yet its width rarely exceeds 1 km. A small area was found just south of the 88 m hill on Niaqornârssuk (fig. 19) but the syenite is best exposed on the SE shore of Qôroq due north of Igdlerfigssalik summit. The rock is characterized by numerous well-formed tabular crystals of alkali feldspar (to 30×8 mm). It is often extremely well laminated in a direction parallel to the line of outcrop, the lamination dips south at angles from 20° to over 70°, or SE at similar angles on Niaqornârssuk. Other minerals include rectangular crystals of nepheline often partially replaced by cancrinite, fayalitic olivine, aegirine-augite and alkali amphibole. The amphibole is interstitial in habit, it has developed partly at the expense of olivine and pyroxene. Close to SI. 2 a marginal phase of SI. 3 consists of a fine-grained dark-coloured syenite containing scattered irregular patches up to 5 cm diameter of coarse-grained pegmatite. This marginal phase may be of very restricted width, only 35 cm was measured in a stream section west of Agdlerulik but several metres was present in the stream section on the SE slopes of Igánarssuánguaq. In the upper reaches of this stream, coarse SI. 3 is cut by veins of the later syenite SI. 4.

(v) Age relations of the early Igdlerfigssalik syenites

Near the contact with earlier syenite the foyaitic SI. 3 becomes fine-grained and develops a patchy, pegmatitic texture closely similar to the marginal facies of other syenites in the Complex (*e.g.* SN. 5, SS. 5) and to the syenite SI. 6. Fine-grained marginal SI. 3 is in contact with equigranular, medium-grained SI. 2 in a stream section about 900 m ESE of the 577 m summit of Igánarssuánguaq and similar contacts can be found in the stream sections on the northern side of the Igdlerfigssalik mountain mass. The same syenite develops a similar marginal facies against dark-coloured SI. 1 on Niaqornârssuk, on the SE side of the 88 m hill; here, the relative ages are difficult to establish but SI. 3 becomes coarser away from SI. 1 and has a pronounced lamination (fig. 19).

The syenites SI. 2 and SI. 1 were not found in contact.

(vi) External margins of the early Igdlerfigssalik syenites

The contact between SI. 2 and SS. 5 near "Gieseckes Dal" is sharply transgressive. The syenite SI. 2 develops a fine-grained marginal facies in a zone up to 50 m in width, it cuts across structures in SS. 5 and also transgresses the contacts between SS. 5 and a later dyke of alkali-gabbro (Plate 4). Xenoliths of SS. 5 are also found in the marginal, fine-grained SI. 2.

The contact between SI. 1 and members of the South Qôroq Centre is well exposed at several places about 100 m from the shore between Niaqornârssuk and Tunugdliarfik. Although SI. 1 develops a fine-grained marginal phase against three different members of the South Qôroq Centre and is clearly the later intrusion, the detailed field relationships may be quite complex. This is exceptionally clear on the Tunugdliarfik coast section where the contact of SI. 1 with SS. 3 ends at the fjord. Here, the syenite SS. 3 has apparently been remobilised by the intrusion of SI. 1. The syenite SS. 3 shows unmistakable signs of alteration in several hundreds of metres of coast section: the feldspar and nepheline outlines are blurred and indistinct and the mafic minerals occur as fine-grained granular aggregates of deep-brown biotite and aegirine-augite. At the actual contact fine-grained marginal SI. 1 is cut by several irregular dykes and sheets of syenite originating in the zone of altered SS. 3. This contact is considered to show an example of rheomorphic veining closely comparable with the rheomorphic veining found at many contacts between late basic intrusives and earlier acid rocks (Hughes, 1960; Wadsworth, 1961). Indications of similar back-veining are found at intervals to the NE but exposure is not sufficiently continuous to determine the relations in detail. In addition to SS. 3 both SS. 4 and SS. 5 show unmistakable signs of thermal alteration near SI. 1. In SS. 5, ill-defined fine-grained granular aggregates of biotite and aegirine-augite are common in place of the normal mafic minerals for several hundreds of metres in shore sections NE of Niaqornârssuk, this alteration is attributed to a NE extension of SI. 1, now concealed by Qôroq.

(vii) Syenite SI. 4 (Augite Syenite)

This syenite is the oldest of the four syenites making up the younger group of syenites in the Igdlerfigssalik Centre. It is the Augite Syenite of Ussing (1912, p. 238) and earlier workers. The syenite is well exposed from the southern side of Tunugdliarfik to the slopes of Tavdlorutit about 7 km ESE of Igaliko village. It also forms a narrow strip extending from the SE side of Qôroq along the northern slopes of Igdlerfigssalik, parallel with the outcrop of SI. 3 as far as the western slopes of Agdlerulik. The exposure of this strip is poor except in stream sections but further west it is once more well exposed near Qôroq and in the col between Igdlerfigssalik and Igánarssuánguaq.

A variety of rock-types is present within the unit mapped as SI. 4. Although several of the variants were quite distinctive and could be followed for considerable distances, no internal intrusive contact was found; complete gradation exists between the different varieties. Detailed mapping south of Tunugdliarfik showed that there is a regular distribution to the varieties within SI. 4 which, in general, strike parallel to the outer margin of the intrusion. The junctions between the variants, and their internal structures, are steeply inclined or vertical near the margin of the centre but eastwards they tend to decrease in dip to a moderate angle towards the east or SE. The internal variation of SI. 4, the complex relationships between the syenite and the country rocks, and the occurrence of the celebrated pegmatites at Narssârssuk make this area one of the most varied and interesting in the Complex.

The principal variants distinguished in SI. 4 in the Narssârssuk area will now be described, their distribution is shown on the large-scale map (Plate 2).

Dark biotite-rich syenite:

This syenite outcrops in a belt about 300 m wide, it is found throughout the area mapped in detail but it diminishes rapidly in thickness near the river section 1.3 km south of Narssârssuk and was not recognised during the mapping further south, near Igánaq.

The typical rock is dark-coloured with abundant mafic minerals including biotite, fayalitic olivine, pale brown augite and brown amphibole. Well-formed rectangular crystals of alkali feldspar vary in size up to 40×10 mm, they may have schiller structure. Nepheline is not seen in hand specimen, a few small interstitial areas are present in section and small amounts occur within the feldspar. Scattered large xenocrysts of black plagioclase (ca. An 45) occur throughout the syenite; good examples may be seen near the base of the cliff about 400 m ENE of the 25 m spot height near Tunugdliarfik (Plate 2). At this locality, and elsewhere, there is a certain amount of thin vertical mafic banding, in the cliff section it is possible to verify that the plagioclase xenocrysts and phenocrysts of alkali feldspar have a random orientation within the plane of the layered structures.

The syenite is fine-grained towards its contact with the supracrustal rocks to the west; the contact facies shows good lamination and may contain small feldspar phenocrysts which are also laminated. Xenoliths are rare in this syenite except near the outer margin where there are occasional fragments of the country rocks.

Pale syenite:

The contact between this syenite and the eastern edge of the dark syenite is sharp (63869) but neither syenite shows any modification towards the other, nor are there any intrusive structures. The mineralogy of the pale syenite is similar to that of the dark variant except that the proportion of mafic minerals is very much reduced. The feldspars are rather less well formed, they sometimes show good schiller structure. Thin mafic bands were found at sevaral places, notably near Narssârssuk; they are steep, striking more or less parallel to the syenite margin.

Layered, dark syenite:

This group of rocks was rather ill-defined in the field. It is often fine-grained and slightly more mafic than the pale-coloured syenite, but the general mineralogy is very similar. The rock may become quite dark in places, usually with the development of conspicious biotite, but it has never been found containing the black feldspars that are quite common in the dark, biotite-rich syenite. The syenite becomes very much finer grained in the mafic banded parts. Here, the feldspar crystals are only 2–4 mm in length and the mafic minerals not much over 1 mm diameter.

Mafic banding is a conspicious feature of this variant. The mafic bands are about 5 mm thick, spaced 10 mm apart and rhythmically-repeated; gravity stratification is virtually absent. The structures are vertical or else steeply inclined to the east, they strike parallel to the syenite margin. Certain of the intensely-banded mafic structures have curving, contorted forms with steeply inclined axes; in these areas arc-like banded structures are found to be truncated by other curving structures (fig. 20). Usually the structures are concave towards the east, and cut-offs occur in this direction, but examples are known where the curved bands are concave to the west. These structures bear a strong resemblance to steep mafic banding in the Eastern Border Group of Kûngnât (Upton, 1960).

Layered and laminated syenite:

In the area mapped in detail, this variant of SI. 4 appears to be confined to the lower ground close to Tunugdliarfik. The syenite is extremely well laminated and layered, both structures are concordant. The typical rock contains thin tabular alkali feldspars (up to 50×5 mm in section), interstitial nepheline, pale green clinopyroxene with deep green aegirine augite fringes, opaques and dark brown botite.

The syenite outcrops in two areas separated by the cone of alluvial débris deposited by a fast-flowing stream. The more northerly area,

Fig. 20. Steep layering in marginal syenite SI. 4 near Narssârssuk. Banded structures on the right transgress more regular banding on the left; the outer contact of the syenite lies off the left of the photograph. Scale: hammer shaft = 35 cm long. (Photo: C.H.E., GGU.)

next to Tunugdliarfik, is about 150 m in width. It consists of strongly laminated and banded syenite in which the structures dip SE at 25° to 40°. To the south of the stream the syenite forms a series of crumbling outcrops in the steep slopes and crags about 800 m north of Narssârssuk

Fig. 21. Mafic layering in the syenite SI. 4, Igdlerfigssalik Centre. Shore section on the south side of Tunugdliarfik, near the mouth of Qôroq. Scale: hammer head 15 cm long. (Photo: C.H.E., GGU.)

(275 m point). The outcrop width narrows south until the variant disappears in the slack ground south of the cliffs. At the same time, when followed south, the well-laminated, banded rock at the base of the cliff gradually loses its tabular feldspars in favour of anhedral crystals, the lamination is gradually and the banding increases in dip until it is almost vertical at the top of the cliffs about 400 m north of Narssârssuk. By this stage the character of the rock has so changed that it now resembles the layered dark-coloured syenite variant into which it grades.

Several large inclusions and areas of inclusions were found in the layered and laminated syenite. A large xenolith of anorthositic gabbro is present at about 170 m altitude in the cliff face north of Narssârssuk, together with several small piecøs of similar rock. The structures in the laminated syenite wrap around the inclusions. A group of similar smaller xenoliths is present in the syenites close to Tunugdliarfik (fig. 22). Again, the inclusions are separated by well laminated syenite in which the structures appear to flow around the inclusions. Lamination is disturbed in the syenites immediately below the inclusions but undisturbed layering and lamination occur in the syenites immediately above the inclusions (fig. 22, b). From these relations it is concluded that the xenoliths were incorporated in the syenite during the formation of the layered and laminated rocks. The xenoliths

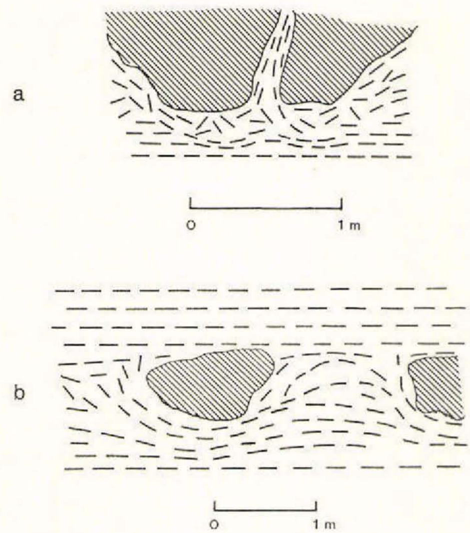

Fig. 22. Diagram showing the mafic inclusions in the layered and laminated syenite SI. 4 on the south side of Tunugdliarfik. Structures in the syenite either side of and below the blocks are disturbed while the layering and lamination in the overlying syenite is completely undisturbed.

include biotite-rich basic rocks (63805) comparable with the altered basic sheets in the country rocks adjoining the centre, black anorthosites (63811), and blocks that probably were derived from Big Feldspar Dykes (63809, 63811).

Syenite with rare tabular feldspar phenocrysts:

The hand specimens of this syenite resemble some of the more leucocratic varieties of the dark-coloured layered syenite. The distinguishing feature is the presence of scattered thin phenocrysts of alkali feldspar. The feldspars measure about 40×7 mm in section, they are pearl-grey coloured in hand specimen and are often slightly schillerized. A common feature is the presence of a small granular inclusion of mafic minerals arranged zonally towards the edges of the crystals.

The outcrop of this syenite is restricted to a narrow strip of ground north of Narssârssuk, and on the north side of the stream near Tunugdliarfik (Plate 2).

Syenite with abundant tabular feldspar phenocrysts:

This syenite forms an extensive tract about 1 km wide to the east of Narssârssuk; the width narrows towards the south as the syenite is gradually cut out by the thin dyke-like SI. 6 intrusion. Internal structures are virtually restricted to weak developments of mineral layering; despite the abundance of tabular crystals of alkali feldspar, mineral lamination is not common. The layered structures dip east at moderate to steep angles, in the northern part of the outcrop the angles are between 35° and 55° but steepen to the south where layering is in any case much less common.

The mineralogy of the syenites of this group is similar to the previously-described group except that there is more nepheline present. It occurs as anhedral interstitial areas, and as blebs and small cuspate patches intergrown with the feldspars. Sometimes it is also found as myrmekite-like intergrowths within an alkali feldspar host (42000). Clinopyroxene in this group is often crowded with oriented rod-like areas of opaque minerals.

Syenite with macroscopic nepheline:

In the Narssârssuk area the outcrop of this syenite is restricted to the ground between the main outcrop of the syenite SI. 6 and the thin, dyke-like intrusion of the same syenite to the west (Plate 2; fig. 23). In this area it attains a width of about 800 m to the south, northwards it is cut out completely by the SI. 6 intrusions near the col about 1 km due east of Narssârssuk.

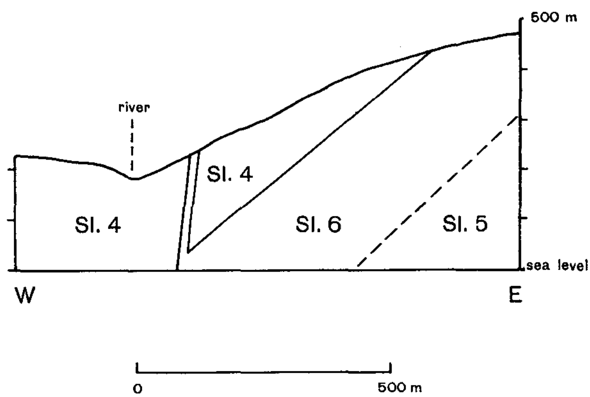

Fig. 23. Diagram showing the downward-termination of a wedge of the syenite SI. 4 (variety with macroscopic nepheline, Plate 2) between two arms of the syenite SI. 6, SE of Narssârssuk, Igdlerfigssalik Centre.

The normal syenite is a coarse-grained grey rock with well-formed rectangular feldspars to 25×10 mm; these are often strongly perthitic, with slight alteration and selective weathering the coarse albitic streaks may be visible in hand specimen. Nepheline occurs in irregular interstitial areas, similar to (42000) but in much greater abundance; it is also intergrown with the alkali feldspar on a fairly coarse scale. In several specimens the intergrowth of alkali feldspar and nepheline resembles granophyric texture (87109). The mafic minerals are fayalitic olivine,

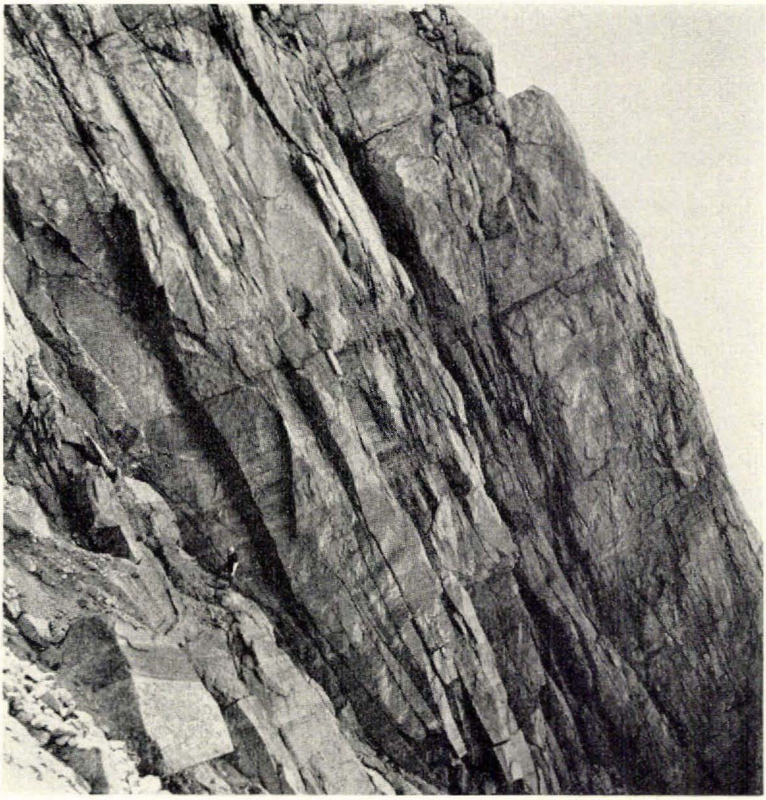

Fig. 24. Large-scale mafic layering in the syenite SI. 4 on the SE. side of Qôroq, about 2.5 km NW of Igdlerfigssalik. The principal structure is planar rhythmic layering, often with gravity stratification. Some cross-cutting through banded structures were also observed. Scale: figure near bottom left. (Photo: W.T.H., GGU.)

a green to deep green sodic clinopyroxene, interstitial brown amphibole, and in some sections a blue to blue-green amphibole is present as rims about olivine. Opaque minerals are often abundant and well formed; biotite and apatite are generally present in accessory quantities.

This syenite is not usually laminated, but zones of intense mafic banding are common. The bands are vertical or very steep-dipping. In section, the mafic rocks contain euhedral pale green clinopyroxenes, opaque minerals and apatites, enclosed by anhedral alkali feldspar, nepheline and brown amphibole; the well-formed pyroxene may be mantled by an irregular margin of deeper green sodic pyroxene (87108). Olivine is also present in some of the mafic rocks.

SI. 4 on the SE side of Qôroq:

The SI. 4 outcrops north of Narssârssuk cease at Qôroq, about 700 m ENE of the river mouth at Qinguassakasik. After a gap of about

Fig. 25. Layering in the syenite SI. 4 on the SE side of Qôroq seen from Niaqornârssuk. Thick, repeated mafic layers, dipping from left to right, are visible on the left; apparently horizontal structures are seen in the centre of the photograph near the fjord. The steep cliff in the right of the photograph is about 500 m high. (Photo: C.H.E., GGU.)

2.5 km they reappear to the NE of Nûgssuánguaq in cliff exposures and steep slopes on the side of the fjord. SI. 4 is present as a thin veneer backed by later SI. 6 and SI. 5 on the NW side of Igdlerfigssalik. In this area the syenite SI. 4 is very strongly layered, thick mafic banded structures dip south at from 30° to 45° (fig. 24), the layering is so extensive and conspicuous that it is seen clearly from Niaqornârssuk (fig. 25). The layering is mostly as planar structures up to 3 m thick, separated by leucocratic syenite of similar thickness; the layered sequence was observed through a vertical distance of about 200 m. A few examples of transgressive structures in the layering, and of trough banding were found; the section as a whole is highly reminiscent of the structures developed in parts of the Western Lower Layered Series of the Kûngnât Complex (Upton, 1960). In the mafic rocks cumulus fayalitic olivine, dull-green clinopyroxene, opaque minerals and apatite are enclosed by poikilitic or anhedral cryptoperthitic alkali feldspar, smaller amounts of nepheline and by analcite. Brown, poikilitic amphibole is usually present. The clinopyroxene may be mantled by an irregular border of bright green sodic pyroxene. The mineralogy of the associated leucocratic bands is similar except that the alkali feldspar is generally subhedral and amphibole is uncommon.

The exposures of SI. 4 on the south side of 'Gieseckes Dal'' are of leucocratic syenite containing occasional steeply-inclined thin mafic layers. The marginal fine-grained syenite of this area is in sharp intrusive contact with SI. 3; near the col about 1 km SW of Igánarssuánguaq (577 m) thin, dyke-like apophyses of SI. 4 intrude coarse-grained SI. 3.

SI. 4 near Igánaq:

The syenite exposed between the southern continuations of the two dyke-like intrusions of SI. 6 is similar to the variety of SI. 4 with macroscopic nepheline found east of Narssârssuk. The hand specimen characteristics persist and the syenite contains narrow, north–south striking bands of mafic layered rock, dipping steeply or else vertical and occasionally showing highly contorted structures.

SW of the outer edge of the westerly SI. 6 dyke much of the syenite resembles the variety with tabular crystals of alkali feldspar that occupies most of the ground east of Narssârssuk. Strongly banded rocks are also present, as in the stream section at the west end of Qôrorssuaq, these are tentatively correlated with the dark-coloured layered group that forms a narrow continuous outcrop due south of Narssârssuk.

The marginal dark-coloured syenite was not recognised south of Igánaq; indeed, this variety appears to die out at, or just south of, the river section about 2 km NNW of Igánaq. The ground near and south of Igánaq has not been mapped in the same detail as at Narssârssuk so it is possible that some of the groups recognised to the north are present but have escaped recognition.

(viii) Syenitic rocks intruding SI. 4 near Narssârssuk

Two distinct varieties of syenitic and microsyenitic rocks cut the syenites near Narssârssuk. They are a group of sheets and dykes of extremely leucocratic syenite and pegmatite, and several dykes and an extensive sheet of porphyritic microsyenite. The leucocratic syenites are later than the porphyritic microsyenite since they cut the latter about 0.5 km north of Narssârssuk (Plate 2).

The leucocratic syenite is a very conspicuous rock, it is highly feldspathic, consisting almost entirely of pale cream-coloured or white alkali feldspar; it weathers to give a light-coloured, coarse feldspathic gravel. Although sometimes pegmatitic, the rock is generally coarse-grained with tabular perthitic feldspars 3 cm long, together with small crystals of aegirine-augite, sphene and albite. Alkali amphibole and astrophyllite may be present.

The porphyritic microsyenite forms a continuous thin sheet extending from the south shore of Qôroq to the stream section about 1.8 km south of Narssârssuk. The section from Narssârssuk north to the fjord forms a 20–30 metre thick sheet dipping east at much the same angle as the SI. 4 varieties but south of Narssârssuk the porphyritic microsyenite thins to a few metres, becoming dyke-like and steep and irregular in detail. A few thin dykes of the microsyenite cut SI. 4 east of Narssârssuk.

In section, the phenocrysts are perthitic or cryptoperthitic alkali feldspar. Small rounded or subhedral crystals of mafic minerals may be arranged zonally about an inclusion-free core. Both phenocrysts and groundmass feldspar may show flow-alignment; both may display very fine grid twinning resembling anorthoclase. The mafic minerals are pale green to green clinopyroxene, anhedral crystals of blue-green or dark brown alkali amphibole, apatite and opaque minerals with a thin mantle of red-brown biotite. Olivine is occasionally present. No nepheline was found but there is interstitial analcite.

The porphyritic microsyenite thickens at Narssârssuk, with the development of a north-south striking lobe on the eastern side. This lobe is about 400 m long and between 100 and 150 m from east to west. Within this lobate area only a small part of the rock is actually porphyritic microsyenite, it is restricted to the marginal zone where it appears to form an envelope, surrounding the Narssârssuk pegmatite body and everywhere separating it from the syenite SI. 4. The microsyenite is clearly intrusive towards the syenite SI. 4 but has equivocal relations with the pegmatite.

The porphyritic syenite also contains numerous large xenoliths of SI. 4, and rounded to sub-angular masses of anorthosite and anorthositic gabbro, as in the cliff exposures about 600 m north of Narssârssuk and again about 150 m north of the pegmatite locality (Plate 2). 500 m south of Narssârssuk a very large anorthosite inclusion in the microsyenite measures 60 m NNW–SSE and up to 20 m ENE–WSW. It consists of dull pale grey or chalky white plagioclase and interstitial epidote.

(ix) The structure of SI. 4 at Narssârssuk

The most marked feature of the syenite SI. 4 in this area is the rapid variation in syenite type in a series of zones more or less parallel to the contact with earlier rocks. Although the different zones are relatively easily distinguished they do not display intrusive contacts towards one another; all the field evidence points towards complete gradations at their junctions.

A possible explanation of these features may be found in the changes encountered between the pegmatite locality at Narssârssuk and the exposures in the low ground between the south side of Tunugdliarfik and Qôroq, and the cliffs a short distance to the south. Near the fjord the syenite is well layered and laminated; by analogy with other syenites in the Gardar province it is most probable that the syenite formed by bottom accumulation during the crystallization of SI. 4; that is, this syenite is a layered intrusion that once formed a steep-sided stock but is now much reduced in outcrop by later intrusions. The position of the syenites at Narssârssuk is clearly marginal; the interpretation put on them is that in large part they represent a Border Group analogous to the Border Group of the Skaergaard Intrusion (WAGER & DEER, 1939), providing a condensed sequence through part of the concealed layered rocks of SI. 4. Due to the topography and later intrusions it is only near the fjord, and possibly NE of Narssârssuk, that one can find a section of the layered syenites that must once have made up the bulk of SI. 4, although the strongly banded syenite NW of Igdlerfigssalik clearly forms a part of the layered series. At Narssârssuk, the key to this interpretation lies in the structural and petrographic changes between the layered and laminated group and the dark-coloured layered group.

(x) Pegmatites associated with SI. 4

Pegmatites are uncommon in SI. 4. The celebrated Narssârssuk pegmatite lies wholly within SI. 4, but it appears to be closely related to the post-SI. 4 intrusion of porphyritic microsyenite (Plate 2).

Small pegmatite-lined veins were found at several places near Narssârssuk. A coarse feldspathic pegmatite outcrops on the right-hand bank of the small river about 1400 m SSE of Narssârssuk, another was found on the north side of the same river 1750 m S 20° E of Narssârssuk. Here, the pegmatite body is a dyke-like mass about 1 m in width with elongate crystals of aegirine, pink natrolite, nepheline, alkali feldspar and aggregates of golden-brown astrophyllite (63986).

(xi) Syenite SI. 5

This coarse-grained, massive syenite builds the group of mountains which include Igdlerfigssalik (1752 m) and the arc of mountains south of Agdlerulik, on the southern side of Qôrorssuaq. The hillsides are often steep with slabs or a covering of scree; several small glaciers occupy high north facing valleys on Igdlerfigssalik and steep NW facing valleys in the mountains east of Qôrorssuaq.

The syenite SI. 5 is remarkably uniform throughout its outcrop. The principal minerals are stoutly prismatic perthitic alkali feldspar up to 40×10 mm, fairly abundant nepheline in white-weathering anhedral crystals about 10 mm across, fayalitic olivine, soda-bearing clinopyroxene zoned outwards to deep-green margins of aegirine-augite, alkali amphibole, opaques and occasional biotite. Small amounts of pink natrolite are often present. The alkali feldspar, olivine and cores to the pyroxenes are generally well-formed, nepheline is moulded on feldspar but can be euhedral. Analcite and natrolite are invariably interstitial. In hand specimen the mafic minerals appear anhedral but this is partly the result of overgrowths on clusters of fairly well-formed or rounded olivine, pyroxene and opaques. Bright green aegirine-augite and blue green or brownish green alkali amphibole develop as overgrowths on the clusters extending outwards between the nepheline and feldspar to give mafic areas with irregular, poikilitic outlines.

Preferred orientation of the minerals is uncommon in SI. 5, but several localities were found where there is distinct feldspar lamination and at a number of places mafic mineral layering was also mapped. These structures are generally steeply dipping towards the centre of the intrusion or else are vertical; at a few places steep outward dips were encountered. The layered structures were usually formed by concentrations of euhedral olivine, zoned clinopyroxene, opaque minerals and apatite. In a few instances however, the cumulus mafic minerals were interbanded with thin, relatively leucocratic layers where nepheline was an important cumulus phase (43804).

Although the syenite SI. 5 is remarkably homogenous, a number of variants were recognised. Of these, the most conspicuous and the commonest is a dark-coloured porphyritic rock containing feldspar phenocrysts up to 50×15 mm. These are set in a fine-grained, granular matrix of olivine, green clinopyroxene, nepheline, and perthitic alkali feldspar (41922). This variety is widely distributed. It is found in a belt at about 650 m altitude on the western slopes of Igdlerfigssalik, several sheets are present in SI. 5 at and near the pass at 1100 m between the 1640 m and 1650 m peaks SE of Qôrorssuaq, and many sheets were mapped in the stream section SE of this pass. The variant is particularly extensive in the lower parts of this stream section, near the river junction at 540 m where it appears to constitute a marginal zone to SI. 5. This porphyritic variant probably constitutes a mappable unit within SI. 5; however, no attempt has been made to separate it except near Igdlerfigssalik. A complete gradation into normal SI. 5 was found at the large number of contacts examined; because of this the porphyritic syenite is considered to be an integral part of SI. 5.

Irregular areas of a patchy, pegmatitic syenite resembling the syenite SI. 6 occur within SI. 5. These areas, which can be as much as twenty metres in diameter, are sporadically developed at a number of places. Some of the clearest examples were found on the SW slopes of the Igdlerfigssalik massif, about 2.5 km NNE of Igánaq. Although the variant is petrographically identical with the syenite SI. 6 (see p. 90), there is always a complete passage into normal SI. 5.

(xii) The relationship of SI. 5 to earlier rocks

There is no true marginal variant to SI. 5. The syenite was not found in contact with earlier rocks; the later syenite SI. 6 intervenes everywhere between SI. 5 and the older rocks no matter whether these are the Julianehåb Granite, the satellitic syenites, or earlier members of the Igdlerfigssalik Centre. The possibility that SI. 5 and SI. 4 form part of the same intrusion, now separated by the SI. 6 ring-dyke, was examined. It is difficult to find support for this suggestion despite the very narrow width of the SI. 6 intrusion. There is little resemblance between SI. 4 and SI. 5 in relatively close outcrops and, furthermore, the combined SI. 5 and SI. 6 outcrop is transgressive towards SI. 4 (Plate 4). The only place where an approach to a marginal phase was found in SI. 5 is the river section near the Østfjordsdal syenite but even here a thin body of SI. 6 is interposed between SI. 5 and the altered Julianehåb Granite.

(xiii) Syenite SI. 6

The syenite SI. 6 is characterized by a distinctive patchy appearance, caused by the formation of irregular coarse-grained or pegmatitic areas about 20 cm in diameter in relatively fine-grained surroundings (fig. 26). There is not usually any directional structure to the rock fabric except in the marginal parts where the coarse-grained areas may be elongated parallel to the contacts.

The normal medium-grained syenite consists of perthitic alkali feldspar, nepheline, fayalitic olivine (frequently with a mantle of blue-green alkali amphibole), clinopyroxene zoned outwards to a green or bright green sodic rim, apatite, and opaque minerals. The coarse-grained areas often consist of an outer zone of leucocratic rock with alkali feldspar and nepheline in crystals up to 3 cm long and small amounts of interstitial alkali pyroxene or alkali amphibole. The central part contains alkali pyroxene, alkali amphibole, aenigmatite, natrolite and other minerals. The succession of crystallization in the mafic minerals is noteworthy: the euhedral olivine is mantled by blue-green amphibole, the original colourless or pale-green clinopyroxene is zoned outwards to a deeper green sodic pyroxene or else the sodic pyroxene is intimately-intergrown with the pale-coloured cores suggesting a replacement relationship. The sodic pyroxene is rimmed by deep green to blue-green alkali amphibole, this is zoned to a clear blue-green alkali amphibole not unlike the amphibole rimming the olivine. Finally, the amphibole may be mantled by, or intergrown with clear green to yellow-green aegirine. Large anhedral crystals of deep red-brown aenigmatite are closely associated with the mafic minerals, they appear to have formed at much the same stage as the deep-green alkali amphibole or else slightly later. The crystallization sequence in the mafic minerals is broadly similar to that deduced for the alkali rocks of Tugtutôq (Upton, 1964a, p. 46–47) although there are differences of detail. A very similar

Fig. 26. Patchy pegmatitic structure in the syenite SI. 6. Locality in stream section about 1 km east-south-east of Qinguassakasik, Igdlerfigssalik Centre. Scale: ruler = 1 metre. (Photo: W.T.H., GGU.)

sequence is observed in the coarser parts of SI. 5, especially in the variant with pegmatitic patches.

The syenite SI. 6 forms a virtually complete ring dyke about 35 km in circumference, completely enclosing the earlier syenite SI. 5. There is a duplication of the dyke for about 6 km near Igánaq and Narssârssuk, and there are also minor off-shoots and parallel sheets within SI. 5, and intruding SI. 4 on the SE side of Qôroq. The ring-dyke has an outcrop width of about 600 m on the SW of Igdlerfigssalik, it is thinnest on the eastern side where it may be as little as 30 m in width near the Østfjordsdal syenite.

(xiv) The relationship of SI. 6 to earlier rocks

Sharp, cross-cutting contacts between SI. 6 and earlier SI. 4 were found at several places. 1.5 km NNE of Igánaq well-defined eastward-dipping feldspar lamination in SI. 4 is sharply truncated by marginal

Fig. 27. Sharp contact of the syenite SI. 6 against SI. 4. Hillside about 1.3 km northeast of Igánaq, Igdlerfigssalik Centre. Scale: hammer head 15 cm long. (Photo: C.H.E., GGU.)

SI. 6 (fig. 27), the contact dips WSW at about 60°. Another sharp contact is well exposed in a cliff section on the SE side of Qôroq 2.8 km NW of Igdlerfigssalik (1752 m). Here, strong mafic banding in SI. 4 dips SE at about 35°. The layered structures terminate against marginal, later SI. 6 dipping to the NNW at about 60°. Where SI. 6 is in contact with SI. 4 and earlier rocks at its outer margin, it is a fine- to medium-grained rock which retains its characteristic patchy appearance although on a smaller scale; it is often somewhat darker than the normal SI. 6

and bears a close similarity to certain of the more sparsely porphyritic examples of the porphyritic, dark-coloured facies of SI. 5 (p. 71).

The contacts between SI. 6 and SI. 4 near Igánaq and Narssârssuk vary in attitude. The thin westerly intrusion of SI. 6 is steep-sided with either a steep westerly dip or else nearly vertical margins. The outer margin of the thicker easterly part of SI. 6 is inclined west at about 50°. If these attitudes are maintained to any depth, the strip of nepheline-bearing SI. 4 between the SI. 6 intrusions must have a limited downward extent, probably not more than 250 m below the present surface in the vicinity Narssârssuk (fig. 23).

It was frequently difficult to interpret the contacts of SI. 6 with the syenite SI. 5. There is no marginal modification to SI. 5 next to SI. 6, nor was there often any obvious change in SI. 6 at its outer margins next SI. 5. However, unequivocal evidence for the later age of SI. 6 was found at several places. The contact is exposed at about 480 m altitude in a stream 1800 m N 20° E of Igánaq. It is vertical, sharply defined and in detail it is slightly irregular. Over a distance of 30 m from SI. 5 the coarse-grained patches in SI. 6 become evenly-spaced, smaller and less distinct. For 2 cm next to the contact, SI. 6 is a fine-grained, rather mafic equigranular rock. On the south side of "Gieseckes Dal", SI. 6 is found in sharp contact with SI. 5 in a stream section 2 km N 47° E of the 1752 m summit of Igdlerfigssalik. Here, SI. 6 is fine-grained, enriched in mafic minerals and contains rounded xenoliths of unmistakable SI. 5. At another locality on the NW side of the northern end of Qôrorssuaq both syenites are seen in steep-sided sheets in a cliff section about 2.8 km NE of the 1505 m summit of the Igdlerfigssalik massif. Close examination of the outcrop showed that steep, northward-dipping dyke-like bodies of SI. 6 cut SI. 5 enclosing rounded xenoliths of the coarse-grained syenite. There is, therefore, little doubt that SI. 6 is the later of the two syenites although it is probable that no great interval of time separated their intrusions.

(xv) Syenite SI. 7

This is the youngest major intrusion in the Igaliko Complex. It forms a steep-sided stock about 7 km from NW to SE and 5 km from NE to SW. It is situated in the centre of the Igdlerfigssalik Centre with its outer margins everywhere in contact with the syenite SI. 5. The only intrusions which cut it are a curving dyke-like intrusion of alkali gabbro, a few thin dykes of mafic syenite either side of the northern lake at 570 m in Qôrorssuaq, and several Late-Gardar alkali trachyte and lamprophyre dykes.

The syenite SI. 7 is a medium-grained, generally leucocratic foyaite. It is characterized by thin tabular crystals of perthitic alkali feldspar to

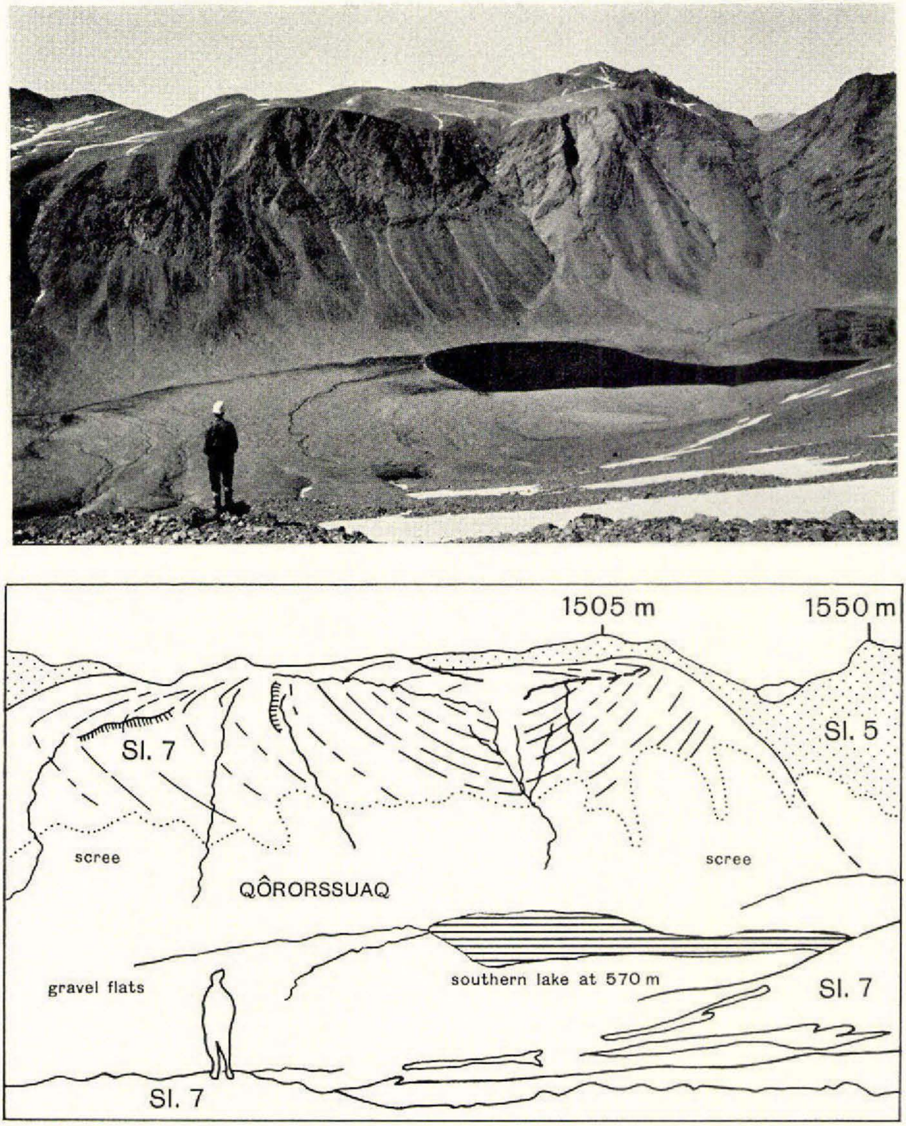

Fig. 28 a & b. Layered structures in the syenite SI. 7. View from the south-east side of Qôrorssuaq looking towards Igdlerfigssalik. (Photo: C.H.E., GGU.)

15×3 mm, small, fairly well-formed nepheline crystals, interstitial analcite and some cancrinite, and rather anhedral to poikilitic areas of mafic minerals. The mafic minerals are a green sodic pyroxene often present as relics within dark green to brownish-green alkali amphibole. Small amounts of biotite are generally seen, together with opaques and apatite. Certain of the rocks have a distinctive, spotted appearance with poikilitic amphibole enclosing alkali feldspar and perfectly formed small nephe-

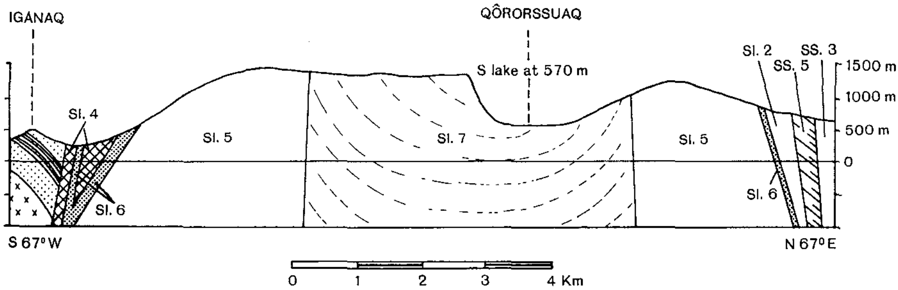

Fig. 29. Cross-sectio through the Igdlerfigssalik Centre from Igânaq to a point near the northern end of Qôrorssuaq.

line crystals. Olivine is comparatively rare but olivine-bearing SI. 7 does occur, especially near the southern edge of the intrusion. Slight variations in the amount of mafic minerals, their relations to the other minerals, and general variations in grain-size of all minerals combine to produce a fairly wide variety of rock types within the SI. 7 intrusion.

The various syenites within SI. 7 form a series of thick layers, each in the shape of a shallow saucer with slightly upturned margins generally dipping at 50°–60° although steeper dips are recorded. These saucer-like layers are stacked one on top of another to form a superb series of layered rocks within the steep margins of the stock-like intrusion; the layering is well-exposed in the steep cliffs on the NW side of Qôrorssuaq (fig. 28 a and b; fig. 29). Within each of the major layers there is broadly conformable feldspar lamination and rather infrequent small-scale mineral layering.

(xvi) Inclusions in SI. 7

Close to the edge of SI. 7, on the north of Tavdlorutit, there is an area several hundreds of metres in length where the syenite contains a profusion of large and small inclusions of a rock with rectangular, chalky-white to dull black plagioclase crystals to 5 cm long, biotite, alkali feldspar. There are also blocks of altered anorthosite (43880). The inclusions resemble the altered anorthosites and Big Feldspar Dykes present within SI. 4 and associated intrusions near Narssârssuk.

(xvii) The contact between SI. 5 and SI. 7

The steep-sided junction between the two syenites is well exposed at each end of the long cliff on the NW side of Qôrorssuaq (fig. 29). It is also found over a considerable vertical extent on the saddle-like twin peaks (1610 m) east of the valley. In all places the contact is found to have a steep outward dip of the order of 75°–80°.

Fine-grained SI. 7 is in sharp contact with normal SI. 5 about 1 km ESE of the 1475 m summit of the Igdlerfigssalik massif. At the contact, the normally flat-lying lamination of SI. 7 steepens next to SI. 5 until it is vertical at the contact. In exposures in a small stream 1500 m NNE of Tavdlorutit (1588 m), coarse- and medium-grained syenite xenoliths resembling SI. 5 are enclosed by a patchy-textured marginal facies of SI. 7. Elsewhere, SI. 7 has been found invading SI. 5, detaching single crystals and small fragments of the coarse syenite. Thus, SI. 7 is clearly later than, and intrusive towards, the syenite SI. 5.

(xviii) The margin of the centre between Tunugdliarfik and Tavdlorutit

The marginal relationships south of Tunugdliarfik are more varied and complex than elsewhere in the Igaliko Complex. The western edge of the syenite SI. 4 is in contact with earlier Gardar dykes, members of the Eriksfjord Formation, and Julianehåb Granite over a distance of about 8 km. The syenite is cut by several trachytic dykes as well as by sheets of leucocratic syenite, microsyenite and pegmatite. In addition, the syenite and the earlier rocks are thoroughly brecciated at two localities. The events fall into two groups: first, those that probably accompanied the emplacement of the syenite SI. 4 and, secondly, events that definitely post-date this syenite.

Events pre-SI. 4 and contemporaneous with the emplacement of SI. 4:

The succession in the country rocks has already been outlined: Julianehåb Granite is unconformably overlain by Igaliko sandstone, intercalated with which are three basic sheets. West of the Complex, the supracrustal rocks are generally flat-lying, but in a zone up to 1 km in width next to the syenite there is a progressive increase in dip eastwards, reaching 60° E next to the syenite (fig. 3). This steep inclination towards the syenite probably led Ussing to interpret the syenite as overriding the earlier rocks at Narssârssuk and in the Igánaq area (Ussing, 1912, p. 252, figs. 21, 22). The recent detailed mapping has shown that the syenite contact has an outward dip of about 60° to the WSW at Igánaq; similar steep westerly dips at the edge of SI. 4 are found south of Tunugdliarfik. Near this fjord the curving line of the contact gives a superficial impression of an easterly dip but the steep westerly dip may be verified in the cliff section.

The structure in the contact zone resembles a sag or subsidence of the sediments towards the syenite (fig. 3). No unequivocal explanation of the downfolding presents itself; two possible causes may be considered. It is possible that the structure results from downdrag during the subsidence of a large block of country rock at the time of the emplacement of SI. 4; another possibility is that there has been downwards sag of the supracrustal rocks when the underlying Julianehåb Granite was weakened and partially mobilised on the emplacement of SI. 4. At present it is not possible to prove or disprove either mechanism. No shearing or small-scale faulting has been found in the country rocks next to SI. 4 such as might have been expected had the former mechanism operated; in particular, there was no field evidence to support the contention that a fault, or series of faults, separates the flat-lying supracrustal rocks from the steep-dipping altered rocks near the syenite. Some support for the second suggestion is to be found in the numerous acid veins that cut the quartzites and metabasalts, occupying a well developed series of tension cracks in the contact zone. However, the amount of acid material in these sheets, dykes and veins is too small to account for the volume of material that would have to be removed from the underlying granites and gneisses to permit the downfolding to take place. Since there is at present no evidence that there has been extensive assimilation of Julianehåb Granite by SI. 4, this cannot be invoked as a possible means for the removal of excess country rock. The origin of the structure must be left open for the present.

A large number of dykes cut the rocks of the contact zone. At least 27, of various types, are present between Tunugdliarfik and the river about 2.8 km SSE of the fjord. Of these, three are aphyric trachytes which cut SI. 4 and younger syenites. Another four aphyric or sparsely porphyritic fine-grained red-brown trachytes intrude post-SI. 4 marginal breccia but die out eastwards before they reach the syenite. The remainder of the dykes, which include porphyritic and non-porphyritic trachytes, and Big Feldspar Dykes, pre-date the syenite SI. 4. In the contact zone these early dykes all show signs of thermal alteration. The effects of progressive contact metamorphism can be observed in several of the dykes that extend unbroken for a long distance west of the contact. The relationships of the dykes and syenite are similar at Igánaq and to the south. A few dykes are clearly later than the syenites, one or two die out eastwards in the post-SI. 4 breccia, while the majority pre-dates the syenites.

For about 100 m from the margin of SI. 4 the country rocks are thoroughly veined by sheets and dykes of quartz syenite, syenite, granite and 'hybrid' rocks. The minor intrusions are best seen on Igánaq and west of Narssârssuk where they have reacted to a limited extent with the quartzites and metabasalts. The country rocks are often so extensively disrupted that they form breccias, cemented by the syenites or alkali granites forming the sheets and dykes. The assemblage was termed the Mixed Zone since it was initially thought that there was continuous gradation into the syenite SI. 4. The later mapping, however, showed that SI. 4 has a fine-grain marginal facies in sharp intrusive contact with the Mixed Zone.

Post-SI. 4 events

In addition to the late aphyric trachyte dykes there are two areas of breccia which post-date the syenite SI. 4. In the north the breccia extends for about 800 m in a north-south direction in a zone up to 150 m wide, south of the lake at 215 m altitude near Narssârssuk (Plate 2). The southern area of breccia is of similar length and width, it extends SSE from a point about 300 m south of Igánaq to within a few hundred metres of the Qôrorssuaq river.

The breccias consist of rounded to subangular blocks of Julianehåb Granite, quartzite, metabasalt, trachytic and other dyke rocks, fine- and medium-grained syenite of SI. 4 type, and a leucocratic syenite similar to the sheets cutting SI. 4. The larger blocks, which may be as much as 2 m in diameter, do not appear to have undergone much displacement but there has been thorough mixing of the smaller pieces. The blocks and smaller fragments are altered. Pieces of SI. 4 have a dull, brick-red colour inside a 3 cm-thick zone of marginal bleaching. In section, the mafic minerals are clouded and altered, the small amounts of original nepheline are now replaced by aggregates of iron-stained micaceous material, and the alkali feldspar is heavily dusted with finely-disseminated hematite flakes. Alteration of the Julianehåb Granite is similar. Many of the blocks have a thin coating of fibrous, blue-grey alkali amphibole which also permeates the breccia matrix. This matrix consists of finely comminuted material from the syenite and the country rocks, along with small rock fragments and single crystals all of which show signs of alteration. The fragmental character of the matrix is one of the features which distinguish these late breccias from similar-looking breccias in the Mixed Zone where the matrix is a thoroughly crystallized igneous-looking rock.

The breccias are appreciably younger than the syenite SI. 4 since fragments of sheets cutting SI. 4 are present as inclusions. They are earlier than the latest alkaline trachyte dykes, and earlier than the remarkable, impersistent trachytes which die out eastwards in the breccias. It was not possible to establish the relative ages of the breccias and other late members of the Igdlerfigssalik Centre; it is possible that a connection exists between the breccias and one of the post-SI. 4 syenites since the location of the breccias is obviously controlled by the margin of the centre.

(f) The Klokken Intrusion

The Klokken Intrusion is a small intrusion of quartz-syenite and alkali-gabbro. It cuts Julianehåb Granite on the south side of Østfjordsdal, about 10 km ENE of the settlement of Søndre Igaliko (Plate 1). Preliminary work by K. Ellitsgaard-Rasmussen has shown that within a thin marginal zone of alkali gabbro or syenogabbro there is a series of superbly layered saturated or slightly oversaturated syenites. The layering consists of bands rich in alkali feldspar, and in olivine or clinopyroxene. It is generally flat-lying or else gently inclined towards the centre of the intrusion; the layered series may be likened structurally to a series of saucers stacked one on top of another.

The intrusion differs from all the members of the Igaliko Complex in being quartz-bearing. It is not, therefore, regarded as part of the Complex. However, from the evidence of the few dykes in the country rocks around the intrusion together with its fresh, unaltered condition and the absence of faulting in the syenites, it is likely that the Klokken Intrusion is of similar age to the younger members of the Igdlerfigssalik Centre.

These notes are based on observations made during a brief visit in the company of K. Ellitsgaard-Rasmussen. Field data for the dykes was kindly supplied by S. Andersen.

V. THE LATE ALKALI GABBRO

An arcuate, dyke-like intrusion of alkali gabbro and alkali dolerite is intermittently exposed for a distance of about 6 km in the eastern part of the Igdlerfigssalik Centre (Plate 4). The dyke varies in width from a few metres in the east to over 200 metres near Qôrorssuaq. It is well exposed in a stream section 1 km SE of the southern lake at 570 m in Qôrorssuaq, in a steep-sided cleft between the peaks at 1800 m and 1650 m south of Agdlerulik, and in a stream about 1.5 km east of the cleft. The intrusion is steep-sided, it has an inclination to the south or SW and has the field attributes of a partial ring-dyke. It is one of the youngest intrusions in the Igaliko Complex since it cuts the syenites SI. 5, SI. 6 and SI. 7 of the Igdlerfigssalik Centre as well as the earlier Østfjordsdal syenite. No intrusion cuts the alkali gabbro; late dykes are, however, uncommon in this part of the Complex.

The rock is medium to fine-grained, often doleritic rather than gabbroic. The principal minerals are olivine, purple-brown clinopyroxene, labradorite zoned marginally to sodic plagioclase and alkali feldspar, poikilitic areas of deep-coloured red-brown biotite, abundant small apatite crystals, opaques, and interstitial alkali feldspar and nepheline.

Good mineral layering occurs in exposures in the stream section east of Qôrorssuaq. The layering, which dips at 45–50° SW, consists of about 15 cm of fine-grain granulose rock rich in olivine, apatite and opaques interbanded with normal dolerite. The banded structures, which sometimes show excellent gravity stratification (fig. 30), often have feldspar growth structures similar to growth structures described from the basic ring dyke of the Kûngnât Intrusion (Upton, 1960, p. 45). Thin plagioclase crystals 1.5–2 cm thick, up to 4 cm in length, grow upwards from the floor provided by the sharply-defined base of the mafic layers; the structures resemble some of the features of the Willow Lake type of layering (Taubeneck & Poldervaart, 1960).

The intrusion is regarded as an incomplete ring-dyke. Although largely within the Igdlerfigssalik Centre it is clearly later and has a different focus. It provides another example of the common association of alkaline basic rocks with syenites and nepheline syenites in the Gardar Igneous Province, an association found elsewhere in the Igaliko Com-

Fig. 30. Layered structures in the late alkali dolerite dyke cutting the syenite SI. 7. Locality on the south-east side of Qôrorssuaq, Igdlerfigssalik Centre. Scale: hammer shaft 35 cm long. (Photo: C.H.E., GGU.)

plex, at Klokken, spectacularly developed on Tugtutôq (Upton, 1962, 1964 b) and at Kûngnât (Upton, 1960).

The kilometre-long dyke mapped either side of the northern lake at 570 m in Qôrorssuaq (Plate 4) is a mafic syenite or syenogabbro; it is probably unconnected with the late alkali gabbro. It is a dark coloured granular rock of medium grain size, in section it is strictly a mafic syenite containing alkali pyroxene, alkali amphibole, nepheline and perthitic alkali feldspar. It is petrographically distinct from any facies of the alkali gabbro intrusion.

VI. THE GARDAR DYKES

(a) Introduction

The numerous dykes intruding the syenites and earlier rocks are one of the more striking features of the geology of the country around Igaliko Fjord and Tunugdliarfik. The abundance of dykes impressed the earliest geologists to visit the area, one of the first geological papers on this part of Greenland was concerned with the porphyry dykes at Igaliko (PINGEL, 1843).

The dykes provide an excellent example of a dyke swarm. Regional mapping by GGU has shown that the swarm occupies a broad zone 25 to 30 km wide extending from the vicinity of Tugtutôq near Julianehåb Bugt ENE to the country north and east of the Igaliko Complex, a distance of over 100 km. Included within the zone are the major centres of Gardar igneous activity at Tugtutôq, Narssaq, Ilímaussaq and Igaliko (Plate 1). The north-western and south-eastern limits of the swarm are sharply defined. The northern margin has been mapped in Johan Dahl Land by B. J. WALTON (1965, Pl. 3); to the WSW the dykes cease at a line slightly north of the northern shore of Sermilik and Bredefjord. Near the Igaliko Complex the southern limit is close to Klokken and near Søndre Igaliko (BERRANGÉ, 1966, Map 2). To the south-west and north-east the swarm is 'open-ended'; dykes persist to Julianehåb Bugt in the west, to the east many cut the syenites and earlier rocks east of Qôrqup sermia and NE of Motzfeldt Sø where they have also been found north of Geologfjeld (A. WEIDICK, personal communication).

Several generations of dykes are present in the Igaliko syenites and the surrounding rocks. The close parallelism of the strike of the different types makes it difficult to determine relative ages; however, in the ground north and NE of Narssarssuaq, distinct generations of dolerite, Big Feldspar Dykes, and alkali trachyte dykes have been recognised (WALTON, 1965), several of which may be matched with dyke generations within the Igaliko Nepheline Syenite Complex. The Gardar dykes in the Igaliko Complex may be divided into three major groups on their relations with the nepheline syenites: there is an early group cut by relatively old syenites, a second group that was intruded after the emplacement of the Motzfeldt, North Qôroq and South Qôroq centres and the first three syenites of the Igdlerfigssalik Centre but which are earlier than the four late syenites of the Igdlerfigssalik Centre, and a third, late group that cuts the youngest syenites of the Complex. Within the second group it is possible to make further subdivisions on the basis of dyke intersections and rock types.

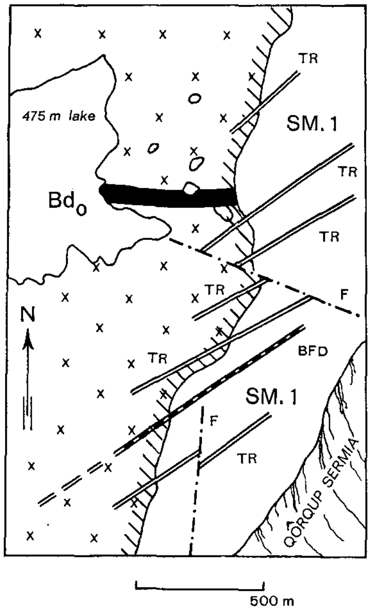

Fig. 31. Marginal relationships of the syenite SM. 1 west of Qôrqup sermia. A limited zone of fenitization (shaded) is found in the Julianehåb Granite (shown with cross symbol). A thick dolerite dyke (Bd_0?) is truncated by the syenite which, in turn, is cut by several Mid-Gardar alkali trachyte dykes and a Big Feldspar Dyke.

(b) Early Dykes

Evidence for the existence of early dykes comes from the ground west of Qôrqup sermia and from the southern margins of the Complex. West of Qôrqup sermia a dolerite dyke striking slightly north of west is truncated and altered by the syenite SM. 1 about 400 m east of the 475 m lake (fig. 31). This dyke is probably the eastern continuation of one of several early SE dolerites mapped in Mellemlandet and Johan Dahl Land (Walton, 1965, Pl. 3). In the field the dyke appears to cut the margin of the syenite (Walton, 1965, p. 51); however, while it is found (in an altered state) in the metasomatically-altered country rocks margining the syenite, it is cut off at the edge of the syenite SM. 1.

Near the southern margin of the Complex several alkali trachyte dykes striking between N 40° E and N 60° E cut the Julianehåb Granite

Fig. 32. Nepheline porphyry dyke with large nepheline phenocrysts and smaller lath-like alkali feldspar phenocrysts. North-east edge of the Østfjordsdal syenite. Scale: pencil 13 cm long. (Photo: C.H.E., GGU.)

and are in turn cut and metamorphosed by the Østfjordsdal Syenite. The dykes include aphyric trachytes (52275) and several highly porphyritic trachytes with large alkali feldspar and nepheline phenocrysts (fig. 32) in a fine grained microsyenite groundmass (52276). Similar porphyritic dykes, also somewhat altered, were mapped by S. ANDERSEN south of Sulugtssugutaussâ, south of the Igdlerfigssalik Centre. This early group is probably the NE continuation of the nepheline porphyry dykes described by USSING (1912, p. 272, Fox Bay type) from the coast of Igaliko Fjord; they are probably also the same as the nepheline porphyry dykes of the Vatnahverfi area (BERRANGÉ, 1966, p. 42).

(c) Dykes of intermediate age

(i) Alkali trachytes

The great majority of the dykes mapped in and around the Igaliko Complex come within this group; they are the eastern members of the Mid-Gardar dyke swarms (UPTON, 1962, 1964 a). From the map (Plate

4) it will be seen that dykes of this generation are common throughout the country west of Narssârssuk, in the syenites of the Motzfeldt, North Qôroq and South Qôroq igneous centres, and south of "Gieseckes Dal" where they cut syenites SI. 2 and SI. 3. Their absence in the ground north of "Gieseckes Dal", in the syenites west of the southern end of Motzfeldt Sø, and north of the syenite SS. 1 is probably apparent rather than real; much of this ground is virtually unmapped.

The swarm is made up of a number of petrographically distinct types. The most common are trachytes and microsyenites, including porphyritic and non-porphyritic types, and also extremely fine-grained varieties which are almost glassy. On the basis of the petrography, the trachytic and microsyenitic dykes evidently range from undersaturated to oversaturated types. Several varieties may be distinguished. Of these, the most common type consists of lath-like strongly perthitic alkali feldspars to 0.2 mm in length with turbid, anhedral alkali feldspar, nepheline and analcite. The nepheline is frequently altering to 'gieseckite', analcite or cancrinite. The mafic minerals are a pale-lilac, colourless or pale green clinopyroxene zoned to deep green aegirine-augite margins. This is accompanied by brown to dull green biotite and sometimes by a small amount of grey-green to violet-grey alkali amphibole. The alkali feldspar laths may be arranged in typical trachytic flow-aligned bundles but more often have a random arrangement with the other minerals occupying the intervening spaces. These dykes are clearly soda-trachytes, thoroughly undersaturated; they should probably be classed as tinguaites or phonolites. They bear a strong compositional and textural resemblance to one of the more abundant types of trachyte recognised in the Grønnedal-Íka Complex (Emeleus, 1964, p. 58); they probably correspond to the group of soda-trachytes distinguished by Walton (1965, p. 46). These dykes may or may not be porphyritic, alkali feldspar is the only common phenocryst. A second group is invariably porphyritic, with aggregates of alkali feldspar up to 1 cm in diameter together with single crystals of a fayalitic olivine, augite and sometimes magnetite. The alkali feldspar aggregates may be complex, the individual crystals are often rounded and corroded, sometimes they are zoned with a core of grid-twinned anorthoclase mantled by a zone of clear, untwinned alkali feldspar. The groundmass is fine-grained, not unlike that in the first group, with laths of perthitic alkali feldspar sometimes with trachytic texture, altered nepheline, zoned alkali pyroxene, occasionally fayalitic olivine, biotite, and sometimes alkali amphibole and aenigmatite. Members of this group are termed porphyritic tinguaites or porphyritic phonolites. A limited number of oversaturated alkaline dykes have been mapped; they probably correspond to the quartz-bearing potassic trachytes of Mellemlandet (Walton, 1965, p. 47);

they also bear a strong resemblance petrographically to the oversaturated microsyenites of Tugtutôq (UPTON, 1964 a). Not all are porphyritic, but where phenocrysts are present they are of single or aggregated crystals of turbid perthitic alkali feldspar; unlike the porphyritic phonolites the phenocrysts are not usually obvious anorthoclases. The groundmass generally consists of short, rectangular turbid perthitic alkali feldspars, sometimes arranged in typical trachytic texture. The feldspar margins may be clear albite which is also found in wedge-shaped, interstitial areas. An alkali amphibole is the commonest mafic mineral, occurring is anhedral crystals strongly pleochroic from grey-green to violet-grey, the intensity of the colour increasing towards the margins especially when adjacent to an area of interstitial albite. Some opaque grains are present, associated with which there may be deep-brown biotite although biotite is otherwise an uncommon mineral in this group. The quartz is in small, clear interstitial areas. A fourth group is of extremely fine-grained almost glassy rocks. These may be black or green coloured, often with very strongly developed flow-structures and spherulitic areas (46277). The group is generally non-porphyritic although very fine-grained members of the porphyritic phonolites have similar groundmass features. In section the rocks are extremely fine-grained; usually the only identifiable mineral is frond-like aegirine in spherulitic aggregates in the green dykes (*e. g.* 46277) or alkali amphibole in the black dykes (58086).

(ii) Big Feldspar Dykes

In addition to the alkaline dykes there are more basic types represented by highly porphyritic dolerites, trachydolerites and mafic microsyenites, mapped under the collective field term of Big Feldspar Dykes. This highly porphyritic and xenolithic group of dykes is a conspicuous and widespread member of the suite of Gardar igneous rocks in southern Greenland, almost all the accounts of the GGU geologists working between Igaliko Fjord in the south and Ivigtut in the north contain well-documented descriptions of these rocks (BRIDGWATER & HARRY, 1968; STEWART, 1964; BERRANGÉ, 1966; WALTON, 1965), and the type occurs even further afield. The dykes found in the Igaliko Complex do not differ appreciably from those already described from adjacent areas. The individual dykes remain remarkably constant in width throughout their length; they measure from 15 m downwards. The margins are generally very fine-grained, without phenocrysts and sometimes flow-banded. The central parts contain dull, white plagioclase crystals up to 15 cm in length, crystal fragments, and blocks of anorthosite or anorthositic gabbro from 20–30 cm in diameter. The groundmass consists of plagioclase strongly zoned from andesine to oligoclase and interstitial alkali feldspar, augite often altered to green amphibole and chlorite, opaques, biotite and apatite. Occasionally olivine is present in the rocks with unaltered groundmass. The large plagioclase crystals and anorthosite blocks are usually altered, the plagioclase is heavily impregnated with sericitic mica and epidote, the mafic minerals are altered to fibrous green amphibole and chlorite. Calcite is common in the altered dykes. Big Feldspar Dykes with a sodic trachyte groundmass are found in several places outside the Igaliko Complex (*e.g.* WALTON, 1965, p. 49) but few, if any of those mapped at Igaliko are microsyenitic. The majority of the dykes have a trachydolerite matrix, a few more basic examples being found in the relatively fresh dykes cutting the Motzfeldt Centre (58327) and the North Qôroq Centre (59745).

The Big Feldspar Dykes maintain remarkably constant widths within the area mapped. Individuals also have very characteristic assemblages of plagioclase crystals, anorthosite blocks, or both. Because of these constant features the dykes were of particular value in determining the amounts of movement on the faults, when taken in conjunction with certain distinctive trachytic dykes.

(iii) Lamprophyres

No intersections were found between the lamprophyres and any of the other dykes. With the exception of a vogesite (54168) cutting the Julianehåb Granite near the southern end of Motzfeld Sø, the lamprophyre dykes are either kersantites or spessartites. Two fresh biotite spessartites (52285, 52287) cut the NE of Østfjordsdal Syenite, augite kersantites intrude the syenite SS. 2 near Agdlerulik (52274) and SM. 4 near the 1410 m summit south of "Flinks Dal" (63726).

(iv) Intrusive sequence

Because of their parallel strike, it is difficult to determine the relative ages of the dykes in this group. A few intersections were found on the plateau between Narssârssuaq and Qôroq, as well as at a number of other localities. On the basis of these intersections it is possible to draw up a tentative sequence. The Big Feldspar Dykes are the earliest major group, at only one place within the syenites were they observed cutting a trachyte. The locality is 1.3 km NNW of the 970 m hilltop in the northern part of the South Qôroq Centre. Here, a 5 m wide sparsely-porphyritic trachyte (58242) striking at 130° is cut by a thick Big Feldspar Dyke (= 58262) at 160°. The trachyte contains scattered small augite phenocrysts in a groundmass of turbid flow-aligned perthitic alkali feldspars, augite zoned to aegirine-augite, deep brown biotite, opaques and chlorite.

Numerous dyke intersections were found in the vicinity of the 970 m hilltop in the northern part of the South Qôroq Centre (fig. 33).

Here, the Big Feldspar Dykes are the oldest and a 12 m-wide sparsely porphyritic microsyenite (58241) is the youngest intrusion. The sequence determined is, starting with the youngest, a 12 m sparsely porphyritic trachyte or microsyenite (58241), a porphyritic trachyte with anorthoclase phenocrysts (58238) and a porphyritic phonolite (58240), followed

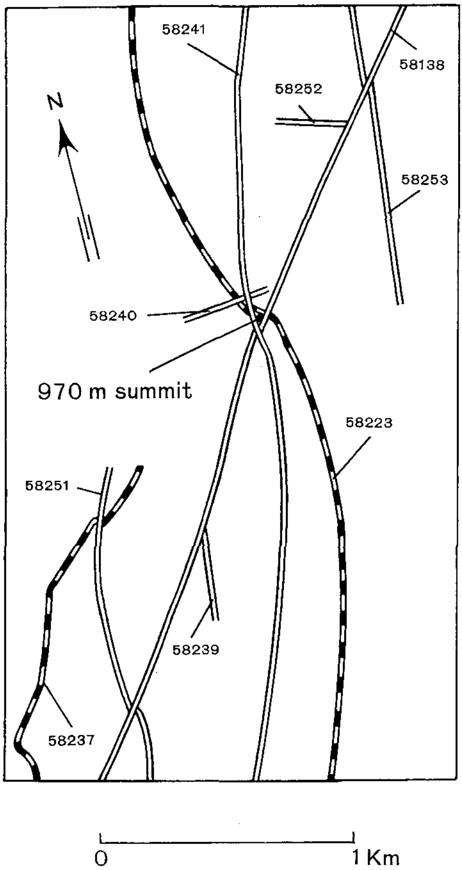

Fig. 33. Sketch map of the intersections between Big Feldspar Dykes and alkali trachyte dykes near the 970 m summit, South Qôroq Centre. The numbers (58251, etc.) refer to GGU specimens.

by a non-porphyritic phonolite (58239), two porphyritic phonolites (58252, 58253) and a porphyritic trachyte (58251). Other intersections were mapped in the North Qôroq Centre where porphyritic phonolites with mantled anorthoclase phenocrysts cut non-porphyritic phonolites and trachytes. All the intersections observed have been between saturated and undersaturated dykes, none of the quartz trachytes was observed cutting or cut by other dykes; there is a strong possibility that these oversaturated dykes should be placed with the latest group (p. 91).

(d) Late dykes

The most reliable criteria for deciding whether or not a dyke belongs to the youngest group are either that it is found cutting one of the four late syenite of the Igdlerfigssalik Centre or the associated intrusions, or else that the dyke is found in an unmetamorphosed condition within country rocks that have been thermally altered by the late Igdlerfigssalik syenites. Since this virtually limits recognition to dykes mapped in and adjacent to the Igdlerfigssalik Centre a number of late dykes elsewhere will have been incorrectly classified as belonging to the group of intermediate age. At present, the only way in which it may be possible to assign these dykes to the later group is on the basis of petrographic similarity to known late dykes, on the somewhat uncertain assumption that petrographically similar dykes are of similar age. On this basis, together with their generally unaltered state, it appears most likely that both the quartz trachytes and the porphyritic phonolites with phenocrysts of mantled anorthoclase, olivine augite and some opaques, may belong to the late group. None of these has been definitely recognised amongst the altered trachytes dykes in rocks bordering the Igdlerfigssalik Centre whereas non-porphyritic trachytes, non-porphyritic phonolites, phonolites with altered nepheline and alkali feldspar phenocrysts, porphyritic phonolites with altered phenocrysts of alkali feldspar and complexly intergrown aegirine-augite and alkali amphibole have been recognised amongst the pre-Igdlerfigssalik Centre dykes. It is possible that the last-mentioned porphyritic phonolites are the altered equivalents of some with anorthoclase, augite and olivine phenocrysts, but this has not been proved as yet. Dykes that definitely fall into the late group include a lamprophyre and a variety of alkali trachytes. No intersections were observed between any of the late dykes.

The most common late trachytes are a group of porphyritic phonolites with phenocrysts of alkali feldspar and aegirine-augite (41951, 43897) and occasional nepheline (43802). Belonging to this group is a dyke described by Ussing (1912, p. 250) as a 5-m wide green-coloured tinguaite dyke "near the river south of the Narsarsuk plateau a little above the waterfall made by this river where it falls onto the low granite area north of the Igaliko Fjord". Ussing identified cordierite in this rock, occurring as 3–5 mm grains with the appearance of milky quartz. He regarded the cordierite as of extraneous origin. Specimens collected from several points on this dyke are all tinguaite (or phonolite; 43802, 54325, 87118). They correspond well with Ussing's description but cordierite has not been identified. In one (54325) the areas resembling milky quartz in hand specimen were found to consist of rounded nepheline crystals, often partially altered, with numerous minute inclusions.

Several of the late dykes are non-porphyritic trachytes (41925, 41932) with turbid lath-like alkali feldspar, biotite and alkali feldspars, aegirine augite, analcite and occasionally fresh nepheline (41935). A single quartz trachyte (63836) cuts the syenite near Narssârssuk, this dyke is petrographically similar to the quartz trachytes found cutting the earlier syenites near Narssarssuaq, and elsewhere. One of the porphyritic phonolites is very similar petrographically to dykes cutting the earlier syenites of the Motzfeldt Centre and the North Qôroq and South Qôroq Centres and Narssarssuaq. It contains phenocrysts of olivine, augite and aggregates of anorthoclase with marginal rims of clear alkali feldspar (41954).

A distinctive group of dark fine-grained, sparsely porphyritic trachytes cuts the marginal post SI. 4 breccias on the western edge of the syenite area at Narssârssuk (Plate 2: TR. 2). These dykes contain scattered, turbid perthitic alkali feldspar phenocrysts in a very fine-grained groundmass which is frequently strongly stained by hematite. The recognisable groundmass crystals are restricted to spherulitic growths of alkali pyroxene (54297) or alkali amphibole (54293). Although these dykes cut, and are chilled against the post SI. 4 breccias, they show some signs of shattering and impregnation by veins of albite (*e. g.* 54293, 54297). Because of this alteration they are considered to be relatively early members of the group since other dykes (TR. 3, Plate 2; 41999, 43802) are not affected.

One lamprophyre dyke cuts the syenite SI. 7 in Qôrorssuaq. The rock (43887) is dark-coloured, with scattered feldspar phenocrysts up to 1 cm in length. In section, it consists of plagioclase phenocrysts (An 45) in a groundmass of well-formed brown biotite, and anhedral alkali feldspar and plagioclase, accompanied by scattered opaques and apatite, Other fresh lamprophyre dykes cut early members of the Igaliko Complex, but in the absence of any direct evidence of a late age, they are provisionally assigned to the group of intermediate age.

(e) Carbonatite dykes

The occurrence of carbonatite within the Igaliko Complex is limited to a few thin dykes, and the breccia plug in the North Qôroq Centre. The dykes rarely exceed 1 m in width and a few tens or hundreds of metres in length. Because of their impersistent character it proved difficult to place the carbonatite dykes accurately in the igneous sequence; no intersections were found with other dykes. Carbonatite dykes cut the late members of the Igdlerfigssalik Centre (Plate 2), one example (41996) intrudes the syenite SI. 4 on the west bank of a stream 1.4 km SSE of Narssârssuk, another (41982) cuts the syenite SI. 5 about 2 km

N 80° E of Igánaq summit. Near the same locality, in the country rocks on the west of the syenite SI. 4 there are at least two carbonatite dykes (54243, 54244; 54275) metamorphosed by the syenite (Plate 2). Thus, carbonatite intrusions in the Igaliko area cover a considerable part of the time span of the Gardar igneous activity, a finding in accordance with results from adjacent areas (STEWART, 1964; WALTON, 1965, p. 39).

The majority of the carbonatite dykes consist of calcite with variable, though small amounts of phlogopite or biotite, apatite and opaque minerals. Fluorite, apparently of replacement origin was found in several (*e. g.* 46257), quartz and albite are occasionally present in very small amounts (43931). The two pre-SI. 4 carbonatites near Narssârssuk are distinctive in that they carry appreciable amounts of clinopyroxene and olivine in addition to calcite, large crystals of apatite and phlogopitic mica.

In all, about 15 small dykes were found over the whole of the Complex.

(f) Summary and conclusions

The Gardar dykes mapped in and around the Igaliko Complex are mainly alkali trachytes, members of the extensive dyke swarms of Mid-Gardar age recognised throughout the Tugtutôq–Igaliko zone (UPTON, 1962). The dykes in the vicinity of Igaliko are largely undersaturated types, more accurately termed phonolites or tinguaites than trachytes; although trachytes *sensu stricto* and quartz trachytes are represented. Little has been published on the dykes near the Ilímaussaq Intrusion but on Tugtutôq, UPTON (1962) has described a variety of Mid-Gardar dykes, including many saturated to over-saturated trachytes. He makes the suggestion that these dykes "represent preliminary tappings of the magma source which was subsequently to produce rocks of the Tugtutôq central ring complex" (p. 38). The suggestion has attractions in the Igaliko area where the majority of the dykes and syenites are undersaturated in character.

WEGMANN (1938) and BONDAM (1955) have advanced the hypothesis that some of the alkali trachytes are metatrachytes. This interpretation was based largely on WEGMANN's view that the nepheline syenites near Narssarssuaq had originated through metasomatic transformation of pre-existing country rocks (WEGMANN, 1938, p. 81). Since the transformationist hypothesis for the origin of the syenites cannot be sustained, it is not possible to accept the implication that the dykes were present before the formation of the nepheline syenites (BONDAM, 1955, p. 11). All the numerous trachytic dykes mapped in the Igaliko Complex show intrusive relations towards the syenites although some are highly altered by distinctly later syenite intrusions.

The major alkaline intrusions are cut by trachytic and microsyenitic dykes belonging to the regional dykes swarms and by thin microsyenite sheets and dykes closely connected with the large syenite intrusions. It is generally possible to distinguish between the minor intrusions of different origins on the basis of their relations to the earlier rocks and their crystallizations textures. The members of the dyke swarm have sharply defined margins against the earlier syenite, they often show distinct evidence of chilling at the edges and flow structures are sometimes developed. Though usually very fine-grained, the coarser members contain abundant thin platy feldspar crystals often showing a typical trachytic parallelism. In section, the groundmass feldspars are elongate and well-formed, sometimes showing trachytic texture, with the mafic minerals, nepheline, analcite, etc., generally occupying the interstices between the feldspars. In contrast, the sheets and dykes closely related to the major intrusions are thoroughly welded to the country rocks, they do not have chilled margins, and flow structures are rare although zones of coarse and fine-grained rock may alternate in bands more or less parallel to the margins. Their crystallization differs from that of the trachytes, the feldspars are short, stumpy anhedral or subhedral crystals and the mafics are rounded, subhedral or anhedral crystals, although sometimes distinctly poikilitic mafic minerals are present. Their crystallization is very similar to that of the syenites although on a reduced scale, in this respect they are more truly microsyenitic than the trachytic dykes.

These differences reflect the different cooling conditions of essentially similar magmas: the microsyenitic sheets and dykes intruded syenites that had solidified but not cooled completely, whereas the trachytes cut relatively cold rocks, regardless of whether these were syenites or earlier country rocks.

The Gardar dykes have a very constant strike direction at about N 60° E throughout most of the Igaliko–Tugtutôq zone. However, the dyke swarm undergoes a notable deflection within the Igaliko Complex (Plate 4; fig. 34), on the peninsula between Narssarssuaq and Qôroq and on the south side of "Gieseckes Dal". There is a progressive change in direction to about N 20° E, or even N–S north of Niaqornârssuk, of all the different trachytic dykes and the Big Feldspar Dykes. The effect of the deflection is to off-set the course of the dyke swarm by about 5 km to the NNW. The picture is somewhat confused by the presence of two major and several minor sinistral transcurrent faults, most of which have had post-dyke phases of movement. However, the displacement and change in direction cannot be attributed to successive close-spaced movements along these or associated faults. The deflection appears to

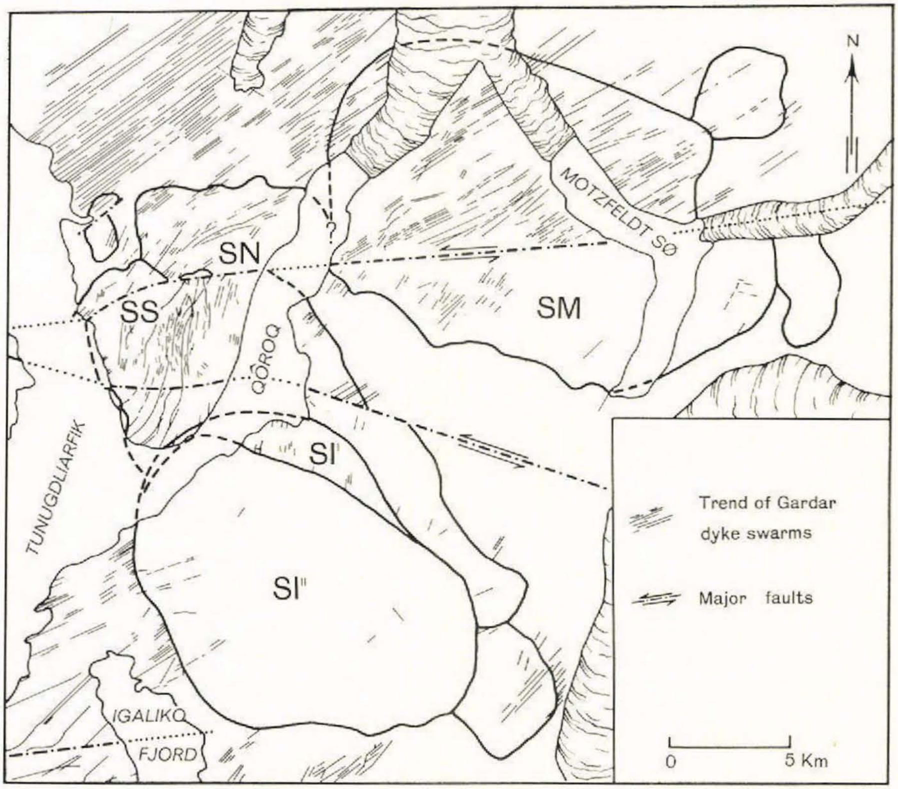

Fig. 34. Sketch map of the Gardar dykes (all generations) in and around the Igaliko nepheline syenites. Note (a) the absence of dykes cutting the late Igdlerfigssalik syenites (SI″), and (b) the approximately N–S trend of all dykes in the country between Qôroq and Tunugdliarfik.

be limited to the dykes passing through the northern half of the Igaliko Complex. No evidence of deflection is found either side of the northern arm of Tunugdliarfik (J. Allaart, personal communication, 1967), nor is there evidence of deflection to the east of the complex although the mapping is far from complete in that ground.

On the available evidence there are two possible explanations of the deflection of the dyke swarm. Deflections of swarms are known in the vicinity of associated major intrusions, as for example in the Crazy Peak area of Montana (Odé, 1957) or the Tertiary Volcanic District of Western Scotland (Richey, 1938). It is therefore possible that the early stages of development of the Igdlerfigssalik Centre caused a modification in the regional stress pattern resulting in a deflection of the dyke swarm from its normal N 60° E strike, although the distribution of the dykes about the Igdlerfigssalik Centre does not match well with the distribution envisaged by Odé (1957). Furthermore, there is the distinct possibility that some of the dykes affected post-date the Igdlerfigssalik Centre. Alternatively, the deflection may have been caused by the superposition of stresses associated with the transcurrent faults on the regional pattern that elsewhere determined the orientation of the dykes. It is significant that there is evidence of overlap in time between the emplacement of the dykes and movement on at least one of the faults (p. 101).

VII. FAULTING

Faulting affected the Igaliko area before the emplacement of the nepheline syenites and at different times during and after the intrusion of the syenites and associated dykes.

(a) Pre-syenite faulting

Between Tunugdliarfik and Igaliko Fjord the Gardar supracrustal rocks are broken up by a series of faults at about N 80° E (POULSEN, 1964, Map 1). The faults have a slight effect on the bedded rocks; their main movements appear to have been vertical. They are cut by alkali trachyte dykes and Big Feldspar Dykes SW of Igaliko village. Further evidence of their early age is found on the west side of Igánaq, on the SW margin of the Igdlerfigssalik Centre, where a fault at N 70° E throws down sandstones against Julianehåb Granite to the north (USSING, 1912, fig. 24). There is no evidence that this fault cuts the syenite SI. 4 on the eastern side of Igánaq. V. POULSEN has mapped another early fault at Narssarssuaq, separating sandstones and effusive rocks from Julianehåb Granite in the valley between the Narssarssuaq Stock and the western edge of the syenite SN. 1. Again, there is no evidence that this fault affects the syenites. Another early fault occupies a prominent NE–SW valley extending from the west side of the Østfjordsdal Syenite to Fox Bay. In the valley, the Julianehåb Granite is crushed and discoloured but the boundary between the Østfjordsdal Syenite and the country rocks is not affected.

(b) Post-syenite faulting

Two groups of faults affect the syenites, one consisting of minor faults with an orientation between north–south and NE–SW, and the other of major and minor faults with a general orientation that is approximately east–west. The first group is not responsible for any major movements, although quite pronounced topographic features may be associated with them, as in the North Qôroq Centre where a long, straight valley extends from near the 587 m hill in the south of the centre NE for over 10 km. The northern margin of this centre is slightly displaced either side of the 550 m lake by the fault but dykes cutting the syenites are little affected. Minor faults in this group cut the late syenites of the Igdlerfigssalik Centre near Igánaq and east of Sulugssugutaussâ; however, there is also evidence that some of the faulting may pre-date these late syenites. East of Igánarssuánguaq, on the SE side of Qôroq, a north–south fault displaces the contact between the syenites SI. 2 and SI. 3 by at least 400 m in a horizontal, dextral sense yet there is no evidence that the contact between the syenites SI. 3 and SI. 4 is displaced although it is well-exposed on the hillside 1 km south of the fjord. It is usually difficult to demonstrate any vertical movement on the faults within the syenites, since all the reference planes provided by dykes and syenite contacts are vertical or steeply inclined. The apparent movements are all horizontal, in either dextral or sinistral senses. However, one fault in the South Qôroq Centre, about 3 to 4 km south of the 970 m summit, provides evidence for vertical movement, with a downthrow to the SE. The contact between the syenites SS. 4 and SS. 5, which is inclined steeply to the west and NW, shows an apparent sinistral movement on the SW part of the fault and an apparent dextral movement about 1 km to the NE on the same fault.

The spectacular valley of Qôrorssuaq (fig. 28 a) is marked by a belt of small fractures, faults and crush lines. The effects of movement are visible in the river exposures towards the SW end of the valley, near the two lakes at 570 m elevation, and in deep gorges eroded along crush lines towards the northern end of the valley, on the south side of "Gieseckes Dal". Despite its prominence as a topographic feature, the faults associated with Qôrorssuaq have had little visible effect on the geological boundaries (Plate 4).

The two major east–west fault zones crossing the Complex both give rise to prominent topographic features. The northern fault zone can be followed eastwards from a small bay on the east shore of Tunugdliarfik, south of Akuliaruseq, across the peninsula to Qôroq, then for 12 km through the Motzfeldt Centre where it forms the broad flat valley of upper "Flinks Dal" (fig. 35), to the eastern corner of Motzfeldt Sø where the fault is in the deep valley filled by the glacier flowing from the Inland Ice into the lake. The fault is marked by a zone up to 200 m wide in which the syenites and dykes are sheared, discoloured and thoroughly brecciated. Off-shoots from the main zone extend for up to 300 metres into the adjoining rocks. The width of the zone is well displayed in the steep exposures either side of Qôroq (fig. 35) as well as several localities in upper "Flinks Dal", for example, south of the lake at 700 m altitude. The horizontal displacement across this fault is of the order of 2 km in a sinistral sense. The displacement remains fairly constant throughout the length of the fault; at the east end the outer margin

Fig. 35. Erosion along the line of the sinistral transcurrent fault in upper "Flinks Dal" (distance) and the Qôroq syenites (foreground). (Photo: C.H.E., GGU.)

of the syenite SM. 1 against the Julianehåb Granite is moved about 2 km, while on the plateau between Narssarssuaq and Qôroq the displacements of distinctive Gardar dykes are of the same amount and in the same sense. No indication of the vertical component of this fault could be obtained within the area mapped; information regarding this may become available when a satisfactory correlation has been established between the faults cutting the syenites near Narssarssuaq and those on the west side of Tunugdliarfik, near Qagssiarssuk. A downthrow to the north appears to be required to account for several features including the relationships between the syenites SS. 2 and SS. 3, and members of the North Qôroq Centre about 5 km SE of Narssarssuaq, as well as the differences between inclusions in the syenite SM. 4 on the northern and southern sides of upper "Flinks Dal".

The southern of the two major faults is well displayed east of Qôroq where erosion along its course determines the position of "Gieseckes Dal" to the east of a point about 2.5 km from the fjord. As with the northern fault, there is a broad zone of crushing and discolouration up to 100 m wide; the full width of this crush zone is exposed on slabs and in the river gorge about 10 km east of Qôroq. In the western part of "Gieseckes Dal" the fault displaces the contact of the syenite SS. 2 with Julianehåb Granite for about 1 km in a horizontal, sinistral sense (the apparently greater displacement shown on the map (Plate 4) is due to differences in elevation of the NE-dipping contact of SS. 2 on either side of the fault). The sinistral sense of the movement is well demonstrated by the distortion of trachytic and other dykes on the

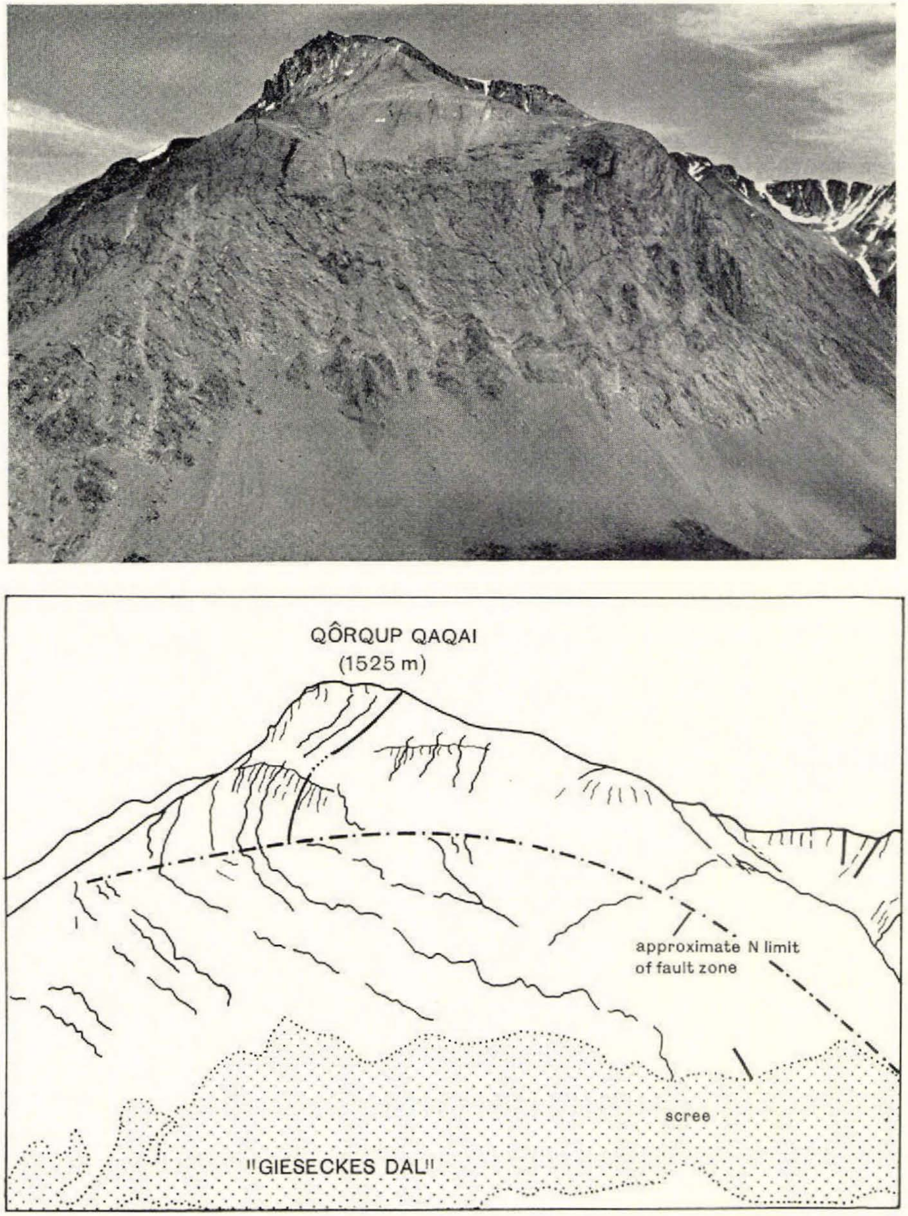

Fig. 36 a & b). View of the south face of Qôrqup qáqai (1525 m) north of "Gieseckes Dal", showing the deflection of Gardar dykes by a major sinistral transcurrent fault. Most of the exposed face is formed of crushed syenites (SS. 2 and SS. 3); the dykes stand out as dark lines. (Photo: C.H.E., GGU.)

south side of Qôrqup qáqai (fig. 36 a & b). The western extension of this fault on the peninsula north of Niaqornârssuk causes significantly less sinistral horizontal displacement of the syenites and dykes, about

400 m instead of 1 km at "Gieseckes Dal". Part of the difference is due to the fault branching to form a number of smaller faults north of Niaqornârssuk.

It is probable that this fault has a southerly downthrow of at least 400 m. The precise amount is difficult to determine; the figure given has been obtained using the base of the Eriksfjord Formation as a reference plane. East of Narssârssuk this is at about 180 m, while of the north side of the fault, SE of "Flinks Dal", the base of the formation is at about 1400 m. The Eriksfjord Formation has a regional dip of not more than 5° SW, which is the value of dip used in estimating the vertical displacement on the fault. However, at the localities mentioned the beds are almost flat-lying, and consequently the estimate of the downthrow of the fault may be too small.

There is no direct evidence of the relative ages of the two major sinistral faults in the area mapped; if they continue west with the trends found south of Narssarssuaq they should intersect south of Qagssiarssuk or just off-shore in Tunugdliarfik. An indication of relative ages comes from the relationship of a distinctive 12 m-wide sparsely porphyritic microsyenite dyke (59774, 58241, etc.). The dyke undergoes the normal 2 km sinistral displacement across the northern fault. At the southern fault, this same dyke is displaced less than 100 m sinistrally about 2 km N 10° W of Niaqornârssuk compared with displacements of the order of 400 m undergone by the majority of the other dykes. Thus, there is evidence that the northern fault is the later of the two, and that there was a period of overlap between dyke intrusion and movements on the southern fault.

A major fault forms the southern boundary to the Eriksfjord Formation near Igaliko village. The fault truncates trachytic dykes of the regional swarms, consequently there must have been movement at a relatively late stage in the Gardar. However, the fault appears to be earlier than the late syenites of the Igdlerfigssalik Centre since there is no indication that an eastern continuation displaces the syenite SI. 4 nor the thin ring-dyke syenite SI. 6. Exposure is not good on Tavdlorutit, south of Qôrorssuaq, but it is sufficient to enable positioning of the syenite–Julianehåb Granite boundary with a fair degree of confidence and, further west, to map the position of SI. 6, and the Østfjordsdal syenite. At a first glance it would appear that this fault must pre-date the late syenites of the Igdlerfigssalik Centre; its direct continuation east from the coast exposures south of Igaliko should bring it against the late syenites. However, there is the possibility that the continuation of the fault swings slightly to the south thus missing the nepheline syenites; the sinistral displacement of SI. 6 east of Sulugssugutaussâ (Plate 4) may occur along a branch from this major fault. The question of the relative ages of the late syenites and this fault should remain open for the present, particularly in view of the evidence that the movement on the major "Flinks Dal" fault is later than late members of the Igdlerfigssalik Centre (p. 107).

The origin of Qôroq must be considered when dealing with faulting within the Complex; it is possible that there is a fault along the line of the fjord. No definite answer can be given on the evidence available from the Igaliko area alone, but the following facts indicate that the possibility is worth considering. Shears with a NE trend commonly occur on the shores of Qôroq on both sides of the SS. 2/SS. 3 contact west of "Gieseckes Dal"; there are dissimilarites between the complex in the lower part of Flinks Dal and that on the opposite NW side of Qôroq; there is mineralization and crushing following the trend of the fjord at Niaqornârssuk; numerous small displacements with a similar direction to the fjord are present on the Narssarssuaq peninsula. The fault would have to change course with the bends in the fjord (Plate 4), but these changes could be readily explained by its displacement along the major sinistral faults which cross the fjord. Against the hypothetical fault it may be argued that there is a lack of apparent displacement of the small strip of Igdlerfigssalik Centre syenites at Niaqornârssuk relative to the main body of this Centre and also the fault would not have to effect a notable movement of the Julianehåb Granite near "Flinks Dal"; otherwise, Julianehåb Granite would appear on the north shore of Qôroq where none has been found. On the whole, the arguments for a fault along Qôroq outweigh those against, but the matter cannot be finally settled on the evidence available. The continuation towards Tunugdliarfik will also have to be taken into account.

VIII. CONCLUSIONS

(a) The sequence within the Igaliko Complex, and the position of members of the Complex in the Gardar chronology

The sequence of events within the Complex is summarized in Table 1.

The earliest recorded event, after the erosion of the Julianehåb Granite, was the deposition of the continental arenaceous sediments, the pyroclastic deposits, and the associated lavas, to form the group of supracrustal rocks known collectively as the Eriksfjord Formation (POULSEN, 1964; BERTHELSEN & NOE-NYGAARD, 1965). Elsewhere, there is some evidence that certain of the Gardar dolerite dykes pre-dated, or were contemporaneous with the lavas and pyroclastic rocks (B. G. J. UPTON, personal communication). Before emplacement of any of the Igaliko syenites, the supracrustal rocks were extensively faulted, and cut by two volcanic pipes NE of Motzfeldt Sø.

The exact order of emplacement of the earlier nepheline syenites is not known. It is assumed that activity began at a number of points now represented by the early satellitic intrusions of North Motzfeldt, East Motzfeldt, Tunugdliarfik, Narssarssuaq and Østfjordsdal, though whether these were all equally early or merely preceeded the adjacent major centre could not be ascertained. The Østfjordsdal syenite cuts a minor swarm of nepheline porphyry dykes striking NE from Igaliko Fjord (these are the Fox Bay Porphyry type of USSING (1912)).

The earliest major centre was probably the Motzfeldt Centre, this was emplaced with successively younger members towards the west; the syenites are cut by arcuate dykes and partial ring-dykes of alkali gabbro and syenogabbro. Large rafts of highly altered supracrustal rocks and of Julianehåb Granite are preserved within SM. 4; it also is possible that the large area of coarse syenite SM. 5 may be a sheet or raft enclosed by SM. 4. At its extreme western margin, the syenite SM. 1 truncates a 15 m-wide dolerite dyke which strikes at 90°. This intersection is useful since it demonstrates that the Motzfeldt Centre is later than some of the Gardar dolerite dykes and thus almost certainly later than the nepheline-syenite–carbonatite complex of Grønnedal-Íka (EMELEUS, 1964).

Table 1. *Geological development of the Nepheline Syenite Complex.*

Post-Gardar.	Quaternary glaciation, erosion.
Late-Gardar.	Final 2 km sinistral transcurrent movement on major fault in upper "Flinks Dal" and the Narssarssuaq plateau. Displaces Gardar dykes which probably post-date late members of the Igdlerfigssalik Centre.
	Partial ring-dyke of alkali gabbro (cuts SI. 7, etc.).
	Late-Gardar dykes, including: quartz trachytes trachytes porphyritic phonolites lamprophyres (?)
	Minor NE–SW faulting (in Qôrorssuaq).
	Sinistral transcurrent movements on the faults in "Gieseckes Dal" and cutting the South Qôroq syenites 3–4 km N and NW of Niaqornârssuk.
	(N.B. There is overlap between movement on these faults and intrusion of the Late-Gardar dykes.)
	Late breccias along the western margin of SI. 4 near Igánaq and Narssârssuk.
	Late members of the Igdlerfigssalik Centre: SI. 4 → SI. 5 → SI. 6 → SI. 7.
	(The Porphyritic microsyenites and leucocratic syenites probably fall between SI. 4 and SI. 5.)
	Early faults, trending N–S and NE–SW.
Mid-Gardar.	Majority of the dykes, including:— trachytes phonolites porphyritic phonolites lamprophyres Big Feldspar Dykes
	Early members of the Igdlerfigssalik Centre: SI. 1 → SI. 2 → SI. 3.
	Syenogabbro (cuts SS. 5 but cut by SI. 2).
	Syenites of the South Qôroq Centre: SS. 1 → SS. 2 → SS. 3 → SS. 4 → SS. 5.
	(N.B. Microsyenite sheets cutting SS. 3 near SS. 4 are probably associated with the later syenites.)

(continued)

Table 1 (cont.).

Satellitic syenites:

Narssarssuaq stock (probably pre-SS. 2).
Tunugdliarfik syenite (pre-SS. 2).
Østfjordsdal syenite (pre-SS. 1).

Breccia plug cutting SN. 5.

Syenites of the North Qôroq Centre:

SN. 1 → SN. 2 → SN. 3 → SN. 4 → SN. 5.

Alkali gabbro and syenogabbro cutting the Motzfeldt Syenites.

Syenites of the Motzfeldt Centre:

SM. 1 → SM. 2 → SM. 3 → SM. 4 → SM. 5.

Satellitic syenites:

North Motzfeldt syenites (pre-SM. 1).
NM. 1 → NM. 2.
East Motzfeldt syenite (pre-SM. 1 ?).

Early-Gardar.

Early dykes:

Dolerites (in Mellemlandet).
Fox Bay nepheline porphyries.

Faulting (At Narssarssuaq and near Igaliko).

Eriksfjord Formation (sediments, lavas and pyroclastic deposits).

——— (angular unconformity) ———

Pre-Gardar. Julianehåb Granite suite.

The sequence from the North Qôroq Centre, to the South Qôroq Centre, to the early members of the Igdlerfigssalik Centre calls for little comment; the centres are elongated about NW–SE axes, as are the Motzfeldt Centre and the late Igdlerfigssalik Syenites. Taken overall, the focus of igneous activity has moved southwards with time. Within each centre there was probably an appreciable time interval between many of the syenites; evidence for this comes from the sharp intrusive contacts between syenites and the development of internal feldspar lamination, sometimes accompanied by concordant mineral layering, all of which had time to form before the intrusions were cored out by a later syenite. As in other complexes, the successive intrusions are usually slightly off-set in a consistent direction within individual centres,

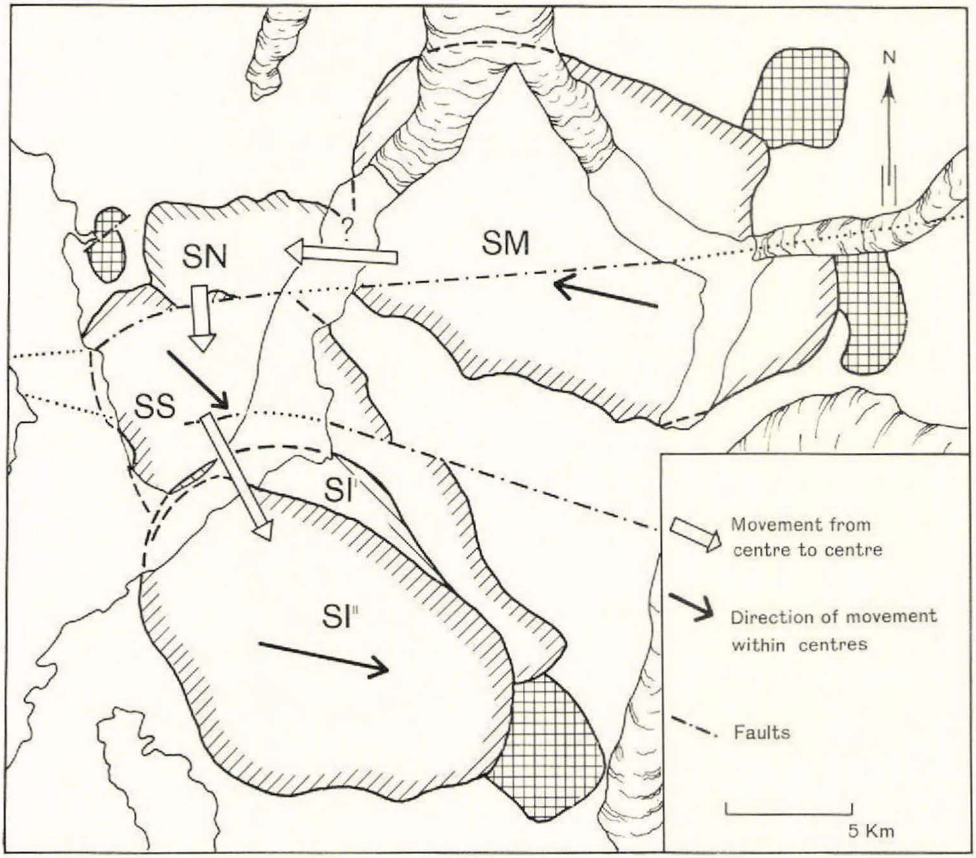

Fig. 37. Sketch map showing the directions of migration of igneous activity within individual centres and from centre to centre.

while the change of the focus of activity from centre to centre followed a regular pattern (fig. 37).

A break in plutonic intrusion is evident after the emplacement of the early members of the Igdlerfigssalik Centre. The ensuing event was the intrusion of numerous dykes to form the regional dyke swarm. In the Igaliko area, the earliest dykes are several long Big Feldspar Dykes, these were followed by numerous alkali trachytes. The swarm contains a few lamprophyre dykes which cut syenites in the southern part of the Complex. The dykes are members of a major regional swarm extending from Mellemlandet WSW to Tugtutôq and beyond; the Igaliko syenites lie slightly to the south of the main concentration of dykes which is in the ground north of Tunugdliarfik, between Qagssiarssuk and the Ilímaussaq Intrusion. Some of the N–S to NE–SW-trending faults were formed during the period of dyke injection but the exact timing of the movements on the two major E–W sinistral transcurrent faults are less certain; a major part of the movement on these faults is very late.

A minor event within the North Qôroq Centre aids correlation with the Qagssiarssuk area. A small plug of carbonated breccia of monchiquitic affinities cuts the junction between the syenites SN. 1 and SN. 5. This breccia plug is petrographically identical with breccias described by J. W. STEWART (1964) from Qagssiarssuk where they are placed fairly late in the intrusive history of that area. The North Qôroq breccia plug is cut by an offshoot of an alkali trachyte dyke which is probably a member of the regional dyke swarm.

From their relations to the Gardar dolerite dykes and to the later swarm of alkali trachyte and other dykes, the Igaliko syenites (with the exception of the late members of the Igdlerfigssalik Centre) are thought to be slightly older than the alkali syenites and granites of the Narssaq Complex (SØRENSEN, 1966) but younger than the Tugtutôq giant dykes of gabbro, syenogabbro and syenites (UPTON, 1962).

The latest events at Igaliko are the sequence of syenite intrusions SI. 4 to SI. 7, the late alkali dolerite dyke, and the last movements on the major sinistral transcurrent faults. Although these faults do not intersect any of the late Igdlerfigssalik syenites nor the alkali dolerite intrusion, they do cut all the alkali trachyte dykes on the Narssarssuaq peninsula, in "Flinks Dal", and in "Gieseckes Dal". Since the late Igdlerfigssalik syenites are cut by a few dykes that are petrographically identical with dykes displaced by these faults it must be assumed that the last movements on the faults were probably the latest events in the Complex. Consequently, the latest syenite intrusions at Igaliko may be slightly older than the Ilímaussaq Intrusion (FERGUSON, 1964; SØRENSEN, 1966, p. 9), and possibly older than the Central Complex of Tugtutôq (UPTON, 1962), the Nunarssuit Complex (HARRY & PULVERTAFT, 1963) and the Kûngnât alkaline complex (UPTON, 1960).

(b) The mode of emplacement of the syenites

The emplacement of the syenites of the Igaliko Complex has, in general, been accomplished without appreciable disturbance of earlier rocks, regardless of whether these were Julianehåb Granite, Gardar supracrustal rocks, or other syenites. A useful pre-syenite reference level is provided by the unconformity of the Gardar supracrustal rocks on the basement granites and gneisses; this is present near the Igdlerfigssalik and Motzfeldt centres as well as in the vicinity of Narssarssuaq. Except near Narssârssuk, where there has been a certain amount of downwarping towards SI. 4, disturbance which can be attributed to the syenites is at a minimum. While the supracrustal rocks at Narssarssuaq have a moderate SSE dip, directed towards the South Qôroq Centre, this inclination can hardly be directly attributed to the centre since the structures are truncated by the earlier North Qôroq Centre (Plate 4). Elsewhere, slight upwards displacement may be suggested by a pattern of small, repeated normal faults downthrowing northwards on the north side of the Motzfeldt Centre, near the 1550 m summit area.

The contacts between syenites do not provide evidence of disturbance or crushing. Junctions are generally clear-cut, unless no great time interval separated the intrusions, and the structures in the older rocks have not been disturbed or distorted as far as could be ascertained. Crushing is certainly present in the syenites but this appears to be related to regional small-scale faulting rather than to the intrusions.

Within each centre the majority of the syenites have arcuate outcrops resembling broad ring-dykes. However, inspection of the contacts shows that in most instances the outer margin of each intrusion is against older rocks but the inner margin is the contact with a younger syenite; thus, the ring-dyke form is an apparent rather than a real feature. Two exceptions are the syenite SM. 3 of the Motzfeldt Centre which is regarded as a partial ring-dyke, and the syenite SI. 6 of the Igdlerfigssalik Centre which is a thin, almost continuous ring-dyke. Otherwise, the syenite intrusions are steep-sided, stock-like bodies, the centres of which are generally occupied by later intrusions.

Taking into account the undisturbed surroundings and the form of the intrusions, the mechanism of emplacement favoured is one of combined ring-dyke intrusion and block subsidence. In each, a large cylindrical or steep-sided inverted conical block has been downfaulted, the space formed being filled by syenite magma that moved up the circular fracture and over the top of the subsided mass of earlier rocks. Whether the final intrusion appears as a ring-dyke or a stock would depend on the amount of central subsidence and of subsequent erosion. Repeated subsidence about approximately the same centre, or with slight off-set, has resulted in successively younger intrusions appearing towards the middle of each centre, culminating, in the Igdlerfigssalik Centre, in the perfectly-preserved stock of SI. 7. The mechanism envisaged is that proposed by J. E. Richey to account for the structural relations of granitic and other rocks within the Central Complexes of the Tertiary Volcanic Districts of the British Isles (Richey, 1928, 1932). Proof of the operation of downward subsidence is found within the Motzfeldt Centre. Here, large rafts of country rock are preserved within the syenite SM. 4; since these include a high proportion of altered basalt and agglomerate derived from the Gardar supracrustal rocks, it is necessary to postulate downward subsidence to account for their present position. Structurally similar relationships are known within the Grønnedal-Íka nepheline syenites where a large raft of altered gneiss and amphibolite separates different syenites (Emeleus, 1964), in the Kûngnât alkaline igneous complex where a conspicious raft of gneiss occurs within the Western Centre, separating two series of layered syenites (Upton, 1960), and probably within the Nunarssuit syenite, although here there is the possibility that the inclusions represent roof pendants (Harry & Pulvertaft, 1963, p. 125). At Igaliko, it is significant that the inclusions within SM. 4 are thoroughly recrystallized and altered metasomatically, indicating prolonged contact with active syenite magma. Apart from the rafts in SM. 4, and occasional inclusions such as those found in SI. 4, the syenites are remarkably free from xenoliths of any sort, a further point of similarity with the Tertiary intrusions of the British Isles.

During the prolonged period of time involved in the gradual build-up of the Igaliko Complex, a succession of centres of igneous activity was established. Within each centre, activity took place in several distinct phases, now represented by the different syenites. In several instances, a considerable amount of time must have elapsed between successive intrusions. Individual syenites have internal structures and other features which indicate that *in situ* differentiation was able to take place during the consolidation of the body. However, several syenites provide evidence that occasionally intrusions succeeded one another quite rapidly; this is suggested by the contact relations of syenite pairs such as SS. 2/SS. 3, and SS. 4/SS. 5, and also by the close similarities and contact relationships of SI. 5 and SI. 6; these may represent successive pulses of magma from the same source (Harry & Richey, 1963) although there may be slight compositional differences between pairs (*e. g.* SS. 4 and SS. 5). Within each centre there is a definite preference for the youngest intrusion to occupy the most central position; the older syenites have usually been cored-out by successively younger intrusions.

The symmetry of the centres calls for comment. Inspection of the map (Plate 4) shows that each centre is, or was oval in outline. The long axes of the centres are all oriented approximately NW–SE at right-angles to the direction of the regional Gardar dyke swarms. It is perhaps worth noting a similar orientation exists in the nearby Ilímaussaq Intrusion (Ferguson, 1964). Furthermore, the succession of centres from North Qôroq to the late member of the Igdlerfigssalik Centre shows a gradual change in a constant direction, that is approximately from NNW to SSE when allowance is made for faulting. Also, within the late Igdlerfigssalik Centre there has been a change in the centre of activity in the same general direction. The progressive and systematic changes provide a similar pattern to changes observed on the Tertiary Centres of NE Ireland where the elongation of the centres lies across the direction of the associated dyke swarms. Many of the features of the Igaliko Complex find a parallel in the ring-structures described by Turner (1963) from Sara-Fier, Nigeria. Here, the author describes progressive migration from one centre to another, the presence of several intrusions within a centre and the tendency for younger members to lie within the limits of the earliest, outermost intrusion. The Nigerian intrusions are frequently steep-sided and Turner points out that it is difficult to envisage their emplacement by a simple cauldron-subsidence mechanism; the difficulty is also present with some of the syenites at Igaliko (*e. g.* SS. 4, SI. 7) although even a slight outward inclination of the intrusion margin may be adequate, provided there is considerable subsidence of the central block; this seems a likely event since the magmas were all of nepheline syenite composition (*cf.* L. R. Wager in discussion of D. C. Turner's paper (1963, p. 365)).

IX. APPENDIX

Access to the Igaliko Complex

There is great variation in the ease of access to the different parts of the Complex (Plate 3). On the western side there is little difficulty; a boat may be used to land at many points on the eastern shore of Tunugdliarfik; it is possible to walk to the syenites from the village of Igaliko or the landing place at Itivdleq, from the shore near Narssârssuk and from Narssarssuaq airport. Access becomes progressively more difficult towards the east of the Complex. Qôroq is usually navigable as far as "Flinks Dal", although extreme care is required especially near the ice front, since sudden föhn winds can blow large masses of loose ice from the foot of Qôrqup sermia to Niaqornârssuk in a matter of hours. However, landings can usually be made on either side of the foot of "Gieseckes Dal", at "Flinks Dal", and at the base of the steep fjord walls at numerous points. From Narssarssuaq airport, it is possible to walk to most of the ground between Tunugdliarfik, Kiagtût sermiat and Qôroq. South of Qôroq there are several ways of reaching the mountain masses centred around Igdlerfigssalik and Agdlerulik. The western slopes, which are generally fairly gentle, are somewhat scree-covered. The broad valley of Qôrorssuaq provides an extremely useful through route from which central parts of this ground may be reached. The southern slopes facing towards Østfjordsdal may be climbed at a number of places though much of the ground is steep and thickly mantled by mobile scree. On the northern side, south of "Gieseckes Dal", the mountains are steep with the upper parts of the valleys filled by small corrie glaciers making access difficult though by no means impossible. From the Qôroq end of "Gieseckes Dal" it is possible to walk along the southern side of the valley to the upper part of Østfjordsdal and thence to Igaliko Fjord near Fox Bay, keeping below 500 metres elevation for most of the distance; however, it should be pointed out that the river flowing through "Gieseckes Dal" is fed by glacier melt waters and cannot be crossed except possibly where it spreads out over the gravel flats at Qôroq or in the area of gravel flats at the southern end of Motzfeldt Sø.

The ground bounded by "Gieseckes Dal", Qôroq, the two arms of Qôrqup sermia, and Motzfeldt Sø is fairly easily approached from the northern side of "Gieseckes Dal", and through "Flinks Dal" and its various branches. To reach the southern side of the upper part of Motzfeldt Sø and the corresponding SE arm of Qôrqup sermia it is necessary to walk the length of "Flinks Dal", descend to the lake through a col about 3 km east of the mountain Ivnârâ, past the lake at 700 m elevation in the uppermost part of "Flinks Dal". To reach the southern end of Motzfeldt Sø, follow a fairly well-defined sheep track on the northern side of "Gieseckes Dal"; however, it is doubtful if it is possible to traverse all the western shore of Motzfeldt Sø in order to join the route through "Flinks Dal".

The most difficult ground to reach is that lying to the north and east of Motzfeldt Sø. During our field work both of these areas were mapped from camps established with the help of helicopters. To reach either on foot, carrying tents and supplies for a prolonged stay, would be arduous but quite possible for a well-equipped group. The eastern part would have to be approached from the southern side of "Gieseckes Dal", across the gravel flats west of the large glacier. To reach the northern area of syenite it would be necessary to walk through "Flinks Dal", get to the SE arm of Qôrqup sermia and cross the glacier which was, in 1963, very slow moving and relatively little crevassed compared with the active western arm of Qôrqup sermia. Once the northern shore of Motzfeldt Sø is gained there is little difficulty in walking into the syenites using the NE–SW river valleys. It is also possible to walk as far east as the foot of the glacier at the NE corner of the lake. Obviously, a boat on this lake would be of considerable help; however, great care would have to be exercised in its use, the two principal hazards being sudden, violent föhn winds, and submerged rocks—the waters of Motzfeldt Sø are densely charged with rock flour. There should be no difficulty in reaching the Geologfjeld and Syenitknold areas once the north side of Motzfeldt Sø is reached, the obvious route is by way of the valley of the Storeelv.

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Færdig fra trykkeriet den 6. april 1970.

Plate I.

Generalized geological map of the country around Ivigtut and Julianehåb, showing the positions of the Gardar Igneous Centres and the principal areas of surpracrustal rocks of the Eriksfjord Formation.

Plate II.

Geological map of the Narssârssuk area, south of Tunugdliarfik.

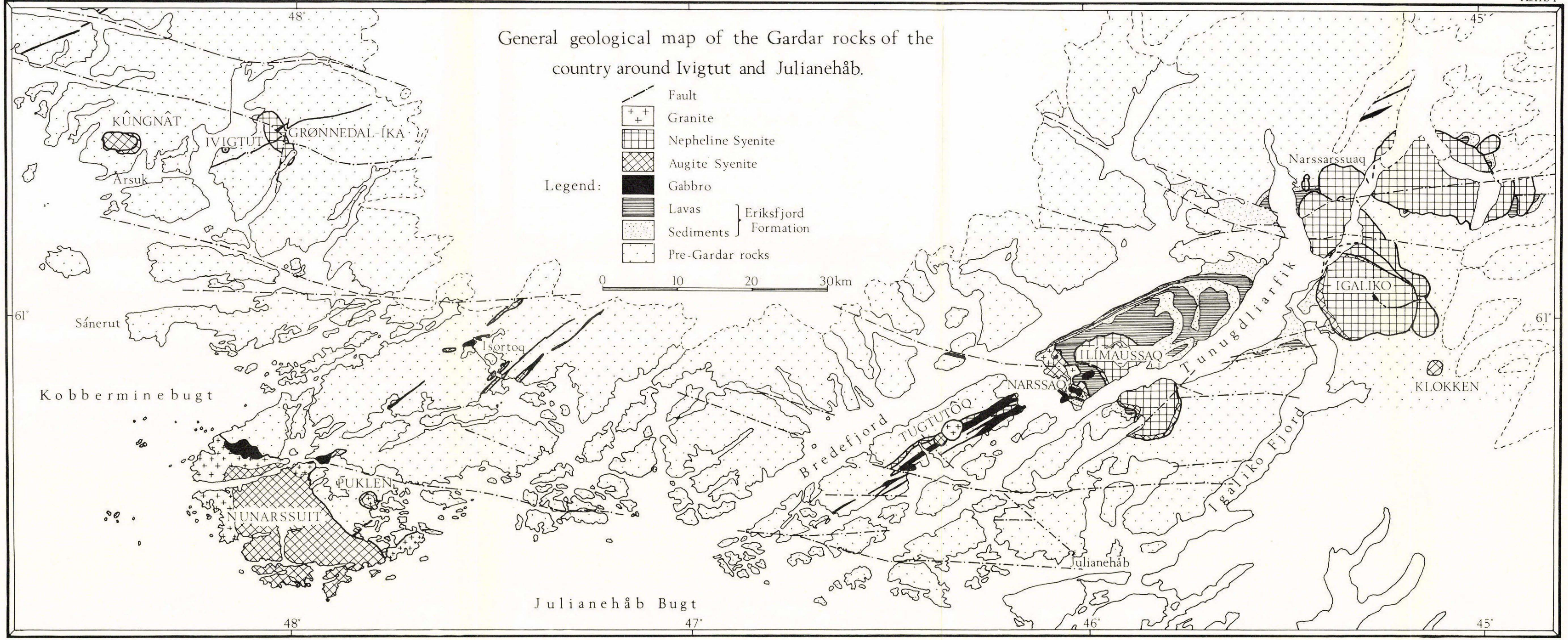
Plate III.

Topographic sketch map of the country between Igaliko Fjord, Tunugdliarfik, and the Inland Ice to the east. The principal landing places are indicated as well as the main routes giving access to the country at a distance from the fjords. (N.B. The heights shown north of 61°N are taken from recent (1966) provisional maps supplied by the Geodetic Institute, Copenhagen.)

Plate IV.

Geological map of the Igaliko Nepheline Syenite Complex. Scale 1:50 000.

GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND

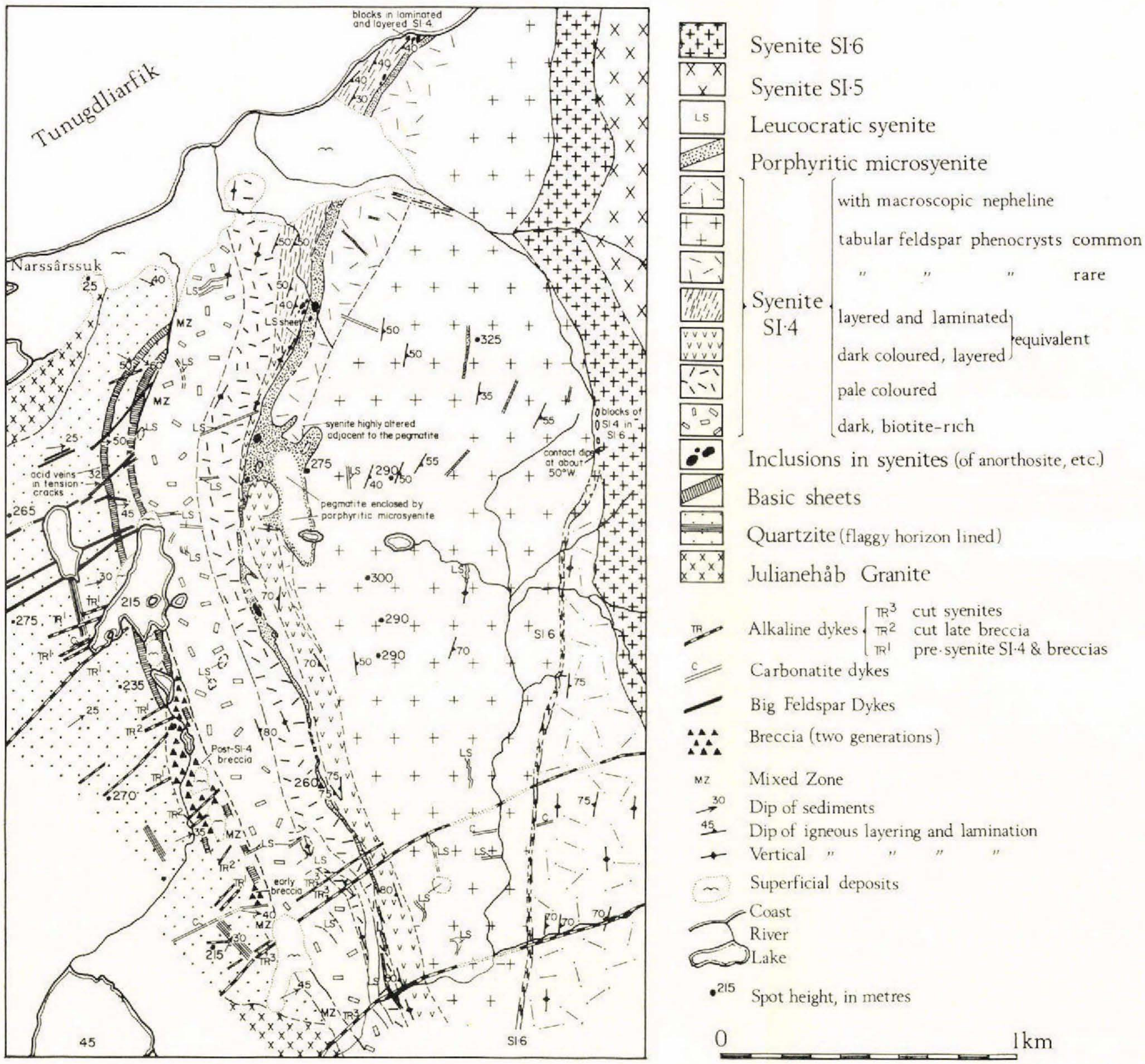


GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND
MEDDR GRØNLAND BD. 186 NR. 3 (C. H. EMELEUS AND W. T. HARRY)

Geological map of the Narssârssuk area

by

W.T.Harry and C.H.Emeleus



GRØNLANDS GEOLOGISKE UNDERSØGELSE
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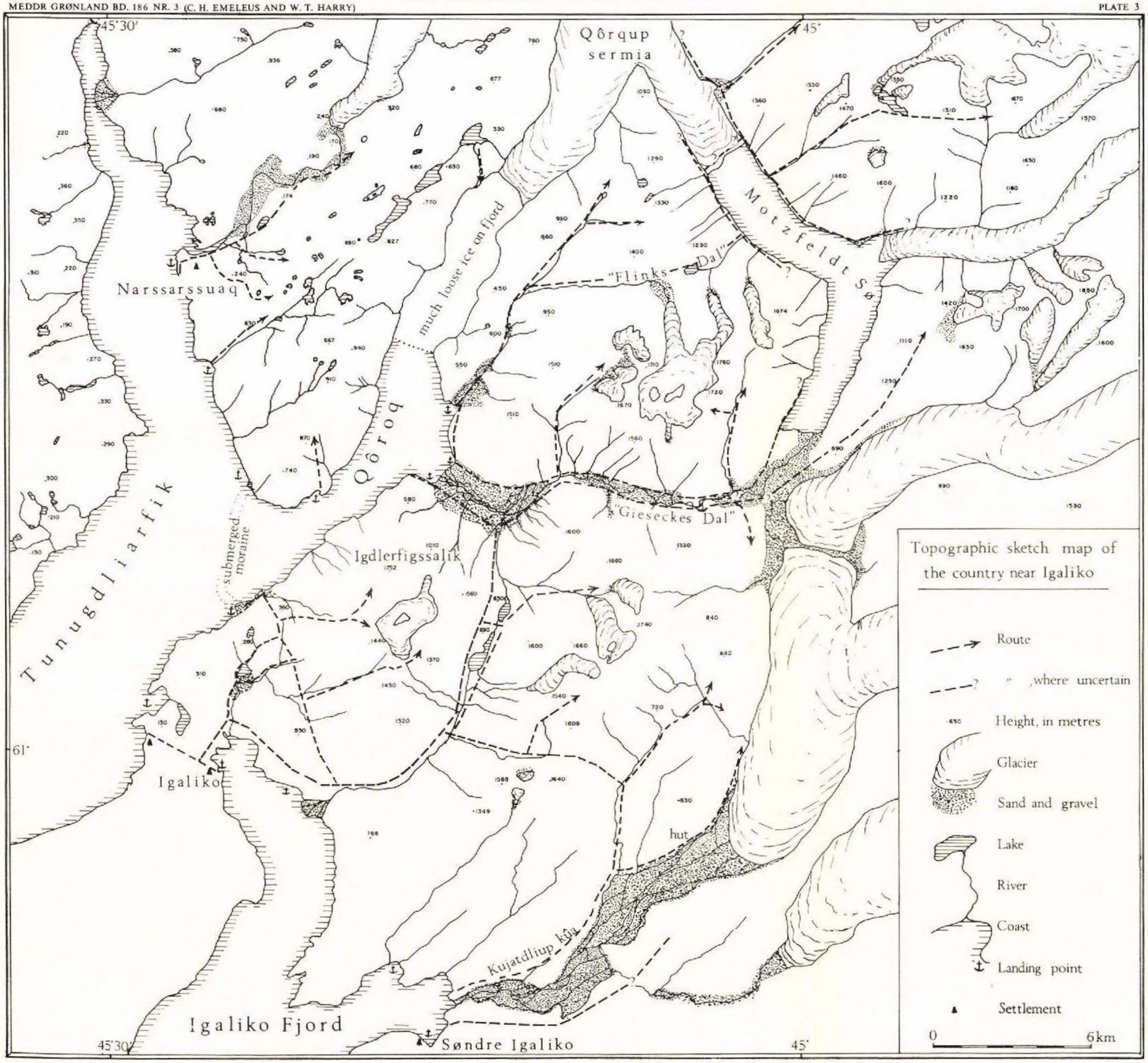
PLATE 3



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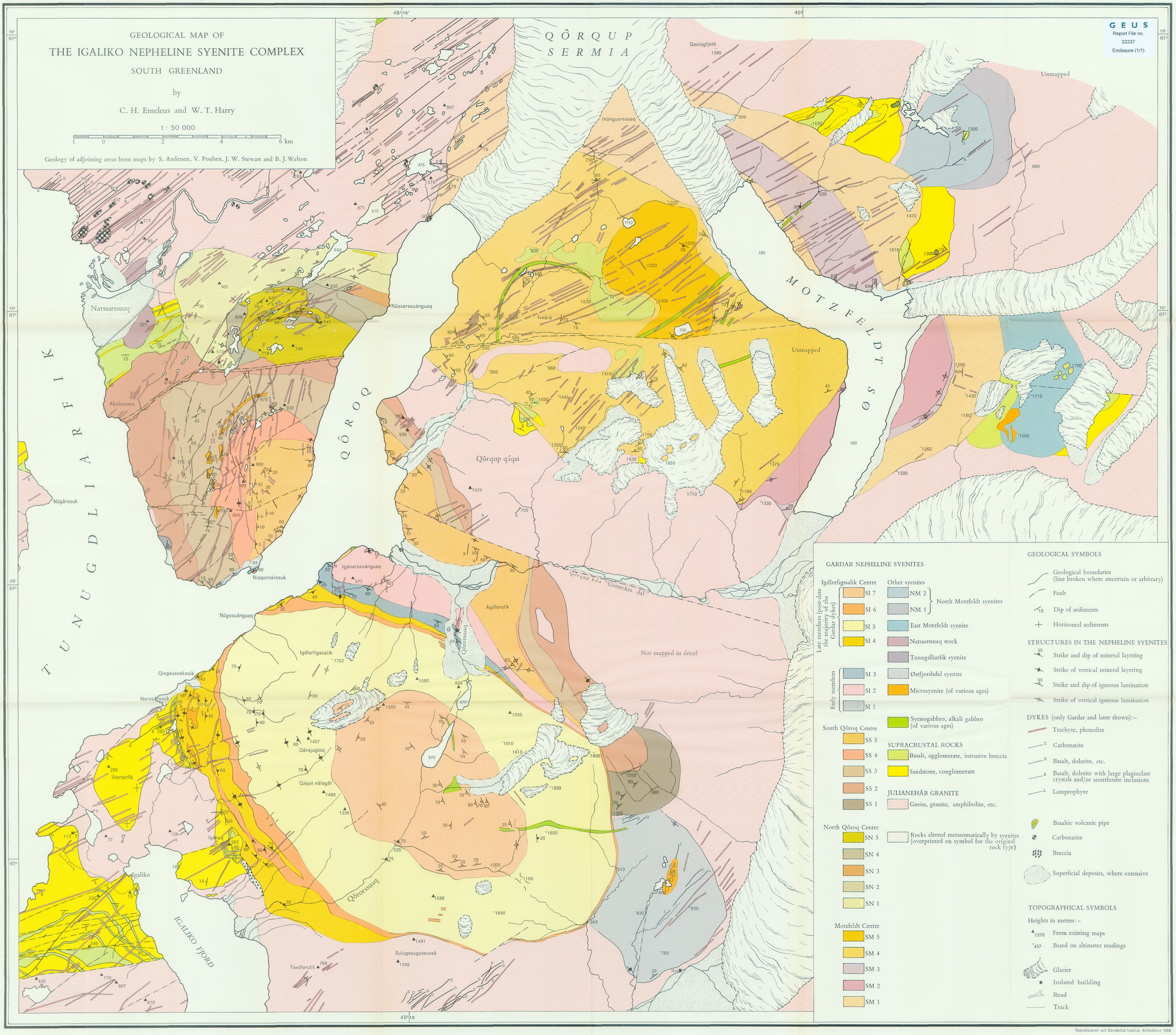

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