GRØNLANDS GEOLOGISKE UNDERSØGELSE
BULLETIN No. 55

THE EQALOQARFIA LAYERED DYKE, NUNARSSUIT, SOUTH GREENLAND

BY

T. C. R. PULVERTAFT

WITH 15 FIGURES AND 2 TABLES IN THE TEXT
AND 1 MAP

DANISH GEOLOGICAL CONTRIBUTION
TO THE INTERNATIONAL UPPER MANTLE PROJECT

Reprinted from
Meddelelser om Grønland, Bd. 169, Nr. 10

KØBENHAVN
BIANCO LUNOS BOGTRYKKERI A/S
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Abstract

The layering in the Eqaloqarfia dyke defines a synform running parallel to the length of the dyke, with a maximum inward dip of the limbs of 36°. The layering is developed in the lower part of a trough of feldspar-phyric gabbro in an otherwise normal dolerite. Homogeneous dolerite both underlies and forms a border to the gabbro. A perpendicular feldspar layer occurs in places at the border between the dolerite and the gabbro: in this layer unzoned plagioclase laths have grown at steep angles to the margin of the dolerite.

The gabbro is characterised by platy feldspars up to 2 cm wide which are set in a doleritic matrix. The cores of the plates have a composition in the range An_{57-64} and constitute an early generation of plagioclase which crystallised at depth. The second generation of plagioclase, forming the shells of these plates and the smaller crystals in the matrix, began crystallising with a composition An_{69-75}, zoning down to An_{30-40} at the margins of crystals.

The layering comprises olivine-rich horizons alternating with layers of the feldspar-phyric gabbro. There is no graded bedding in the olivine-rich layers, nor is there any lamination or packing of the feldspar plates in the gabbro. Intermittent settling of olivine during the early slow crystallisation in the gabbro trough is regarded as the cause of the layering.

A slight cryptic variation is shown by the second generation of plagioclase. In view of the lack of evidence for either magmatic currents or feldspar settling, it is thought that diffusion can contribute more to differentiation than is usually allowed. Diffusion is also required to explain the lack of zoning in the plagioclase laths of the perpendicular feldspar layer.

PREFACE

The investigation of the Eqaloqarfia layered dyke was carried out while I was undertaking a 1:20,000 survey of the island of Nunarssuit, South Greenland, for the Geological Survey of Greenland (Grønlands Geologiske Undersøgelse, GGU). A map of the layered part of the dyke was made on a scale of 1:10,000. The laboratory work was carried out at the Mineralogical Museum in Copenhagen,

My thanks are due to the director of the Survey, mag. scient. K. Ellitsgaard-Rasmussen, for constant support in providing facilities. I am grateful to Mr. B. I. Borgen and Mrs. H. Bollingberg for chemical and spectrographic analyses respectively, and to Dr. J. L. Jambor, of the Geological Survey of Canada, who carried out X-ray determinations of olivine. Finally I wish to thank Dr. W. J. Wadsworth for critically reading the manuscript.

Copenhagen, June 1964. T. C. R. Pulvertaft

INTRODUCTION

Layered igneous intrusions, although for a long time known to exist, have been attracting an increasing amount of attention since WAGER and DEER published their classic description of the Skaergaard intrusion in 1939. There are two main reasons for this: i) Layering is one of the few features of igneous intrusions which can readily be appreciated, and may be spectacular, in the field. ii) As soon as WAGER and DEER had shown beyond all reasonable doubt that the layered structures in the Skaergaard intrusion developed during bottom accumulation of crystals from a single magma, it became clear that the study of layered intrusions could contribute enormously to the understanding of the conditions obtaining during fractional crystallisation of a magma.

As a result of the increased interest in igneous layering since the publication of the Skaergaard memoir, it has become evident that most

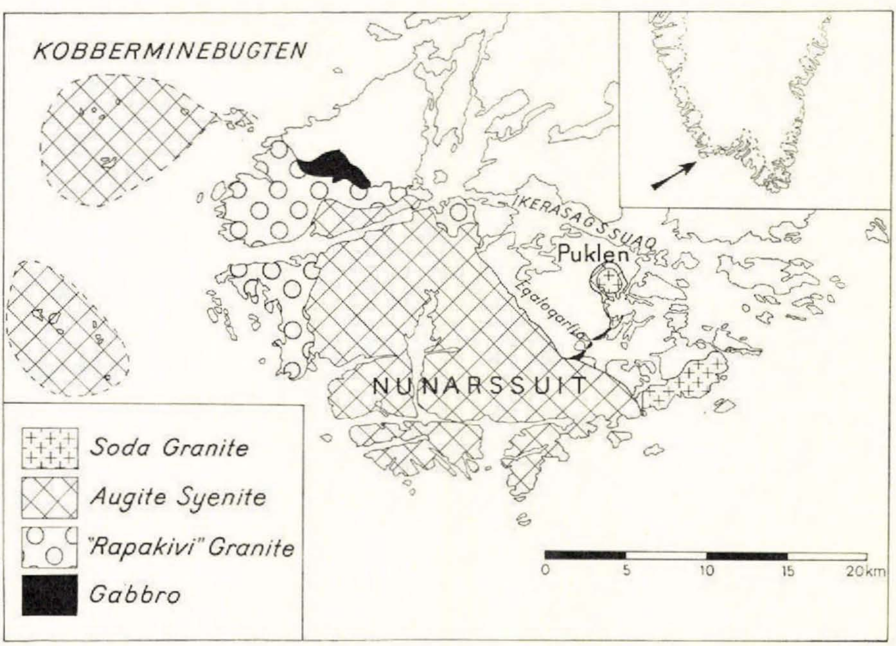

Fig. 1. Index map showing the position of the Eqaloqarfia dyke in relation to the Nunarssuit and Puklen intrusions.

larger igneous masses are layered to a greater or lesser degree. Thus layering alone does not give the Eqaloqarfia dyke a special claim to interest. It was nevertheless the striking layering which prompted the investigation of the dyke, although as the study progressed it became evident that other petrological questions were raised, not all of which it was possible to answer satisfactorily.

The Eqaloqarfia layered dyke is an unusually thick example of the northeasterly doleritic dykes forming an extensive swarm in the Nunarssuit area. These dykes are of Gardar age, and pre-date the alkaline centres in the area. (For an introduction to the general geology of the Nunarssuit area see Harry and Pulvertaft, 1963, pp. 14–20). The Eqaloqarfia dyke was emplaced into basement (Julianehåb) granite. To the south-west it is truncated by augite-fayalite syenite of the Nunarssuit complex, which has locally hornfelsed the dyke with recrystallisation and the development of new biotite. To the north-east, granophyre of the Puklen intrusion also cuts the dyke. The geographical position of the dyke and its relations to these two later intrusions are shown in fig. 1.

The dyke is well exposed (fig. 6), but not so well that it is possible to follow individual layers laterally for more than a few tens of metres. Furthermore an inlet of the sea conceals part of the dyke, but the clean water-worn outcrops on the shore partly compensate for this.

FIELD DESCRIPTION

General

The Eqaloqarfia dyke extends some 3 km in a northeasterly direction from the margin of the Nunarssuit Syenite to the southern end of the Puklen intrusion (fig. 1). In the south-west it is about 400 m thick, but to the north-east it is somewhat thinner, measuring only 200 m. The contacts against the basement granite are steep, but are not so well exposed that one can be quite sure that the widening of the outcrop in the higher ground to the south-west is not due to an upward thickening of the dyke.

The northeasterly outcrops of the dyke are entirely of medium-grained dolerite, and the same dolerite continues south-west to form the outer 25–50 m of the body (see Plate 1). Due to uralitisation this dolerite is grey-green in colour, but typical ophitic texture is preserved and small pseudomorphed olivines can be observed. The rock is fine-grained but slightly sheared at its contact with the basement.

Layered rocks are exposed both north and south of the channel into Eqaloqarfiata sarqâ. Unfortunately it is not possible to relate the layering in the two localities, although in each it occurs at the base of a trough of "feldspar-phyric gabbro" within the dolerite. This lack of correlation is due to: i) the break in exposure caused by the channel; ii) the effects of the two small ESE faults, one along the channel and the other a little north-east of this; between these faults a small block of the dyke has been displaced slightly to the south-east and down-thrown so that the layered zone is below the present level of exposure. Since there are differences in the appearance of the layering and the mineral compositions in the two localities they will be described separately.

Layering south of the channel

The layering describes a synform, with its axis horizontal and approximately parallel to the trend of the dyke; the maximum inward dip at the margins of the trough is 32°. The total vertical thickness of the layered rocks is less than 50 m.

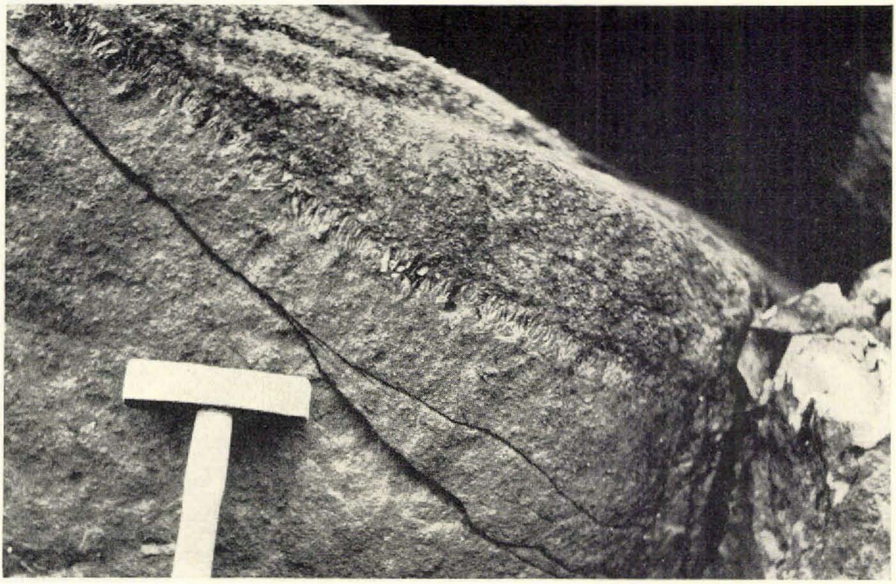

Fig. 2. Basal perpendicular feldspar layer, south of the channel. Specimen no. 20632 was collected about 1 m below this layer here, 20633 from the layer and 20643 10 cm above it.

On the south-east flank of the synform the lowest part of the layered succession is exposed on the shore. At the floor of the trough, separating the dolerite below from the layered gabbro above, is a layer of perpendicular feldspar rock (fig. 2). Within the rather limited extent of its exposure this layer has a fairly constant thickness of about 2.5 cm. It is composed principally of laths of plagioclase up to 3 cm long oriented roughly at right angles to the plane of the layer. There is a tendency for the plagioclase laths to thicken upwards, and they give the impression of having sprouted upwards from the dolerite at the floor of the trough.

The perpendicular feldspar layer is here immediately overlain by a few (less than 5) centimetres of rock which is conspicuously coarser and more mafic than the dolerite below. This rock passes quickly up into coarse feldspar-phyric gabbro, so named because it carries numerous feldspar tabulae 1–2 cm wide and up to 4 mm thick set without preferred orientation in a rather finer-grained matrix. Olivine pseudomorphs can be detected.

The gabbro is layered. The layering consists of alternations of normal feldspar-phyric gabbro with finer-grained, more mafic material, lacking the platy feldspars. These relatively mafic layers are 2–8 cm thick, and spaced 5–40 cm apart; they are also more susceptible to weathering than the normal gabbro. Considered individually the layers are of constant thickness, and they are furthermore very regular and almost perfectly

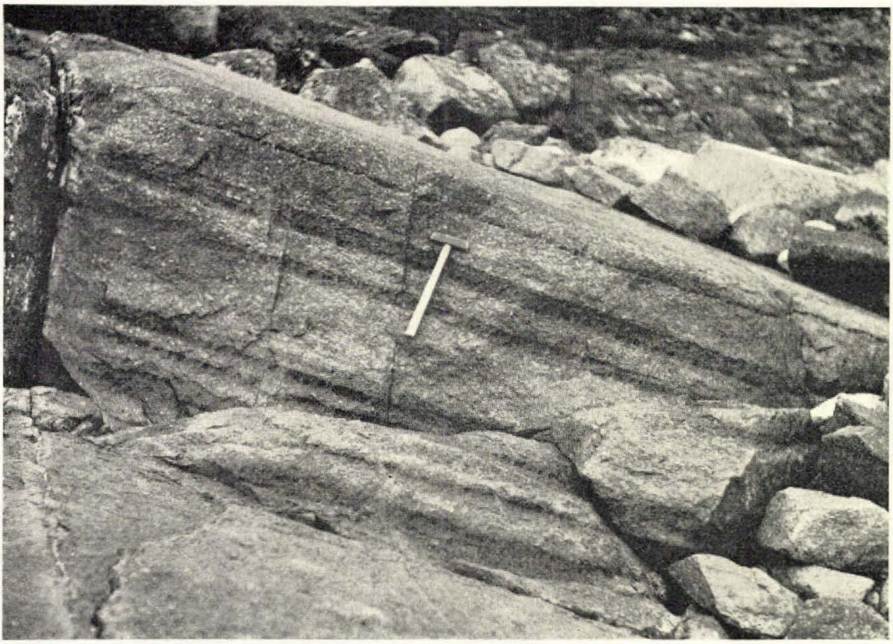

Fig. 3. Lowest layering south of the channel, about 3 m above the perpendicular feldspar layer.

parallel (fig. 3). The top and bottom of the layers are usually fairly sharp: only rarely is there a gradation into gabbro at the upper margin of a mafic layer.

The original mineralogy of the less feldspathic layers is almost impossible to make out due to the nearly complete destruction of the primary mafic minerals by uralitisation. However the layers will be referred to as the mafic layers even though it is not possible to say just how mafic they originally were, or which mafic minerals were concentrated in the layers.

Passing up the layered succession the mafic layers become thicker until they actually predominate over feldspar-phyric gabbro. This is the case where horizontal layering is marked on the map, Plate 1, and is shown in fig. 4. Occasionally in this part of the dyke two mafic bands coalesce to form a single band (fig. 5). On the south shore of the channel there are tabular lenses of medium-fine-grained dolerite around 5 cm thick within the mafic layers: these lenses are parallel to the gabbro bands in the mafic rock.

Continuing some 10 m further up the succession coarse feldspar-phyric gabbro again becomes dominant and the mafic layers become fewer and thinner until eventually they die out altogether and only feldspar-phyric gabbro is found. No banding at all was seen between the

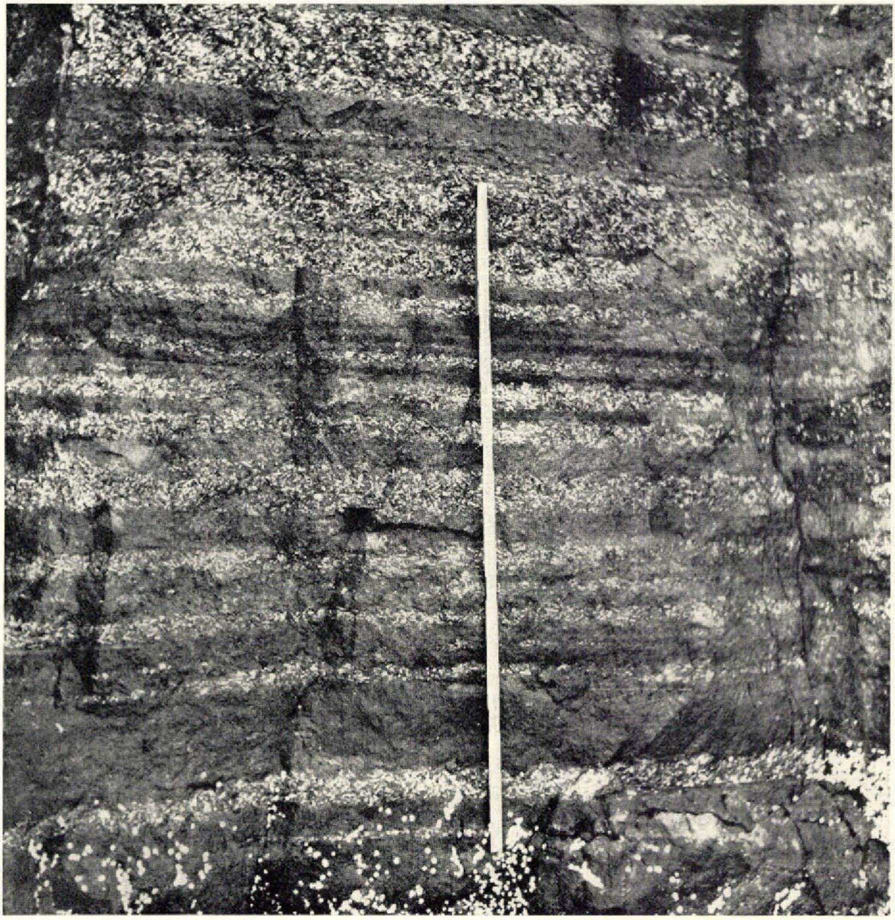

Fig. 4. Layering where mafic gabbro and feldspar-phyric gabbro bulk equally, south of the channel. A metre rule gives the scale.

50 m contour and the highest outcrop of the dyke—some 170 m above sea level. It should be emphasised that at no place in the gabbro is there any suggestion of igneous lamination, although the habit of the larger feldspars is distinctly tabular throughout.

Pegmatitic lenses occur in the gabbro. These are usually roughly concordant to the layering but may also be cross-cutting (fig. 5). The pegmatitic gabbro consists of randomly oriented chalky-looking plagioclase crystals up to 5 cm long by 1 cm thick, clino-pyroxene and plentiful skeletal or platy ilmenite.

The contact between the coarse gabbro and the dolerite at the margins of the dyke is steep and fairly sharp. Nowhere were mafic layers observed in angular discordance with the marginal dolerite. It is likely that these layers wedge out towards the margins in the manner indicated

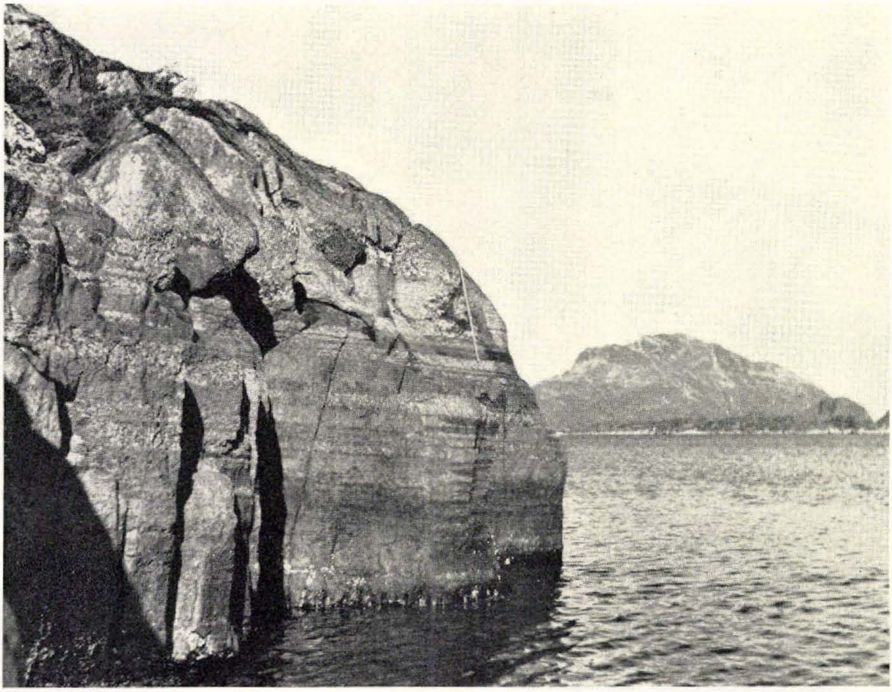

Fig. 5. Layering where mafic gabbro and feldspar-phyric gabbro bulk equally, south of the channel. Note the coalescence of two mafic layers. The metre rule lies on a pegmatitic pod.

in fig. 13, although this was never actually observed. For a short distance on the north-west side of the dyke, just south of the channel, perpendicular feldspar rock again separates the marginal dolerite from the layered gabbro. Here the perpendicular feldspar zone is up to 15 cm thick, and dips inwards at 52°. This is much steeper than the nearby mafic layers in the gabbro.

Layering north of the channel

There is some similarity between the layered section north of the channel (north of the northernmost small fault) and that south of the channel. In the lower part of the section there are mafic layers in gabbro, while in the middle part the mafic material is dominant—more so than south of the channel. Higher up the mafic layers again become progressively thinner and more widely spaced until in the uppermost gabbro exposed there is no banding at all. The thickness of the layered succession in this part of the dyke is only about 25 m. A schematic profile of the layering here is given in fig. 12; the greater part of the layered succession is seen in fig. 6.

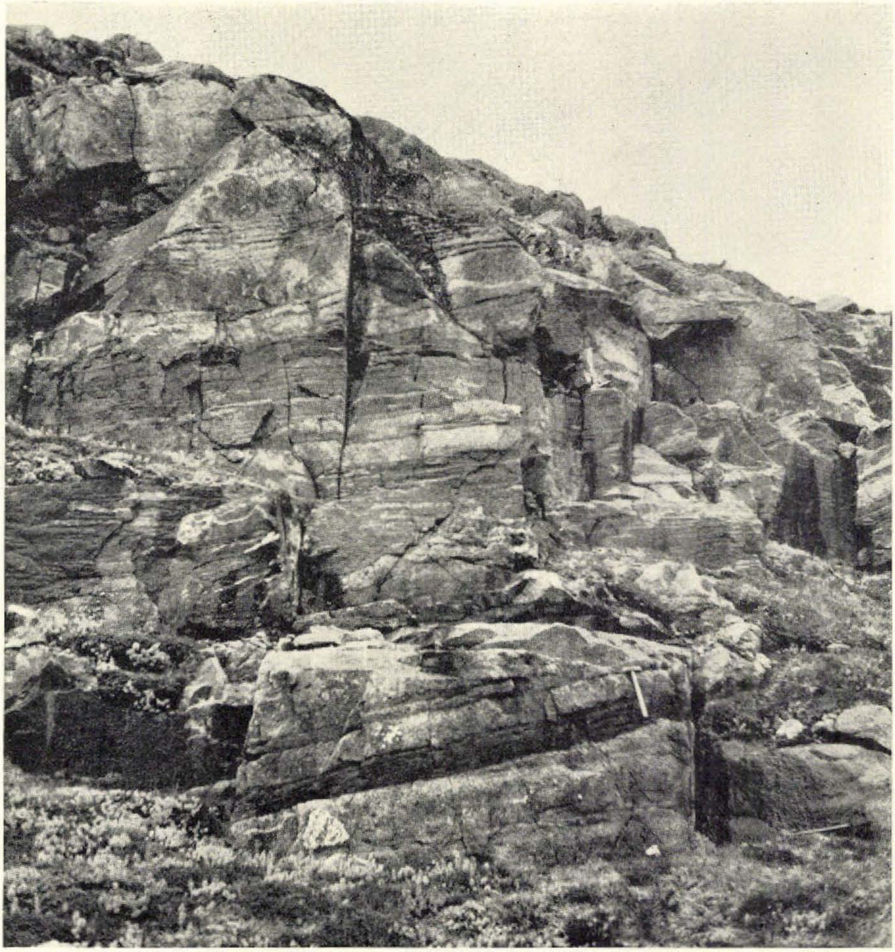

Fig. 6. General view of the layered section north of the channel. 20650 was collected a little below where the hammer is lying.

The synformal disposition of the layering is again evident (see Plate 1). The maximum inward dip recorded in this part of the dyke is 36°. Due to a slight southwesterly plunge the closure of the synform can be mapped out. Not much of the layering can be seen in the closure due to indifferent exposure, but the terraced features reflect the structure and enable it to be traced.

In the layered section north of the channel there is no abrupt change from dolerite to layered gabbro at the bottom of the section, nor is there a basal perpendicular feldspar layer. The lowest indication of layering, occurring within the normal medium-grained dolerite, is a rather vague horizon some 15 cm thick in which there are numerous large olivine crystals (up to 1 cm) set in a typical doleritic matrix.

Fig. 7. Fine-scale layering in mafic gabbro, in which there are also thicker layers of feldspar-phyric gabbro. Small lenses of fine-grained dolerite are also set in the mafic gabbro; that on the left-hand side of the figure, at the same level as the head of the hammer, is slightly discordant to the fine-scale layering.

A little higher in the dolerite there is a much thicker olivine-rich horizon with a well-defined base against medium-grained dolerite. The large olivines, up to 6 mm in diameter, resemble pebbles in a grit band when seen projecting from the weathered surface. There are thin feldspathic layers within this mafic horizon, which also stand out on the weathered surface.

Whether the incoming of the large feldspar tabulae, which distinguish the gabbro of the main layered section from the dolerite below, is sudden or gradual could not be ascertained, but the lowermost rocks in the main layered section (fig. 6) are coarse feldspar-phyric gabbro with feldspar plates up to 2 cm across, and rather more olivine than is normal for this gabbro.

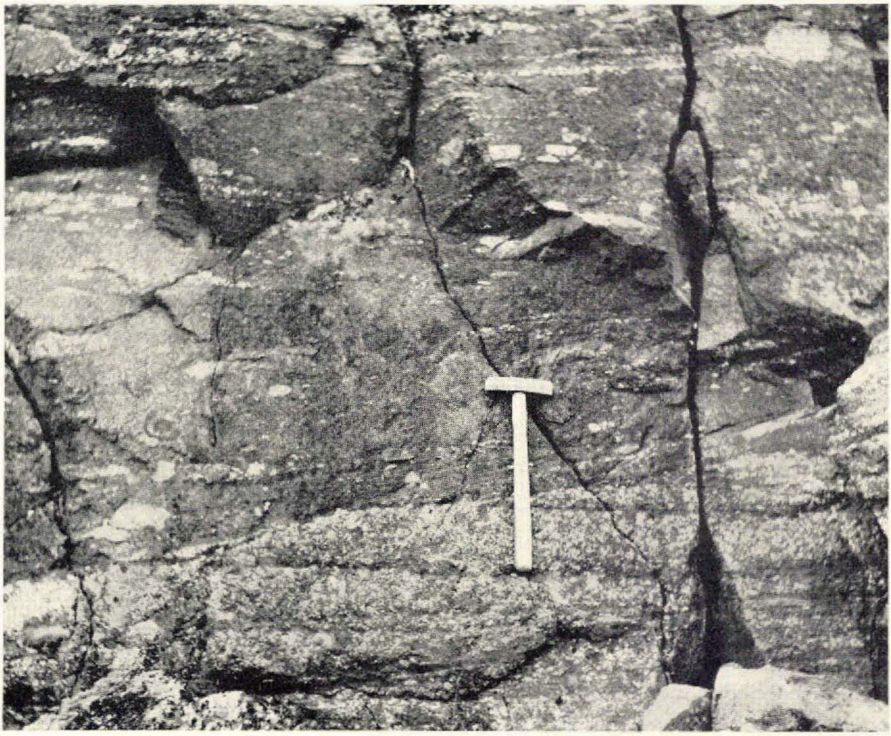

Fig. 8. Discordance in layered gabbro, north of the channel. The mafic gabbro above the plane of discontinuity shows slight fine-scale layering and contains lenses of fine-grained dolerite.

As can be seen in fig. 6, mafic—in this case visibly olivine-rich—rock is strongly predominant over feldspar-phyric gabbro in the middle part of the layered section. In addition to the obvious banding there is also a finer-scale banding within the mafic units, due to the occurrence of a few tabular feldspars (without preferred orientation) at certain horizons (see fig. 7). Also seen at this level are the discontinuous lenses of fine dolerite. These lenses are normally parallel to the fine-scale layering but may be slightly oblique to this (figs. 7 and 8).

On the whole there is a remarkable regularity and parallelism in the layering. Only one discordance was found in the Eqaloqarfia dyke; this is illustrated in fig. 8. The base of the olivine-rich gabbro truncates the layering in the lower feldspar-phyric gabbro, although the dolerite lenses and fine-scale layering a little higher up are parallel to the layering below the discontinuity.

Gradations between mafic layers and feldspar-phyric layers are rare and, just as south of the channel, there is no feldspar lamination.

Higher up in the dyke the proportion of coarse feldspar-phyric gab-

Fig. 9. Striking layering north of the channel. Both large-scale and fine-scale layering can be seen.

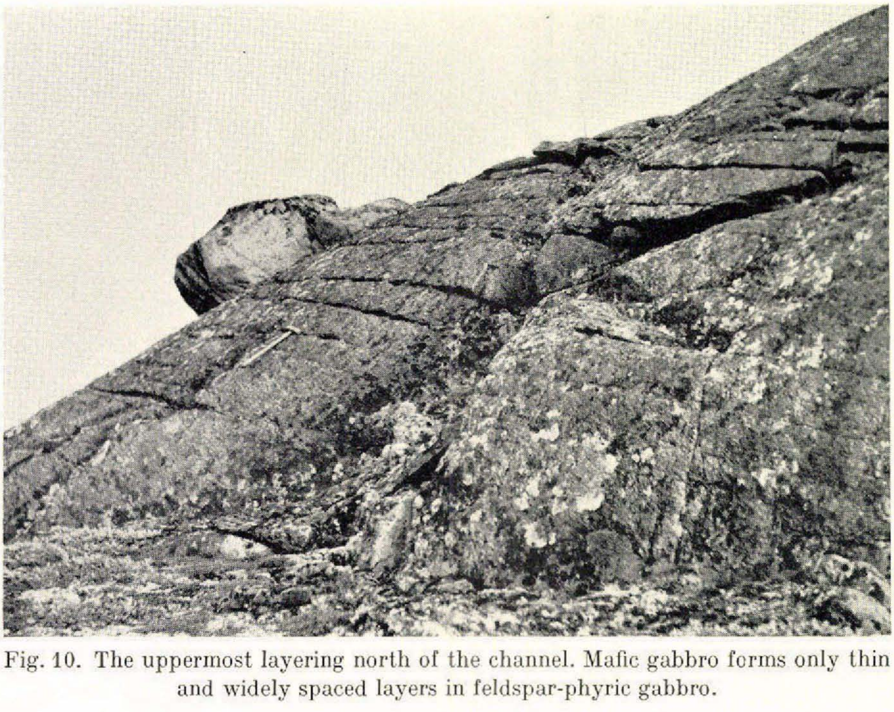

Fig. 10. The uppermost layering north of the channel. Mafic gabbro forms only thin and widely spaced layers in feldspar-phyric gabbro.

Fig. 11. Patchy feldspar-phyric gabbro, north shore of the channel.

bro increases and there are only thin mafic layers (fig. 10). In the uppermost exposures there is no layering in the feldspar-phyric gabbro.

At two places in the northern sector of the dyke perpendicular feldspar rock is seen to mark the contact between marginal dolerite and gabbro (see Plate 1). In both cases the contact is very steep, so that the plagioclase laths extend horizontally from the dolerite into the gabbro. The thickness of the perpendicular feldspar layer here does not exceed 15 cm.

No banding was seen in the gabbro between the small faults, although it is displayed immediately north and south of the faults. Thus the exposures between the faults are almost certainly of feldspar-phyric gabbro above the layered succession, which indicates a small downthrow on the two faults. In the gabbro here there are occasionally small patches, up to 15 cm wide, in which the feldspar tabulae are lacking and the rock is dolerite (fig. 11). These patches are in no sense xenoliths; rather they reflect an uneven distribution of feldspar plates in a doleritic matrix.

Summary of the field evidence from the northern and southern sectors of the dyke

The layering in the Eqaloqarfia dyke occurs at the bottom of a gabbro trough which is bordered and underlain by featureless dolerite

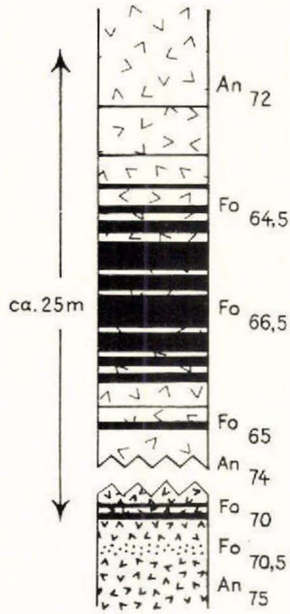

Fig. 12. Diagrammatic profile of the layered section north of the channel. Symbols as in fig. 13 and Plate 1. The compositions of the olivine and 2nd generation feldspar are indicated.

(see the schematic cross-section fig. 13). The layering describes a synform with a horizontal axis running along the length of the dyke. A perpendicular feldspar layer is developed sporadically along the margins and floor of the gabbro trough. In this layer the feldspars are set at right angles to the border of the dolerite from which they project into the gabbro.

In the layered sequence feldspar-phyric gabbro alternates with layers of mafic gabbro. In appearance the feldspar-phyric gabbro is characterised by randomly oriented feldspar plates up to 2 cm long with a finer-grained ophitic matrix. Intense late hydrothermal alteration has rather obscured the original mineralogy, but in the northern exposures it

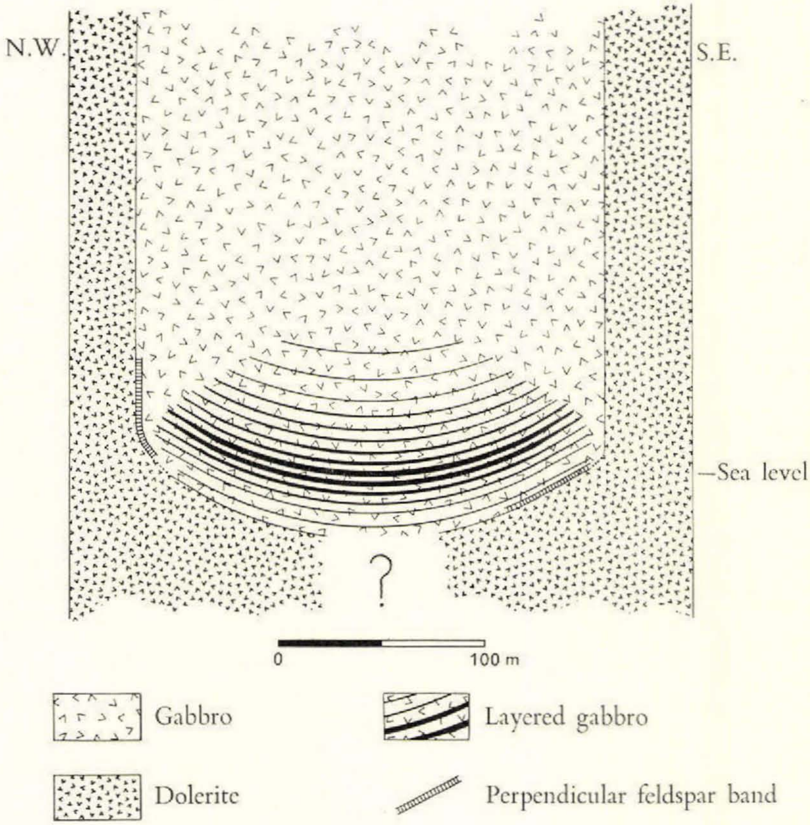

Fig. 13. Cross-section of the south-west part of the Eqaloqarfia dyke. The layering is represented schematically. The vertical scale is slightly exaggerated.

can be seen that enrichment in olivine is the main compositional feature of the mafic layers: the olivine crystals in the very lowest of these layers are also very much larger than those seen elsewhere, reaching 1 cm across. In the middle part of the layered succession, mafic gabbro predominates over the feldspar-phyric type. Small lenses of fine-grained dolerite sometimes occur within the mafic layers: normally these are parallel to the layering but occasionally they are set slightly oblique to the fine-scale banding observed locally within the mafic layers. Feldspar lamination is notably absent in the dyke, in spite of the favourable feldspar habit. Cross-bedding is also unknown, and grading is rare and only poorly developed. A single discontinuity was seen which might be attributed to slump action triggered by a sudden shock such as that of an earthquake. Above the layered zone there is only feldspar-phyric gabbro which is quite uniform.

Something of the history of the dyke can be deduced from the facts set out above. Crystallisation and consolidation of magma first took place along the margins and in the lower part of the dyke to form the featureless medium-grained dolerite. The crystallisation of the gabbro was a later event. During the interval which elapsed between the formation of the dolerite at the margins and the crystallisation of the gabbro in the trough, plagioclase crystals grew inwards from the walls of the chamber. In the southern part of the dyke perpendicular feldspars also grew on the floor of the trough, but north of the channel there appears to be no break between the dolerite and the base of the gabbro. The onset of crystallisation of the gabbro was accompanied by fluctuations in conditions which gave rise to the periodic accumulation of olivine. Later conditions became constant and the remainder of the trough crystallised to form homogeneous feldspar-phyric gabbro. The lack of lamination and cross-bedding, and the scarcity of grading indicate that magmatic flow played little or no part in the formation of the layering.

There are certain differences between the layered sequences in the northern and southern sectors of the dyke. The connection between these sequences is hidden in the down-faulted block (p. 16), so the significance of the differences is not certain. It seems however that the layering was of more or less contemporaneous formation, and the problem of the origin of the layering is the same in each sector.

MICROSCOPIC PETROGRAPHY

The original constituent minerals of the Eqaloqarfia dyke were plagioclase, augite, olivine, Fe-Ti oxide and apatite. Due to extensive late-stage hydrothermal alteration all the rocks in the dyke, the layered gabbro as much as the dolerite, are uralitised. Pale amphibole, pale green chlorite, antigorite and opaque oxides have replaced olivine, leaving fresh relics only in the centres of the largest grains. Augite has usually been altered to light green hornblende. Furthermore even plagioclase has often been partially replaced by chlorite: evidence of this is seen in the lath-shaped chlorite aggregates with plagioclase cores which are in typical ophitic relation with augite or hornblende. As a consequence of this late alteration accurate modal analysis of the original mineral percentages is impossible. In no slice could the original proportion of augite to olivine be more than guessed, and the replacement of plagioclase by chlorite, especially in the mafic layers south of the channel, makes it difficult even to assess the proportion of plagioclase to dark minerals.

The hydrothermal alteration took place after the crystallisation of the dyke as an olivine dolerite and the formation of the layered structures. The original textures in the dyke are textures which developed between plagioclase, augite and olivine. Olivine pseudomorphs often have idiomorphic outlines; there is no indication that reaction to hornblende and other secondary minerals took place during crystallisation from the magma. In the Nunarssuit area as a whole hydrothermal alteration of Gardar dykes is not confined to any particular generation of dykes but rather has a geographical distribution, all the dykes within a particular area being similarly affected. This is further evidence of the late-stage nature of the alteration to hornblende, although it must be added that since it is the Gardar dykes which are preferentially affected the hydrothermal action is related to Gardar igneous activity. In this account the secondary minerals will not receive further treatment: the textures will be described entirely in terms of original minerals without reference being made to whether fresh crystals or pseudomorphs are under consideration.

Of the original minerals, only plagioclase is everywhere fresh enough to allow a representative study of its composition and behaviour. Compositions were determined optically. The normal to (010) was plotted in relation to the vibration directions, and found in every case to fall on or slightly to the left of VAN DER KAADEN's curve for low temperature plagioclases (VAN DER KAADEN, 1951, stereogram II). Maximum extinction angles in the zone normal to (010) were also measured. Compositions determined by the two methods were generally in close agreement ($\pm 1\,^0/_0$ An), so there is no reason to doubt the value of the results obtained for small crystals with thin twin lamellae which lent themselves only to determination by the extinction angle method. No claims are made for the absolute accuracy of the feldspar compositions quoted, but it is the *relative* values which are important in this study.

Olivine compositions were determined from X-ray powder patterns in the only five specimens carrying fresh olivine—all of them from the north-east part of the dyke.

The **dolerite** is a medium-grained rock and has typical ophitic texture. Plagioclase crystals reach 2.5 mm long by .75 mm thick. They are strongly zoned. The composition of the cores is An_{75}, while the margins contain as little as $40\,^0/_0$ An. Generally the zoning is gradual, but rarely a slight increase in An content (ca. $2\,^0/_0$) takes place before normal zoning sets in.

Anhedral ophitic augite ($2V\gamma$ 50–53°) extinguishes patchily, but as a unit, over areas as much as 5 mm wide. Pseudomorphed round-shaped olivine grains average a millimetre in size: they are rather scattered. The accessory minerals are anhedral Fe-Ti oxide and rare small prismatic crystals of apatite.

Specimens of **perpendicular feldspar rock** were collected only from the south-west part of the dyke. In these the long plagioclase laths, which are set at steep angles ($>60°$) to the plane of the layer, totally lack zoning, having a constant composition An_{69}. In contrast the small feldspars in the matrix show some normal zoning, from An_{69} to An_{60}. These small crystals are set in secondary hornblende in which apatite and Fe-Ti oxide are infrequent accessories.

In the **feldspar-phyric gabbro** plagioclase, and possibly also olivine, belong to two generations. The numerous larger feldspar plates reach 2 cm in length, and the rare scattered larger olivines 3 mm. The interstitial material consists of small well-shaped plagioclase crystals and ophitic augite, with apatite and poorly formed Fe-Ti oxide as accessories. The smaller olivine crystals are so completely altered that even their form may be blurred, although euhedral forms can sometimes be made out: their status as a second generation is not completely certain.

The large feldspar tabulae show a striking and consistent pattern of zoning (see figs. 14 and 15). Considered individually the cores, often $50\,^0/_0$ or more of the crystal's volume, are uniform or show slight oscillatory zoning over a range of $3\,^0/_0$ An. However the composition varies from crystal to crystal, even within a single slice, from An_{57} to An_{64}, although it seems that a composition of An_{57-58} is the most common. No pattern of distribution could be discerned in this composition variation. Specimens from high up and low down in the section, and from north and south of the channel, showed the same variation in core composition. These cores are surrounded by a shell of feldspar which begins with a composition 10–15 % richer in An than the core, and zones rapidly and evenly to An_{30-40} at the margin of the crystal. The composition of the innermost part of the shell is constant within a single sample, and the small plagioclases of the matrix show continuous normal zoning over precisely the same range as that of the shells of the large tabulae. It is clear that the cores of the large tabulae belong to an early generation of plagioclase, and the outer shells together with the small crystals in the interstices constitute a second generation.

The behaviour of the plagioclase in the Eqaloqarfia dyke is set out diagrammatically in fig. 14. While the cores of the large plates show the same haphazard distribution in the range An_{57-64} everywhere, a small but meaningful cryptic variation can be detected in the plagioclase of the second generation. The samples in fig. 14 were selected to show this rather than the variation in the first generation. In the northern part of the dyke the second generation plagioclase in the lowest gabbro starts at An_{74-75}, the same as the core composition of the plagioclase in the dolerite below, but passing up the succession the An content of the inner part of the later feldspars falls by 2–3 %, to An_{72}.

A similar cryptic variation is evident south of the channel. Here however the second generation plagioclase began crystallising with a composition of An_{69} in the gabbro at the base of the trough, and of An_{67} some 50 m higher up. Normal zoning brings the compositions of the crystal margins down to ca. An_{32}, but not every crystal shows so much Ab enrichment towards its margin. The plagioclase cores in the dolerite immediately below the trough have the same composition (An_{75}) as elsewhere throughout the dolerite. Thus there is a distinct break in the plagioclase composition between the dolerite and gabbro in the southern sector of the dyke, in contrast to the northern sector.

Fig. 14. Diagrammatic representation of the plagioclase zoning encountered in the Eqaloqarfia dyke. The samples are as follows: 20632: dolerite below the gabbro trough in the southern sector; 20633: perpendicular feldspar rock from the southern sector; 20643: feldspar-phyric gabbro 10 cm above the floor of the gabbro trough, southern sector: 20644: feldspar-phyric gabbro above the layered section in the southern sector; 20650: feldspar-phyric gabbro near the base of the trough in the northern sector; 20658: feldspar-phyric gabbro just above the layered section in the northern sector; 20659: feldspar-phyric gabbro from the down-faulted block, northern shore of the channel.

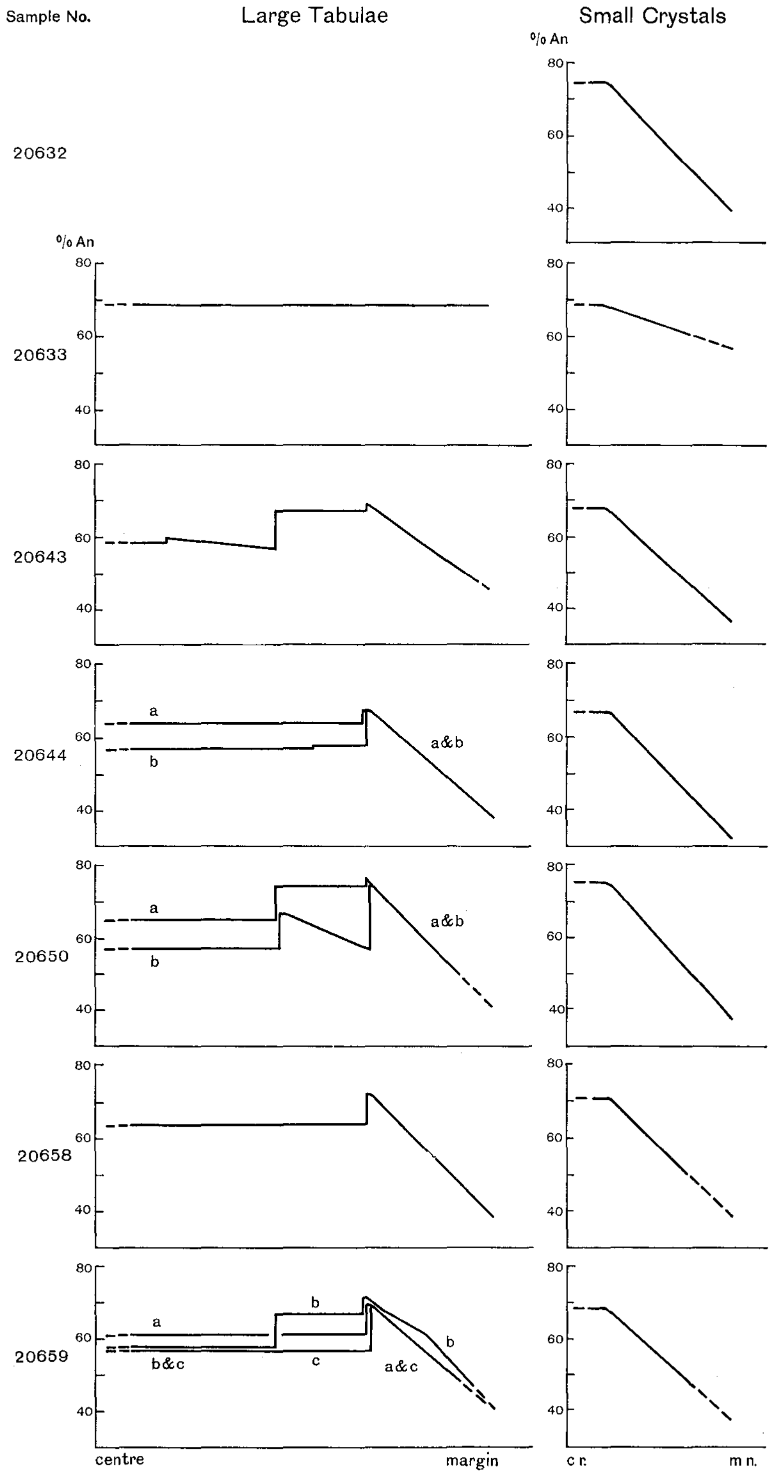
Sample No.
Large Tabulae
Small Crystals
% An
80
60
40
20632
20633
20643
20644
20650
20658
20659
a
b
a&b
c
b&c
a&c
centre
margin
c n.
m n.

Fig. 14.

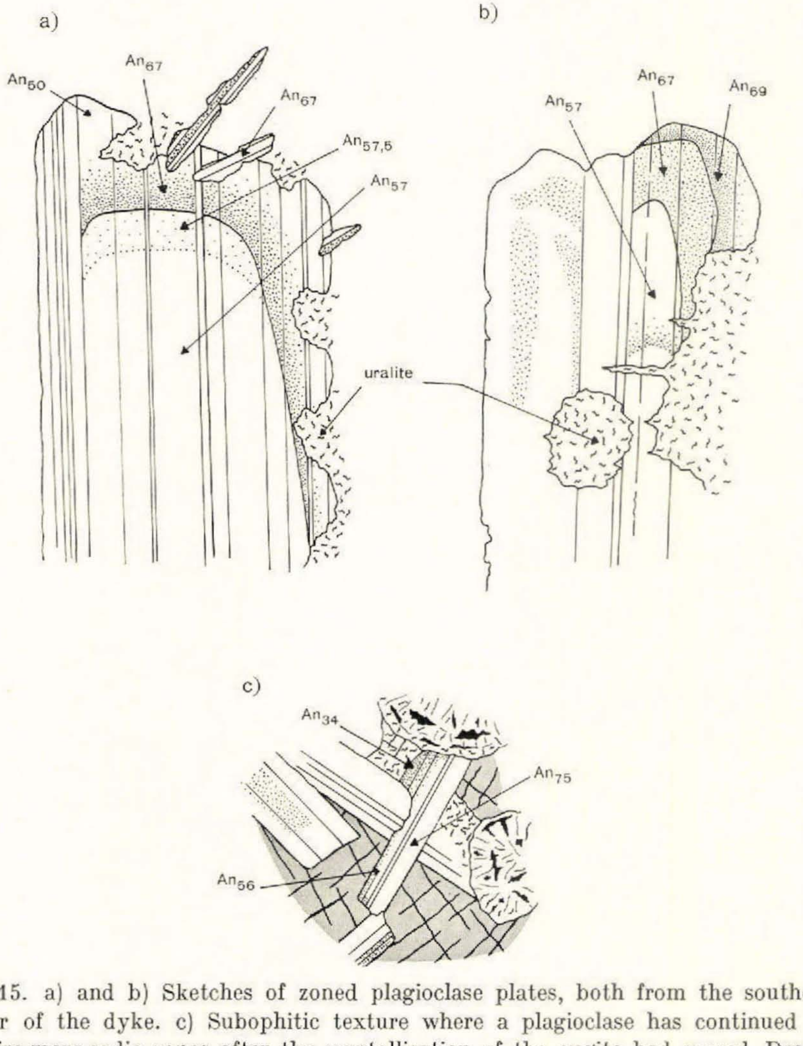

Fig. 15. a) and b) Sketches of zoned plagioclase plates, both from the southern sector of the dyke. c) Subophitic texture where a plagioclase has continued to acquire more sodic zones after the crystallisation of the augite had ceased. Drawn from 20650.

An interesting detail is the zoning shown by small euhedral plagioclases completely enclosed in augite. This may bring the An content of the margin down as low as $42\,^0/_0$, but not usually to the lowest value reached in the rock. One case, shown in fig. 15, was seen of a lath penetrating into augite (in this instance fresh), where the margin is An_{55}, but outside the augite the feldspar has grown out to an irregular shape and zones down to An_{34}. While these random observations do not permit involment in the discussion of ophitic texture, they do indicate that there was simultaneous crystallisation of plagioclase and augite (cf. DALY and BARTH, 1930), augite isolating plagioclase before the lowest An zones had been added, but the period of plagioclase crystallisation may have outlasted that of augite.

Olivine was never found fresh in the feldspar-phyric gabbro. However from the pseudomorphs it is possible to see that there were occasional large euhedral or rounded crystals and also more frequent smaller grains. The large crystals sometimes show idiomorphic relations to the outer shells of the large plagioclase tabulae but never penetrate the cores.

Pale brown augite is interstitial to the large feldspars, has ophitic or subophitic relations to the smaller plagioclase crystals and encloses small olivine pseudomorphs. Extinction is patchy over units up to 8 mm wide: $2V\gamma$ was found to be 49° in a specimen from the northern layered section, and 45.5°–47.5° in a rock just south of the channel.

The **mafic layers** south of the channel are very highly altered and all it is possible to say is that they lack the large feldspar plates, and the numerous vague olivine-like pseudomorphs indicate a concentration of olivine. The layered section north of the channel is more instructive. It is evident here that in the mafic layers olivine crystals, up to 4 mm long and often euhedral, take the place of the plagioclase tabulae in the rock, although the latter are not entirely excluded. Normally in the range 15–25 $^0/_0$, the olivine percentage may reach 30 $^0/_0$ in some layers, while in the gabbro it seldom exceeds 5 $^0/_0$. There is no packing of the olivine crystals, nor as a rule are they sorted. The matrix in the mafic layers is identical to that in the feldspar-phyric gabbro, and the composition of the small plagioclase crystals is the same as those in the matrix of the immediately adjacent gabbro layer. The continuity of the matrix can be seen in large thin slices taken across the boundaries of layers, and is further evidenced by the large ophitic or rarely skeletal augite crystals which straddle the boundary. In the two lowermost layers (see field description p. 12) the olivines are distinctly larger than in the main layered section, attaining a size of 1 cm or more: these large crystals often have a round or even lobate form.

Fresh olivine was only seen in the cores of larger crystals. Its composition was determined in five specimens, all of them from the layered section north of the channel (see fig. 12). The large round grains from the two lowest layers have a composition of Fo_{70-71}; higher up, in the main layered section, the olivines are less magnesian, having a composition of $Fo_{64.5-66.5}$. While it is tempting to relate this difference to a cryptic variation, some caution should be exercised before doing so. It is possible that some of the olivines belong to an early generation which might show a variation like that in the first generation plagioclase forming the cores of the large plates: the olivine determinations are too few to permit any hasty conclusions regarding the nature of the variation. The alteration of the outer parts of the olivine crystals has destroyed the evidence of any zoning there might have been.

The plagioclases of the **small dolerite lenses** in the mafic parts of the layered gabbro have the same composition as the feldspars of the gabbro matrix. Ophitic augite grains straddle the boundaries of the lenses. These observations make it seem that the dolerite in these lenses represents crystallisation of matrix material without either first generation feldspar plates or larger olivines. However a slight preferred orientation of the small plagioclase crystals parallel to the margins of the lenses was noticed under the microscope, and, if such a comment is reasonable about such altered rocks, there is less augite than usual in these dolerite lenses. Possibly they are the result of crystallisation of small pockets of magma which were free of early-formed phases, and which were slightly squeezed before completely crystallised.

THE EVOLUTION OF THE EQALOQARFIA DYKE AND THE ORIGIN OF THE LAYERING

The first rock to form in the dyke was the dolerite, a rock with no special features and resembling the typical Gardar dolerites of the area. This dolerite has ophitic texture and crystallised from the magma without any apparent separation or accumulation of early-formed phases.

The gabbro is later, and is underlain and bordered by the dolerite. From the field evidence alone it would have appeared to have formed from a trough of residual magma shut off from below by the early dolerite. However this preliminary interpretation (Ferguson and Pulvertaft, 1963, p. 12) must be reconsidered in the light of the results of the feldspar study.

The plagioclase in the dolerite began crystallising with a composition of An_{75}; this was presumably the composition of the solidus phase in equilibrium with the liquid at the time of intrusion.

The plagioclase of the gabbro belongs to two generations. The first generation forms the cores of large platy crystals, with a composition in the range An_{57-64} throughout the gabbro. The second generation occurs as shells around the early plates and as small crystals in the groundmass. In the northern sector of the dyke the initial composition of the second generation plagioclase was An_{74-75} in the lowest part of the gabbro trough and An_{72} in the highest exposures of gabbro: normal zoning brings the compositions of crystal margins down to An_{30-40}. In the southern sector the second generation of plagioclase began with a composition An_{69} at the base of the trough and An_{67} higher up. The long feldspars of the perpendicular feldspar layer in the southern sector are An_{69}, and show *no* zoning. By analogy the perpendicular feldspars in the northern sector would be expected to be An_{75}, but no material from them is available to confirm this.

If one considers only the second generation of plagioclase in the gabbro and ignores the early formed plates, a relatively simple pattern of feldspar crystallisation emerges:

	Dolerite	Perpendicular feldspar layer	Gabbro at base of trough	Highest gabbro available
N sector		↗ (?An_{75}) ⟹	$An_{74-75\rightarrow 30-40}$ ⟹	$An_{72\rightarrow 30-40}$
	$An_{75\rightarrow 40}$			
S sector		↘ An_{69} ⟹	$An_{69\rightarrow 30-40}$ ⟹	$An_{67\rightarrow 30-40}$

Considering now the platy An_{57-64} feldspars. The prolonged early crystallisation of plagioclase with this composition does not at all fit into the above pattern. It might be suggested that the crystallisation of these feldspars took place during a phase of supercooling in the residual trough, during which the temperature dropped, before crystallisation began, to that at which An_{57-64} is the composition of the solidus phase. However it is difficult to reconcile the composition of the perpendicular feldspars with this suggestion. These feldspars sprouted locally from the floor and walls of the trough, and are the crystals most likely to have grown during such a phase of supercooling. Yet in the south-west part of the dyke they have the composition An_{69} and are unzoned. Only 10 cm above the basal perpendicular feldspar layer the first generation plagioclase plates in the gabbro are An_{57}. Conditions in the magma at the floor and 10 cm above must have been the same, so An_{69} would be the expected composition of early feldspar in the gabbro, not An_{57}. In fact An_{69} is the initial feldspar of the *second* generation.

The compositional and textural evidence can only be accounted for if the early An_{57-64} feldspar plates crystallised elsewhere. The lack of any lamination or packing of the plates makes it most unlikely that they have arrived in their present position by settling from above.

Furthermore density considerations, often ignored when crystal settling is being discussed, make the proposition that the early plagioclase came from above rather unlikely. Of the various rocks which have been used in density experiments, the Vinal Haven diabase investigated by DANE (1941) has the composition nearest that of the Eqaloqarfia olivine dolerite. At 1150°C, the approximate temperature of crystallisation of plagioclase in the Eqaloqarfia dyke, the density of the Vinal Haven diabase glass was found by DANE to be 2.651. From the data provided by DANE, natural bytownite An_{70} at the same temperature has a density of 2.649. The density of the average early plagioclase plates from the Eqaloqarfia dyke, An_{60}, will be about 0.015 less than this, i.e. ca. 2.634. DANE's figure for the diabase glass may be a little high, since he held the glass at high temperature to bubble off the gas before measuring the density, but the error is likely to be small in an olivine basalt magma which must have been rather poor in volatiles. Even when all allowances are made, one is forced to the conclusion that plagioclase An_{60} will not sink *unaided* in an olivine dolerite magma. It will remain in suspension or may even rise slowly.

The best explanation is that the early generation of plagioclase plates crystallised at depth, and the crystals were carried in by a second pulse of magma in the dyke. The feeder to this may well lie under the wider SW part of the dyke. The gabbro "trough" would then have something of the form of the hull of a yacht, the keel being the feeder and the bow the synformal closure at the NE end of the gabbro.

With the feeder to the second magma pulse unexposed it is difficult to *prove* that the gabbro was formed from a second wave of magma laden with An_{57-64} feldspar plates. But this proposition is far more plausible against the background of other observations on Gardar dykes in the Nunarssuit area. In central Nunarssuit there is a 160 m thick composite dyke belonging to the same generation as the Eqaloqarfia dyke. This dyke has dolerite margins and feldspar-phyric gabbro in the middle. The feldspar plates in the gabbro of this dyke are very like those in the Eqaloqarfia feldspar-phyric gabbro, a rather uniform core ca. An_{60} being surrounded by more calcic plagioclase which zones rapidly to a more albitic rim. It is likely that in this dyke a later pulse of magma carrying feldspar plates was intruded along the middle of a dolerite dyke. On the Malenefjeld peninsula there is a swarm of thin porphyritic dolerites which carry plates of plagioclase with the same pattern of zoning as that described from the Eqaloqarfia gabbro. Not wholly unrelated are the numerous large xenocrysts of plagioclase and anorthosite inclusions found in dykes not only in the writer's area but also throughout the entire Gardar province, and which are the subject of a paper in preparation by D. Bridgwater and W. T. Harry. The composition of the plagioclase in these inclusions is An_{57-64} (personal communication from D. Bridgwater). It seems that something about the conditions and composition of the Gardar parent magma at depth gave rise to the widespread early crystallisation of plagioclase with the composition An_{57-64}. Nor is this feature unique to the Gardar basalt magma. Thomas, in a description of a Tertiary dyke of porphyritic central magma type in Scotland, gives the composition of the feldspar phenocrysts as An_{57}, and remarks that this is "a composition quite commonly assumed by porphyritic plagioclase in rocks of basaltic nature" (Richey and Thomas, 1930, p. 352).

In the petrographic descriptions mention was made of the possibility that the olivine in the gabbro belongs to two generations. It is necessary now to discuss this, together with the corollary that the first generation of olivine might be intratelluric. Compositional evidence like that adduced for the plagioclase, is not available due to alteration of the greater part of the olivine in the rock with the removal of evidence of any zoning there might have been.

The unusually large olivines of the lowest (i.e. earliest) layers in the northern sector differ in composition from those higher up. However since they are a higher temperature form than the later olivines, in contrast to the early generation of feldspar which has a lower temperature composition than the later generation, the compositional evidence need not imply a different place of origin for these big olivines.

In slices where the olivine appears to belong to two generations, the large crystals are thought to be those which crystallised first from the gabbro magma and have sunk the farthest before reaching their present position. The small crystals began their crystallisation later and may in some cases have crystallised entirely *in situ*. This view is strengthened by the observation that olivine crystals in the gabbro as a whole are not confined to two size groups, but occur in every size up to 1 cm. The comparatively few olivine crystals in any one slice of feldspar-phyric gabbro do not give a representative picture on their own.

An intratelluric origin for the larger olivine crystals is in any case unlikely when it is remembered that the gabbro magma was one rich in plagioclase plates and therefore is not likely to have been tapped from a part of the magma reservoir where olivine was accumulating. It is therefore concluded that all the olivine in the gabbro crystallised from the magma after it reached its present position.

It would be best to consider now why the composition of the later magma, as evidenced by the second generation plagioclase, is different in the two parts of the dyke. Various explanations could be proffered, e.g. there are two separate chambers, without much evidence for any of them. However it is worth drawing attention to one difference between the layered gabbro sections north and south of the channel. South of the channel the sharp break between dolerite and gabbro, and the basal perpendicular feldspar layer point to the existence of a solid dolerite floor to the gabbro chamber. No such sharp break, either in the field or in plagioclase composition, occurs north of the channel. Possibly here there was mixing of unconsolidated dolerite with the later feldspar-laden magma. The fact that in the NE the lowest olivine-rich layers occur in dolerite is a further indication that what is now dolerite had not entirely crystallised before olivine began to fall out of the new magma. Mixing, however, is not essential for an explanation of the features described. The magma reaching the northern end of the trough might have been a little more basic, even though it carried the same feldspar plates as are found in the gabbro south of the channel.

After the emplacement of the gabbro magma, there was a period of quiescence and inactivity. This pause allowed plagioclase feldspars which nucleated on the walls of the trough to grow vertically from these walls into the magma trough. The perpendicular feldspar rock of the Eqaloqarfia dyke is closely analogous to that of the Skaergaard intrusion (WAGER and DEER, 1939, pp. 144–150), and could also be described as forming a single layer of Willow Lake-type (TAUBENECK and POLDERVAART, 1960). "Undercooling, combined with vigorous currents in the magma and with attendant rapid crystallisation from cool surfaces inward" is suggested by TAUBENECK and POLDERVAART (*op. cit.* p. 1317) as the cause of Willow Lake-type layering. Strong currents have not been operative in the Eqaloqarfia dyke (see below), so without currents to replenish the magma at the cooling surface, only the slower process of diffusion can account for the absence of zoning in the plagioclase laths. Slight undercooling with slow crystallisation and growth of feldspar into free liquid at the border of the trough would provide favourable conditions for diffusion, and is the best explanation of the Eqaloqarfia perpendicular feldspar layer. Only the relatively cool dolerite margin of the trough provided a site for crystallisation, the early-formed feldspar plates being too near the temperature of the magma to entice further crystallisation around them at this stage.

The origin of the layering in the gabbro can now be discussed. At this point it should be said that the following discussion on the layering and differentiation in the gabbro is equally applicable whether the feldspar-phyric gabbro formed from a residual trough in the dyke or represents a later magma phase.

The layering concerns the relative proportions of early-formed plagioclase and olivine in a doleritic matrix (although not intratelluric, the larger olivines are nevertheless early formed relative to this matrix). There is no lamination of the platy feldspars, no graded bedding and no packing of crystals. Thus it can confidently be stated that magmatic current action has not contributed to the formation of the layering. A single discontinuity testifies to momentary instability, not to sustained magmatic flow.

Much has been made in recent years of the role of varying water vapour pressure in the formation of igneous layering. However this mechanism is not regarded as having been important in the Eqaloqarfia dyke. If varying v.p. H_2O is regarded as causing layering by changing the composition of the eutectic, increase in v.p. H_2O. driving it towards the olivine end, then release of the excess pressure should result in layers enriched in plagioclase. No anorthosite layers occur in the Eqaloqarfia dyke and there is no evidence of periods of excess plagioclase crystallisation. Nor for that matter is there any indication that primary hornblende substituted for olivine in the mafic layers, a feature which might be expected if these formed at high v.p. H_2O.

If varying water pressure is regarded as causing layering by its influence on the order of appearance of the main mineral phases, then it is clear from the work of YODER and TILLEY (1962) that although varying water pressure can exert such an influence, its precise effect on the order of crystallisation varies with the composition of the magma. The only rock examined by YODER and TILLEY in which changes in water pressure could affect the order of appearance of olivine and plagioclase, is the high-alumina Warner basalt (*op. cit.* fig. 28). Without making anhydrous and hydrous runs on the Eqaloqarfia rocks one can no more than guess what effect water pressure might have on the order of crystallisation in these. The alumina content of these rocks is rather high (see table 1), but not so high that one can say that they would behave like the Warner basalt. In the other basalts investigated by YODER and TILLEY the order of appearance of olivine and plagioclase was not affected by water pressure.

There is another aspect of the water vapour pressure mechanism. A substantial build-up in the water vapour pressure would take time, though its release might be rapid. For this reason the varying water vapour pressure mechanism has mostly been proposed for layered intrusions with major stratification, such as the Kapalagulu intrusion (WADSWORTH, 1963). WADSWORTH's suggestion is reasonable, since it accounts also for the change in plagioclase composition that takes place in the sequence. But for thinly layered intrusions the mechanism is less satisfactory: substantial water vapour fluctuations are not likely to be as rapid as required to produce layering such as that in the Eqaloqarfia dyke.

A rather simpler mechanism is considered to have caused the layering in the Eqaloqarfia dyke. Viewed *in toto*, the layered sections in the Eqaloqarfia dyke are olivine-rich horizons at or near the base of a feldspar-phyric gabbro trough, just above the dolerite floor. Olivine concentrations near the floors of sills are well known, and it is proposed here that the layered zone in the Eqaloqarfia dyke should be viewed in the same way as the olivine diabase layer of the Palisades sill (WALKER, 1940).

The olivine-enriched layered zone in the Eqaloqarfia dyke is regarded as having formed by the sinking of olivines into the upwards crystallising floor of a trough of feldspar-laden magma in the upper part of a dolerite dyke. The initial cooling of this magma was slow, as evidenced by the perpendicular feldspar layer. Slow cooling would have allowed the early-formed olivines to attain the rather larger size seen in the mafic layers and to settle. Simultaneous upwards crystallisation *in situ* on the floor prevented tight packing of the olivines, for they became "frozen in" before other crystals settled directly on top of them. The cause of the layering may be nothing more than intermittent interruptions in olivine crystallisation in the main (or upper?) part of the magma. *In situ* crystallisation on the floor was however continuous, so that when there was a pause in olivine accumulation feldspar-phyric gabbro formed with only very few additional olivines. There may also have been inwards crystallisation at the walls of the trough: to take account of this possibility the higher layers have not been extended so far out to the sides as the lower in the schematic section fig. 13.

Coats (1936) showed experimentally that if two minerals of different density are settling from a magma, the heavier crystals can slip through the interstices between the lighter crystals, and actually displace the latter upwards as they (the heavier grains) settle on the cumulate floor. The scarcity of larger platy feldspars in the mafic layers of the Eqaloqarfia dyke can therefore be explained as due to upward displacement by settling olivines. However Coats's mechanism of rhythmic differential settling cannot be applied to the layering in the Eqaloqarfia dyke because it requires that both minerals sink in the magma. In the Eqaloqarfia gabbro textural and density considerations indicate that the plagioclase did not settle, which also may explain why there is no plagioclase enrichment in the feldspar-phyric layers relative to the uniform feldspar-phyric gabbro above the layered zone.

Finally, in the light of the foregoing discussion, how is the slight cryptic variation shown by the second generation plagioclase, and also apparently the olivine, to be accounted for? Hess (1960, pp. 187–190) is one of the few authors who has tried to think of some process by which fractional crystallisation could be accomplished without resorting to settling or rising of crystals. His search was prompted by consideration of the situation in the Palisades and other sills. The Palisades sill shows evidence of crystal settling only in the thin olivine-rich layer. For the rest, like other more ordinary dolerite sills, it lacks igneous lamination, a structure which seems inevitable if the rocks were products of crystal sedimentation, and other evidence of accumulation. At Eqaloqarfia we have a dyke, but the problem is the same. How is differentiation achieved in such a situation? The mechanism suggested by Hess is as follows: After the initial chilling, crystallisation of phases richer in refractory constituents than the magma takes place along the sill margins. Diffusion then operates in the magma in such a way as to minimise the differences in composition between the film impoverished in refractory constitutents and the overlying mass of magma. In this way the remaining magma would become slowly enriched in less refractory constitutents (Ab, Fe). However Hess stresses that diffusion alone is too slow to produce the desired results unless accompanied by circulation of magma. Although HESS is not specific on the point, he implies that there will be no lamination if crystals only grow at the margins and are not carried in suspension by the circulating magma. The trouble with applying this idea to the Eqaloqarfia dyke, which–the mafic layers excluded–differs from a crystal cumulate in all the features listed by HESS for certain sills, is that in the magma which shows slight differentiation by its feldspars, there were early-formed platy crystals which should have been flow oriented by circulation.

There are two possible explanations: i) Diffusion can be more effective than HESS allows. ii) Circulation can be sufficient to remove the film impoverished in refractory constitutents without being powerful enough to flow-orient the early-formed plagioclase tabulae. One or other of these possibilities must also be invoked to account for the unzoned plagioclases of the perpendicular feldspar layer (see p. 31). The writer's view is that diffusion has been rather underestimated since BOWEN (1921) showed the rate of diffusion of diopside melt into plagioclase melt to be very slow. Diffusion through up to 2 m of crystal mush must be contemplated to produce the adcumulates of Rhum (BROWN, 1956; WADSWORTH, 1961) and certain rocks of the Stillwater complex (HESS, 1960). A crystal mush is far from the most favourable medium for diffusion; free magma with the possibility of only slight circulation would greatly increase the efficiency of diffusion.

Comparisons

Thick basic dykes directed towards the centres of large intrusions have also been described from Tugtutôq, some 80 km E of Nunarssuit, by UPTON (1964), and from East Greenland, where a macro dyke some 300 m thick is directed at the Skaergaard intrusion (DOUGLAS, 1964). These dykes also show synformally disposed layering and cryptic variation, but the feldspar lamination and bottom structures in them indicate that crystal settling has been operative. The Eqaloqarfia dyke raises special problems created by the lack of evidence of crystal settling outside the olivine layers, and the behaviour of the plagioclase in the feldsparphyric gabbro.

CHEMISTRY OF THE DYKE

A chemical investigation of the rocks of the Eqaloqarfia dyke was initiated by the writer for two reasons: a) to provide more data on the Gardar basaltic rocks, about which there is little published information, yet which are of prime importance to an understanding of the petrogenesis of the Gardar alkaline province, b) to provide a further basis for comparison between the early-formed dolerite and the feldspar-phyric gabbro.

The three analysed samples were all collected from the south-west part of the dyke: the analyses are presented in table 1. The available samples from the dolerite were not large enough for one to be quite sure that a single analysis would be representative, so two were analysed (20632 and 23144). Inspection of table 1 shows that 20632 is a little more mafic than 23144. However when the Ab and Fe ratios are calculated it can be seen that there is no differentiation involved. Thus the mean of the two analyses is probably representative of the dolerite composition. Since the dolerite cooled fairly quickly, probably without sinking or rising of early mineral phases, this mean is considered to approximately represent the composition of the dolerite magma.

The feldspar-phyric gabbro sample 20645 was carefully selected and of large size, so the analysis is to be taken as satisfactory. The sample was collected from the unlayered gabbro above the layered section, some 60 m above the base of the gabbro trough. Since there has been settling of early-formed olivine and slight differentiation the analysis does not represent the magma. The first generation feldspar plates need not be taken into consideration, for even if these were carried up in a later pulse of magma, they are not regarded as foreign to the magma.

From the norms it can be said that the dolerite magma composition lies very close to the critical plane of undersaturation in the generalised basalt tetrahedron (Yoder and Tilley, 1962, p. 352). The feldspar-phyric gabbro is truly alkaline however: if it is a differentiate of the dolerite magma it indicates the type of alkaline trend the original magma could embark on. The fall in K_2O content in the gabbro contrasts with the considerable increase in $^0/_0 Na_2O$. The high alumina content of the Eqaloqarfia dyke rocks is another noteworthy feature, and one which

Table 1. *Analyses of dolerite and gabbro from the Eqaloqarfia dyke and comparisons with basic rocks from other regions.*

	1 20632	2 23144	3 Mean	4 20645	5 B D	6 Tu'tôq	7 Oslo	8 N.Eng.	9 Nig.	10 Polyn.
SiO_2	44.60	45.16	44.88	47.28	45.77	44.41	47.91	47.82	43.76	44.22
TiO_2	1.49	1.42	1.46	1.87	1.64	2.44	2.53	2.00	5.97	2.84
Al_2O_3	16.46	18.28	17.37	17.40	16.77	16.80	16.42	19.99	17.07	16.20
Fe_2O_3	2.28	2.60	2.44	3.71	3.89	1.97	4.51	2.10	1.75	4.37
FeO	9.44	7.57	8.51	8.23	8.31	12.95	7.60	6.48	10.18	7.12
MnO	0.16	0.12	0.14	0.14	0.14	0.22	0.23	tr.	n. d.	0.18
MgO	9.77	7.92	8.85	6.05	7.37	8.26	4.33	4.94	5.81	6.97
CaO	8.68	9.52	9.10	8.69	7.52	7.42	9.16	11.65	10.94	10.52
Na_2O	2.50	2.50	2.50	4.20	2.38	3.10	3.73	3.51	2.66	2.44
K_2O	0.85	1.01	0.93	0.46	1.78	0.92	2.00	0.67	0.56	1.03
P_2O_5	0.32	0.27	0.30	0.34	0.19	0.65	0.74	0.56	0.15	0.26
CO_2	–	–	–	–	1.70	n. d.	n. d.	–	0.11	n. d.
H_2O^+	2.06	2.78	2.42	1.90	2.51	0.79	} 1.00	0.21	0.88	2.45
H_2O^-	×	×		×	0.09	0.07		0.07	0.20	1.67
Total	98.61	99.15	98.90	100.27	100.23*	100.07**	100.16	100.00	100.04	100.27

C. I. P. W. Norms

	20632	23144	Mean	20645
qz	–	–	–	–
or	5.0	6.0	5.5	2.7
ab	20.9	21.1	21.1	31.8
an	31.2	35.6	33.4	27.2
ne	0.1	–	tr.	2.0
di	8.0	8.0	8.0	11.2
hy	–	0.4	–	–
ol	24.5	18.2	21.5	13.7
mt	3.3	3.8	3.6	5.4
il	2.8	2.7	2.8	3.6
ap	0.8	0.6	0.7	0.8
Feldspar	$Or_9Ab_{36.5}An_{54.5}$	$Or_9Ab_{33}An_{58}$	$Or_9Ab_{35}An_{56}$	$Or_4Ab_{52}An_{44}$
Diopside	$Wo_{52}En_{31}Fs_{17}$	$Wo_{52}En_{32}Fs_{16}$	$Wo_{51.5}En_{32}Fs_{16.5}$	$Wo_{51}En_{30}Fs_{19}$
O. pyroxene		$En_{67.5}Fs_{32.5}$		
Olivine	$Fo_{62.5}Fa_{37.5}$	$Fo_{65}Fa_{35}$	$Fo_{64}Fa_{36}$	$Fo_{60}Fa_{40}$
Ab ratio	41.8	38.6	40.2	58.0
Fe ratio	35.3	35.0	35.2	43.5

×) Sample dried.
*) Total includes S 0.17.
**) Total includes S 0.05 and Cl 0.02.

Key to Table 1

1) 20632. Dolerite below basal perpendicular feldspar layer, SW part of Eqaloqarfia dyke. Analyst B. I. Borgen.
2) 23144. Dolerite marginal to gabbro trough, SW part of Eqaloqarfia dyke. Analyst B. I. Borgen.
3) Mean of 1 and 2, taken to represent approximately the composition of the original magma.
4) 20645. Feldspar-phyric gabbro from above the layered section in the SW part of the Eqaloqarfia dyke. Analyst B. I. Borgen.
5) Olivine dolerite dyke ("BD") of Gardar age, Grønnedal. Emeleus, C. H. 1964. Medd. Grønland, Bd. 172, nr. 3, table 3. Analyst A. H. Nielsen.
6) Fine-grained marginal facies of gabbro giant dyke, Tugtutôq. Upton, B. G. J. 1964. Medd. Grønland, Bd. 169, nr. 3, table 2. Analyst R. Solli.
7) Average of 23 Oslo essexites. Barth, T. W. F. 1945. Skr. Norske Vid. Akad. I Mat.-Naturv. Kl., 1944, No. 9, table 6.
8) Olivine gabbro, Tripyramid Mt., New Hampshire. Pirsson, L. V. 1911. Amer. J. Sci., vol. 31, p. 418. Analyst C. J. Monahan.
9) Jinni Valley gabbro, Nigeria. Jacobson, R. R. E., Macleod, W. N. and Black, R. 1958. Geol. Soc. London, Memoir no. 1, table 13. Analyst Imperial Institute.
10) "Basalte doléritique", Gambier Is. Lacroix, A. 1928. Mém. Acad. Sci. Paris, tome 59, anal. 104. Analyst M. Raoult.

they share with other Gardar basic dykes. Upton (1964), concluded that the initial magma of the olivine gabbro giant dykes of Tugtutôq, dykes of about the same age and trend as the Eqaloqarfia dyke, was an alumina-rich alkali basalt which had already achieved moderate enrichment in iron and alkalies. This enrichment was less advanced in the original magma of the Eqaloqarfia dyke than in the fine-grained margin of one of the Tugtutôq dykes (table 1, no. 6), but otherwise the magmas were rather similar.

The rocks of the Nunarssuit intrusive complex which cuts off the Eqaloqarfia dyke to the SW, and of the Puklen intrusion to the NE, have been compared to the intrusives of the Oslo, New England and Nigerian regions (Harry and Pulvertaft, 1963, pp. 129–130). For this reason it seems appropriate to quote analyses of gabbroic rocks from these regions for comparison with the dolerite and gabbro of the Eqaloqarfia dyke. As can be seen from inspection of the analyses, the gabbroic rocks from these comparable provinces are rather rich in alumina and in this respect resemble the Eqaloqarfia dyke. However they are all relatively improverished in magnesia, and tend to be more calcic than the Eqaloqarfia rocks. Other provinces where alkaline rocks resembling those of the Gardar province are developed include the Monteregian Hills and the Ampasindava province in Madagascar (Lacroix, 1923). The basic intrusives of these regions are essexites and, in common with the average Oslo essexite and the type essexite from Salem Neck, are fairly rich in alumina, poor in magnesia (3–5 $^0/_0$) and contain much potash (2–3 $^0/_0$) compared to nor-

Table 2. *Spectrographic trace element data for the Eqaloqarfia rocks*

	20650	20658	20645	Skaergaard chill
V	80	80	80	140
Cr	90	60	50	170
Co	70	60	60	53
Ni	200	100	150	170
Cu	200	200	150	130
Sc	*	*	+	12
Y	20	20	10	+
Sr	600	450	500	350
Ba	400	300	140	43
Zr	150	180	150	50

*) Not detected.

All figures in parts per million

20650. Gabbro from lower part of layered section, north of the channel.

20658. Gabbro from above the layered section, north of the channel.

20645. Gabbro from above the layered section, south of the channel.

Skaergaard chill. Average of determinations on three samples of the fine-grained marginal facies, taken as representing the original magma of the Skaergaard intrusion (WAGER, L. R. and MITCHELL, R. L. 1951. Geochim. et cosmoch. Acta, vol. I, no. 3, table A).

mal gabbros. Of these features only the high alumina content is shared by the Eqaloqarfia dyke.

The Polynesian basalt analysis is quoted as a representative of oceanic basalts; the rock in question is the least differentiated of an alkaline series, and may be regarded as the parent of an alkaline series (NOCKOLDS and ALLEN, 1954).

The trace element study of the Eqaloqarfia dyke rocks was less fruitful than was hoped. It was hoped that some differences–however small–might be detectable between rocks from different levels in the gabbro north of the channel (20650 and 20658), and that the more differentiated gabbro south of the channel might differ from that north of the channel. No conclusions can be drawn from the results of the study (table 2), for the only element to show a distinct progressive variation is barium, which decreases with advancing differentiation—a quite anomalous pattern of behaviour for this element. Although no other remarkable features are apparent from the trace element content of the Eqaloqarfia rocks, the figures in table 2 may be of some use insofar as they provide new data on Gardar basic rocks.

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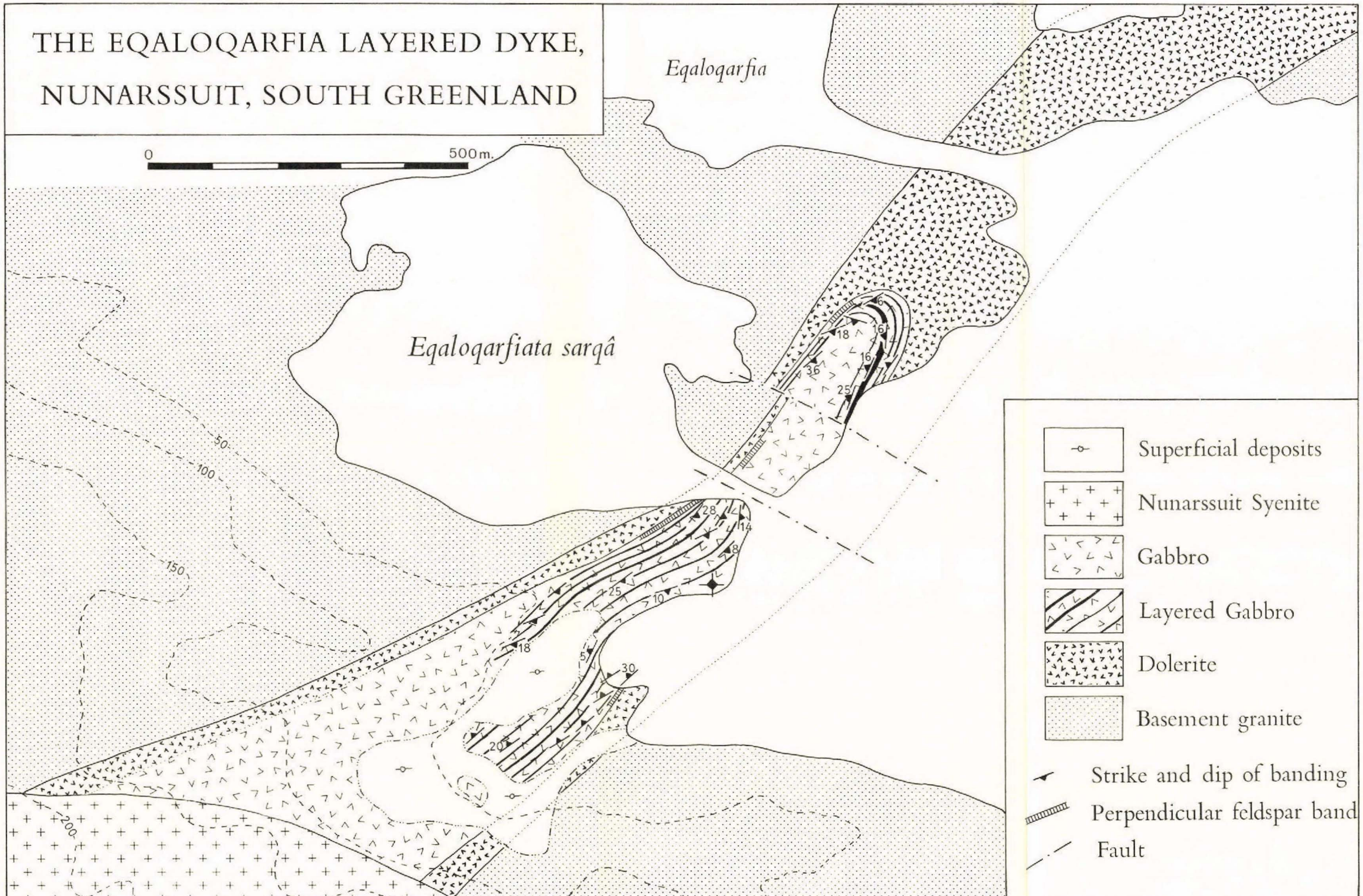
THE EQALOQARFIA LAYERED DYKE, NUNARSSUIT, SOUTH GREENLAND
0
500 m.
Eqaloqarfia
Eqaloqarfiata sarqâ
50
100
150
200
18
16
16
36
25
28
14
8
25
10
18
5
30
20
Superficial deposits
Nunarssuit Syenite
Gabbro
Layered Gabbro
Dolerite
Basement granite
Strike and dip of banding
Perpendicular feldspar band
Fault