MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
Bd. **190** · Nr. **6**

THE BRITISH EAST GREENLAND EXPEDITION 1935–36
Leader: L. R. Wager

THE EAST GREENLAND GEOLOGICAL EXPEDITION 1953
Leaders: L. R. Wager and W. A. Deer

GEOLOGICAL INVESTIGATIONS IN EAST GREENLAND

Part X

THE GABBRO CUMULATES OF THE KAP EDVARD HOLM LOWER LAYERED SERIES

BY

D. ABBOTT and W. A. DEER

WITH 9 FIGURES AND 17 TABLES IN THE TEXT, 10 PLATES AND 1 MAP

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
1972

Abstract

The Kap Edvard Holm complex, situated on the west side of the Kangerdlugssuaq, is one of the major units of the east Greenland Thulean igneous province. The largest part of the complex consists of layered gabbros that, like the Skaergaard intrusion, were emplaced after the formation of the early Tertiary basalts but prior to the large monoclinal coastal flexure. Subsequently the layered gabbros were intruded by the syenites of Kap Deichmann and Kap Boswell. Three separate and major injections of basic magma were involved in the formation of the layered complex, and gave rise to an earlier, Lower Layered Series to the north, a Middle Layered Series occupying the central, and a later Upper Layered Series in the southern part of the complex.

The present contribution is concerned solely with the earliest basic rocks of the complex, the Lower Layered Series, which form a group of rhythmically banded cumulates some 3900 m in thickness. There is no chilled margin exposed and at the only locality in which the Lower Layered Series are exposed close to the Pre-Cambrian gneisses, an earlier fine-grained marginal gabbro, 100 m in thickness, lies between the rocks of the layered series and the gneisses.

The mineralogy of the series is described and includes details of the plagioclase zoning at various heights in the layered succession, the compositional trends of the clinopyroxenes and olivines, and also some details of the primary and secondary amphiboles, and of the iron oxides. Orthopyroxene does not occur, either as a cumulus or interculus phase in the rocks of the layered series.

The Lower Layered Series is divided into a lower and an upper unit, the Lower Zone A and Lower Zone B cumulates respectively. The lower unit has a maximum thickness of 700 m and consists of plagioclase-augite-olivine orthocumulates and includes both extreme feldspar- and ferromagnesian-rich bands. The chemical composition of Lower Zone A is illustrated by three analyses of the cumulates and includes that of a feldspar adcumulate layer. Lower Zone B is 3200 m in thickness and displays progressive cryptic layering from the base of the zone upwards in the succession for 1300 m. Above this level, at a height of 2050 m in the layered succession, the trend of the cryptic layering is reversed, and these higher cumulates, the composition of which are illustrated by eight analyses, show progressively decreasing mafic and felsic indices.

The deduced composition of the original magma from which the cumulates crystallized is compared with the initial chilled margin of the Skaergaard intrusion. The Lower Layered Series magma is less tholeiitic in character than that of the Skaergaard, and has affinities with transitional alkali olivine basalt magma.

ISBN 87 421 0056 9

CONTENTS

I. INTRODUCTION

The Kap Edvard Holm complex is situated on the west side of Kangerdlugssuaq, East Greenland (68°5′ N, 31°30′ W). The complex is 15 km from the Skaergaard intrusion (WAGER & DEER, 1939) on the north-east side of the fjord, and lies to the south of the Kangerdlugssuaq alkaline intrusion (WAGER, 1965; KEMPE, DEER & WAGER, 1970). The complex, of gabbro cumulates and syenites, extends northward from Kap Edvard Holm mountain to the Hutchinson Gletscher (Map 1 and Fig. 1), and occupies an area of approximately 300 km^2; it is extensively covered by small glaciers and ice fields. To the west, the intrusion is in contact with gneisses of the Pre-Cambrian basement complex and to the south with basalts of early Eocene age. The gabbro cumulates probably extend under the Hutchinson Gletscher and small remnants of banded gabbros are exposed on the nunataks along the snout of the glacier and along the southern part of Admiraltinden. Recent mapping has shown that the large rognon to the north of Kap Edvard Holm, consists of basalt and the injection breccia of the Kap Boswell syenite. The relationship of the banded gabbros of Kap Edvard Holm itself to the main gabbros of the complex is not known with certainty, but they are now considered to lie south of the margin of the main complex.

The major part of the basic rocks of the complex are layered cumulates and consist of a lower layered series in the northern area (Plate 1, Fig. 1 and 2), a middle layered series which occupies the central area of the complex, and an upper layered series in the southern area. The division of the lower and middle layered series is based on the presence of a major break in the compositional trends of the major cumulus phases. This break, which occurs at a height of approximately 3900 m. in the layered series, is coincident with the presence of abundant basalt, gneiss, gabbro and anorthositic gabbro xenoliths in the rocks of the middle layered series, in marked contrast to their virtual absence in those of the lower layered series. Thus only one xenolith (Table I), of a gneiss of the metamorphic complex, has been observed in the 3 km, 300 m. high exposure on the west face of the long north-south ridge midway between Kontaktbjerg and Kap Deichmann, compared with the volume, approximately one fifth, of xenolithic material in the lowest rocks of the middle

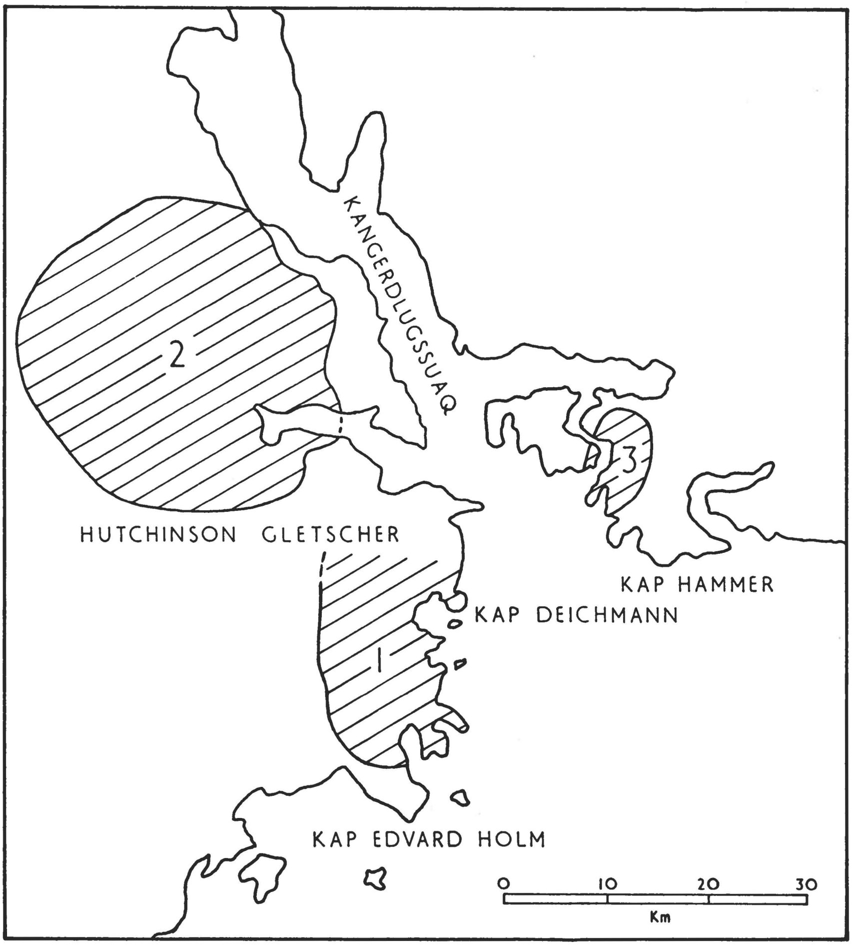


Fig. 1. Map of the Kangerdlugssuaq area showing the position of the Kap Edvard Holm complex (1), in relation to the Kangerdlugssuaq Alkaline Intrusion, (2), and the Skaergaard Intrusion (3).

layered series. The division between the middle and upper layered series is based on a marked petrochemical boundary between the cumulates in the central region of the complex and those in the southern area, as well as by a structur boundary (Elsdon, 1969).

The contact of the gabbro complex with the country rocks is only exposed on the western margin of the intrusion, elsewhere the contact is hidden beneath glacial ice or the waters of Kangerdlugssuaq. The margin of the intrusion can be observed at the western end of Kontaktbjerg where a fine-grained and unbanded gabbro (Table II) is exposed over a distance of 1250 m, forming a unit some 100 m in thickness, and is in contact with gneisses of the basement complex. This gabbro shows only a

Table I. *Xenolith Analysis*

			Norm	
SiO_2	58.32			
Al_2O_3	18.43	Q		0.44
Fe_2O_3	2.56	Or		0.65
FeO	2.96	Ab		63.72
MgO	2.22	An		16.17
CaO	6.10	Di	Wo	4.96
Na_2O	7.40		En	3.45
K_2O	0.11		Fs	1.10
H_2O^+	0.35	Hy	En	2.08
H_2O^-	0.18		Fs	0.66
TiO_2	1.00	Mt		3.71
MnO	0.05	Il		1.90
P_2O_5	0.34	Ap		0.81
	100.02			

Xenolith of metamorphic complex (E. G. 6533). Ridge west of Hutchinson Gletscher Syenite I.
Anal. W. A. Deer.

small increase in grain size across its width and dips inwards at 80° and shows a distinct fluxion structure parallel to the margin. To the east it lies under the banded gabbros of Lower Zone B-type (Plate 2 Fig. 1). In thin section the marginal gabbro is relatively uniform in texture and contains less plagioclase and more ferromagnesian minerals than the average cumulates of either the lower or upper layered series. The texture is also distinctive, the plagioclase occur as interlocking anhedral crystals

Table II. *Marginal Gabbro – Analysis*

			Norm		Mode	
SiO_2	44.05					
Al_2O_3	10.68	Or		2.84		
Fe_2O_3	4.75	Ab		17.52	Plagioclase	27
FeO	9.25	An		18.43	Augite	42
MgO	13.21	Di	Wo	12.76	Hypersthene	6
CaO	10.60		En	9.39	Olivine	14
Na_2O	2.07		Fs	2.16	Hornblende	1
K_2O	0.48				Biotite	4
H_2O^+	0.44	Hy	En	2.12	Opaques	6
H_2O^-	0.00		Fs	0.49		
TiO_2	3.55	Ol	Fo	14.99		
MnO	0.19		Fa	3.79		
P_2O_I	0.55	Mt		6.89		
	99.82	Il		6.74		
		Ap		1.30		

Marginal olivine gabbro (E. G. 6160). Kontaktbjerg. Anal. J. H. Scoon.

and the pyroxenes, including relatively abundant orthopyroxene, and olivines are present as small rounded grains. This recrystallized texture of the marginal gabbro is consistent with its formation prior to the development of the overlying rocks of the lower layered series. In the southern part of the complex a similar rock occurs on the nunatak at the southern end of Polaric Gletscher (Elsdon, 1969). A more complete account of the marginal fine-grained gabbro will be given when the investigation of the middle and upper layered series has been completed.

The cumulates of both the lower, middle and upper layered series are located within the zone of the east Greenland coastal flexure (Wager & Deer, 1938), and are intruded by dykes of the coastal swarm which form an en echelon belt cutting the complex in a general south-west to north-east direction.

Subsequent to the formation of the flexure and the intrusion of the dyke swarm, the syenites and injection breccias of Kap Deichmann, Kap Boswell, Barberkniven, Hutchinson Gletscher Syenites I and II and Kontaktbjerg, were emplaced. The adjacent gabbros are metamorphosed, here the lighter bands are darker in colour due to clouding of the feldspars, and in the field the contrast between the ferromagnesian-rich and feldspar-rich bands of the metamorphosed cumulates is less conspicuous (Plate 2, Fig. 2). The syenites include arfvedsonite-aegirine-, ferrohortonolite-hedenbergite- and hornblende-biotite syenites and quartz syenite. The contacts of the two larger alkaline intrusions of Kap Deichmann and Kap Boswell with the gabbros are vertical or steeply-dipping outwards and the Kap Boswell syenite is surrounded by a broad zone of igneous breccia. In the western area of the complex the rocks of the lower layered series are extensively veined by a later intrusion of quartz syenite (Plate 3, Fig. 2), and on Kontaktbjerg and the mountains to the northeast there is an arcuate zone of gabbro-syenite breccia, 2 km in width. In the central part of this zone the rock is largely homogeneous in character and intermediate in composition; it is hybrid rock produced by the contamination of the alkaline magma by basic material prior to its emplacement.

II. THE LOWER LAYERED SERIES

For the purposes of this description of the petrology of the Lower Layered Series of the Kap Edvard Holm complex, the Hutchinson Gletscher Syenite I – gabbro contact is taken as the base of the lower layered series and heights of the layering refer to this base. The gabbros in the north-west part of the complex do not present a complete sequence of the layered rocks due to the wide zone of syenite-gabbro breccia in that area, and most of the following account is based on the layered sequence in the north-eastern part of the intrusion (Fig. 2). The heights of the layered sequence on the ridges west of Kap Deichmann can be estimated with precision, but lack of exposure to the south necessitates projecting the heights of some of the layering in the area west of Kap Deichmann over long distances so that their relative positions are less accurately known. The total thickness of the lower layered series is estimated to be 3900 m. The first 650 m of the layered series have a distinctive allivalitic texture (see p. 21) and have been termed the Lower Zone A-type cumulates. Above 650 m the rocks have a typical coarse grained gabbroic texture and are named the Lower Zone B-type cumulates.

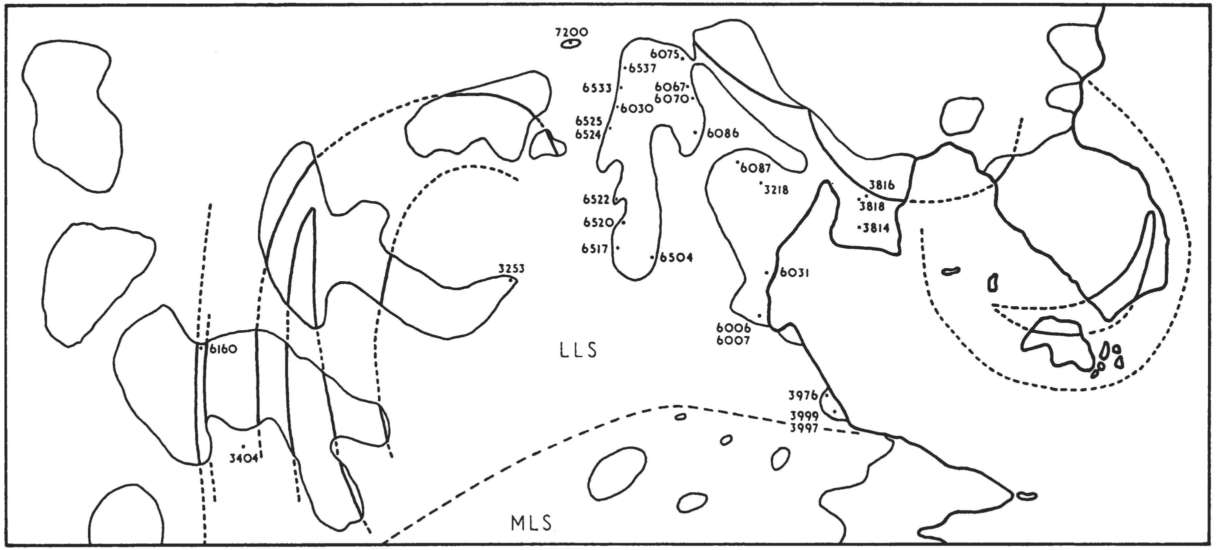


Fig. 2. Locality map of analysed rocks of the Lower Layered Series and other localities referred in the text.

III. MINERALOGY

a) Plagioclase

The plagioclase crystals are zoned in a complex manner and few generalizations can be made, except that zoning is more marked in the cumulates of the lower part of the series (Table III). Zoning in the plagioclase is progressive (normal), reverse, and oscillatory, the latter including both reverse and progressive types. Progressive zoning from calcic cores to more sodic peripheries commonly takes place in steps. The type of zoning also changes from level to level in the series and more than one type of zoning may occur in the plagioclase within a single thin section. In general the cores form a small part of the crystal and growth by zones of different composition commenced early, so that most of the cumulus plagioclase consist of a core, a peripheral zone and up to four intermediate zones. Determinations of the changes in zonal composition were made on crystals of which four, selected to illustrate the features of the zoning, are shown in Fig. 3.

Table III. *Composition of Plagioclase* (*Anorthite per cent*)

	Height Metres	Spec. No.	Composition of zones					Type of zoning
			Core		Periphery			
		Lower zone A						
Plagioclase-augite-olivine orthocumulates	3850	3997	77	72	65			progressive
	3200	6007	80	82	60	62		progressive
	2600	6031	73	67	57			progressive
	2050	6517	67	64	59	54		progressive
	1750	6520	75	77	70	63		oscillatory
	1250	6524	81	73	65			progressive
	750	6537	80	68	76	63	65	oscillatory
		Lower zone B						
Adcumulate zone	600	6070	74	82				reverse
Plagioclase-augite-olivine orthocumulates		6086	76	81				reverse
	500	6067	79	76	80	76		oscillatory

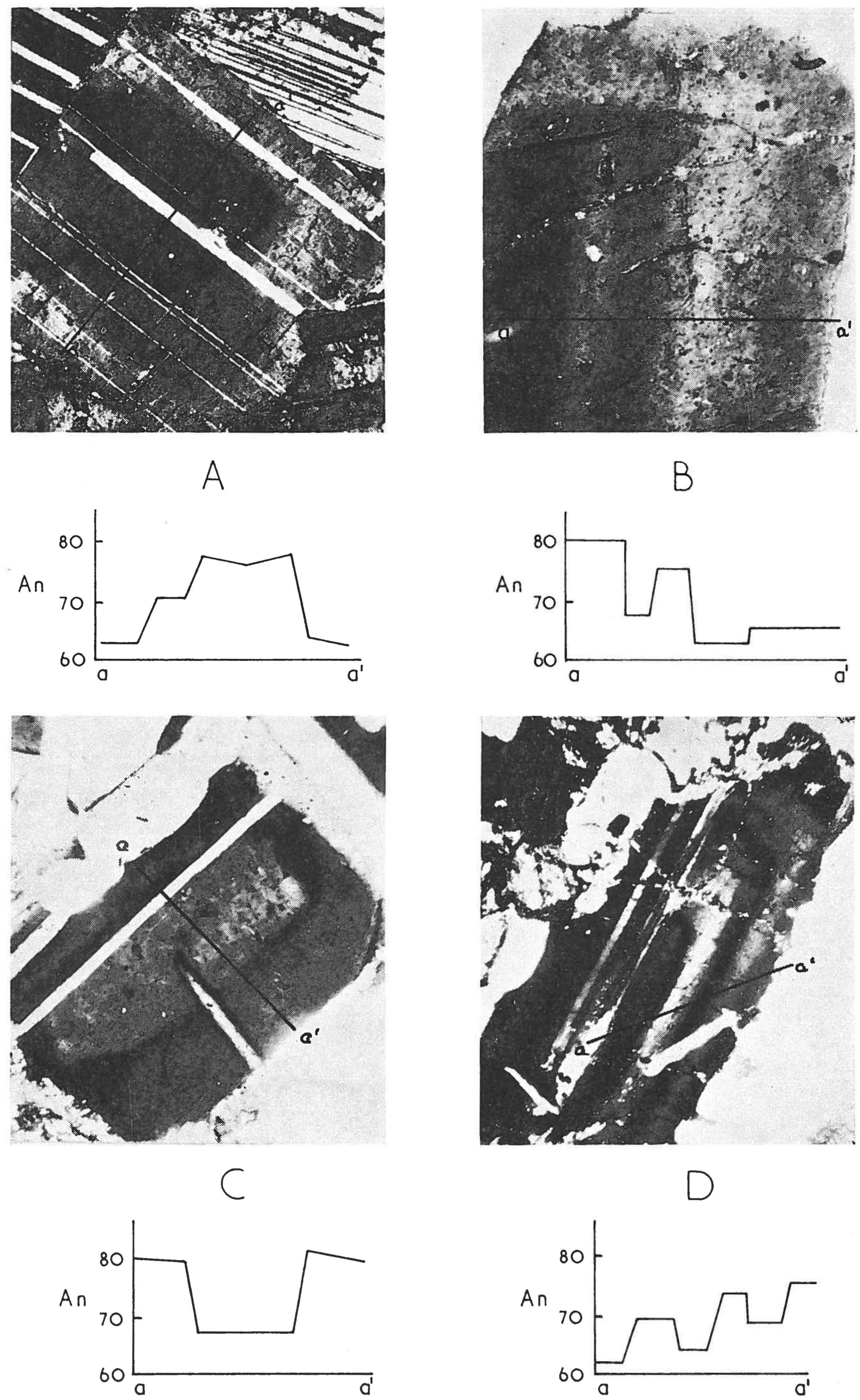


Fig. 3. Types of zoning in plagioclase. (A) Progressive step zoning, E.G. 6520. (B) Oscillatory progressive zoning, E.G. 6537. (C) Reverse zoning, (E.G. 6087). (D) Oscillatory reverse zoning, (E.G. 6534).

Zoning may arise through several mechanisms. While crystallization with falling temperatures and changing magma composition could be expected to produce continuous progressively zoned crystals, this does not explain the more complex types. In addition, movement of crystals to a new environment, undercooling and influx of undifferentiated magma may each separately, and at different periods, have influenced the growth of feldspar. Oscillatory zoning in some Skaergaard feldspars was ascribed by Carr (1954) to alternations of pressure during the vertical movement of growing crystals in the convecting magma of that intrusion, and the oscillatory zoning in some feldspars of the lower layered series can be ascribed to the same mechanism. Reverse and step zoning may also be the result of undercooling, as metastable crystallization, followed by the establishment of equilibrium could also, provided the temperature difference between the metastable and equilibrium states is appreciable, result in reverse zoned crystals. If the temperature difference is small, the change in composition would be very small and would be recorded by no more than a step-like break in the steady trend to more sodic feldspar from core to periphery. Reverse and step zoning can also be explained in terms of magma influxes followed by increases of temperature in the crystallizing liquid when limited resorption of earlier, more sodic feldspar, would take place. If the new influxes were sufficiently large to alter radically the composition and temperature of magma already crystallizing then the precipitation of more calcic feldspar would follow. If the influxes were small, such that composition and temperature were not greatly altered, feldspar crystallization would only be effected to the extent of interrupting the steady trend to more sodic compositions, and would result in step zoning with some resorption. Repeated influxes of magma, each followed by a period of normal crystallization could lead to oscillatory zoning, and indeed to all the features of the zoning in the feldspars, and in this connection it is not without significance that the trend of differentiation is reversed in the upper part of the lower layered series. On the other hand there is no supporting evidence that undercooling took place after each influx of new magma. Any significant degree of undercooling is unlikely in a magma in which a convective system has been established, although the incursion of fresh magma would modify the system and lead to periods of more tranquil conditions. Such a period of undercooling provides the most probable explanation of the reverse zoning in the feldspars of the anorthosite zone at the 600 m level. This is the most distinctive horizon in the lower layered series and consists of a 50 m thick zone (Plate 3, Fig. 1) in which layers containing over 80 per cent plagioclase are associated with a number of thinner layers in which the content of plagioclase, olivine and pyroxene is more nearly that of the average gabbro cumulates.

In the anorthosite zone at the top of the Lower Zone A-type cumulates, the reverse zoning in the feldspars, from An_{74-82}, is clearly related to the conditions of crystallization associated with the formation of the allivalitic-textured Lower Zone A-type rocks. As these rocks formed in the early stages of cooling when heat loss was rapid, conditions favourable to undercooling would be established with the consequent metastable crystallization of the primocryst component during this first period of nucleation. This was followed by the second period of crystallization which involved the mass nucleation of feldspar after an increase in temperature and the establishment of equilibrium. During the period of undercooling, plagioclase, of composition An_{74}, was precipitated and was later followed by equilibrium crystallization resulting from increase in temperature, which gave rise to the reverse peripheral zoning of plagioclase An_{82} in composition.

b) Pyroxenes

The chemistry and compositional trend of the clinopyroxenes of both the lower layered series and the upper layered series have already been discussed in some detail (DEER & ABBOTT, 1965). The analyses of the earlier analysed pyroxenes, and two additional analyses of augite from the 3700 m. level in the layered series and of an augite from a pegmatitic gabbro are given in Table IV. (Anals. 6 and 7). The pyroxenes do not show any primary zoning and the change in chemical composition in the lower layered series is small, ranging from 12.8 atomic per cent (Fe^{+2} + Fe^{+3} +Mn) in the Lower Zone A-type plagioclase-augite-olivine cumulate (E.G. 6067) to 16.3 per cent in the Lower Zone B-type cumulate (E.G.

Table IV. *Augites – Analyses*

	1	2	3	4	5	6	7
SiO_2	49.69	50.25	50.56	50.61	50.89	49.46	50.22
TiO_2	1.05	1.41	0.83	0.93	1.10	1.07	1.19
Al_2O_3	3.95	3.83	3.40	4.01	3.06	4.48	3.67
Fe_2O_3	1.75	1.95	1.46	0.97	1.35	2.07	2.43
Cr_2O_3	0.75	0.24	–	–	–	–	–
FeO	6.25	6.34	7.52	7.98	8.53	7.90	6.12
MnO	0.17	0.19	0.14	0.25	0.28	0.13	0.12
MgO	15.35	14.85	14.79	14.51	14.24	14.68	15.16
CaO	20.91	20.77	20.95	20.55	20.48	20.17	20.82
Na_2O	0.49	0.41	0.50	0.42	0.39	0.37	0.43
K_2O	0.01	0.01	0.03	0.01	0.01	0.03	0.02
H_2O^+	0.03	–	0.13	–	–	0.09	0.12
	100.40	100.25	100.31	100.24	100.33	100.45	100.30

(continued)

Table IV (cont.)

	1	2	3	4	5	6	7
	Numbers of ions on the basis of 6 oxygens						
Si	1.841	1.859	1.879	1.877	1.893	1.841	1.860
Al	0.159	0.141	0.121	0.123	0.107	0.159	0.140
Al	0.016	0.027	0.028	0.042	0.027	0.038	0.020
Ti	0.029	0.039	0.023	0.026	0.031	0.030	0.033
Fe^{+3}	0.048	0.054	0.041	0.027	0.038	0.058	0.068
Cr	0.022	0.007	–	–	–	–	–
Mg	0.830	0.819	0.819	0.802	0.789	0.814	0.837
Fe^{+2}	0.194	0.196	0.234	0.248	0.265	0.246	0.190
Mn	0.005	0.006	0.004	0.008	0.009	0 004	0 004
Ca	0.830	0.823	0.834	0.817	0.816	0.805	0.826
Na	0.035	0.029	0.036	0.030	0.028	0.027	0.031
K	–	–	0.001	–	–	0.001	0.001
	Atomic Percent						
Ca	43.1	43.4	42.9	42.9	42.6	41.8	43.5
Mg	44.1	43.1	42.2	42.2	41.1	42.2	43.0
(Fe^{+2}, Fe^{+3}Mn)	12.8	13.5	14.9	14.9	16.3	16.0	13.5

1 Augite, plagioclase-augite-olivine cumulate (E.G. 6067).
West of ridge south of Hutchinson Gletscher Syenite I.
Anal. J. H. Scoon.

2 Augite, plagioclase-augite-olivine cumulate (E.G. 6537).
Ridge west of Hutchinson Gletscher Syenite I.
Anal. J. H. Scoon.

3 Augite, plagioclase-augite-olivine cumulate (E.G. 6525).
Ridge west of Hutchinson Gletscher Syenite I.
Anal. D. Abbott.

4 Augite, plagioclase-augite-olivine cumulate (E.G. 6520).
Ridge west of Hutchinson Gletscher Syenite I.
Anal. J. H. Scoon.

5 Augite, plagioclase-augite-olivine cumulate (E.G. 6517).
Ridge west of Hutchinson Gletscher Syenite I.
Anal. J. H. Scoon.

6 Augite, plagioclase-augite-olivine cumulate (E.G. 3976).
West of Kap Deichmann.
Anal. W. A. Deer.

7 Augite, gabbro pegmatite (E.G. 3814). West of Kap Deichmann.
Anal. W. A. Deer.

6517). The calcium contents of the lower layered series augites are markedly higher than those of the Skaergaard clinopyroxenes. The variation in calcium content is small, and the crystallization trend of the augites is more nearly parallel to the diopside-hedenbergite join, and shows a marked contrast with the decreasing content in calcium, compared with the earlier clinopyroxenes of the Skaergaard intrusion. The

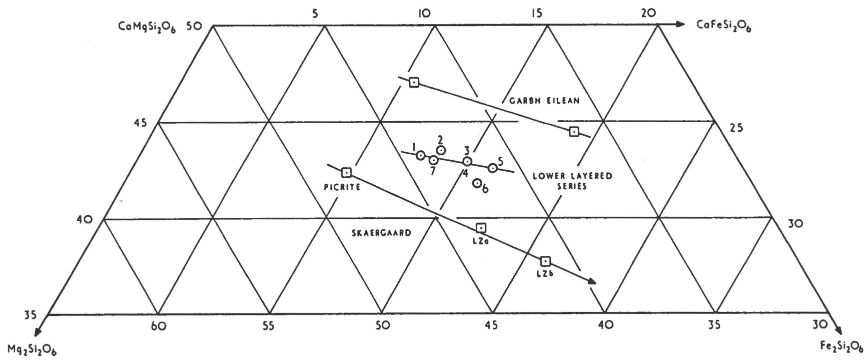


Fig. 4. Plot of the augite compositions in the Lower Layered Series. The trend of the Garbh Eilean sill augites and the augites from the picrite and lower zone of the Skaergaard Intrusion are also indicated.

intermediate character of the composition of the lower layered series augites, between those of the Skaergaard lower zone and pyroxenes crystallized from alkali olivine basalt magmas, as for example the clinopyroxenes of the Garbh Eilean sill (MURRAY, 1954), is illustrated in Fig. 4. In the earlier paper on the clinopyroxenes of the Kap Edvard Holm layered series (DEER & ABBOTT, 1965) it was concluded that their compositional differences, compared with the Skaergaard clinopyroxenes, was the result of their crystallization at somewhat lower temperatures due to the higher water vapour pressures at which the lower layered series magma crystallized.

In contrast to the lower and middle layered series of the Skaergaard intrusion the cumulates of the lower layered series of the Kap Edvard Holm complex contain neither cumulate nor intercumulate orthopyroxene, and this mineral is present only in occasional narrow reaction zones around crystals of olivine. Moreover, like the clinopyroxenes derived by the crystallization of alkali olivine basalt magmas, the augites of the Kap Edvard Holm lower layered series do not contain blebs of an exsolved calcium-poor pyroxene, although augites containing sub-microscopic pigeonite lamellae are present in upper layered series cumulates (ELSDON, 1971).

c) Olivine

The compositional range of the olivines of both the Lower Zone A- and Lower Zone B-type cumulates is small and except for olivine, Fo_{77}, from the 500 m level, is restricted to compositions between Fo_{67} and Fo_{70}. (Table V). The most noticeable features of the olivines are the grain shapes and alteration. In many of the Lower Zone A- and Lower Zone B-type cumulates the olivines tend to be rounded and resorbed and commonly have alteration rims of secondary products. Some of the

Table V. *Composition of Olivines (Forsterite per cent)*

Unit	Height (meters)	Spec. No.	Measured composition
Lower Zone A-type cumulates	3850	3997	70
	3200	6007	67
	2600	6030	68
	2050	6504	67
	1750	6522	68
	1250	6524	67
Lower Zone B-type cumulates	750	6537	68
	600	6086	68
	500	6067	77

olivines of the Lower Zone A-type cumulates, however, are elongated in the direction of the з-axis and in the higher Lower Zone B-type cumulates of the south-west of Kap Deichmann, the olivine crystals have sinuous outlines indicating appreciable intercumulate growth.

The alteration of the intercumulus olivine is largely confined to the lower rocks in which as much as 50 per cent of the ferromagnesian minerals may be altered, and the crystals contain many small magnetite grains which form trails through, and rims around, the crystals. The alteration of the olivine is of three types in decreasing order of abundance:

1) replacement by cummingtonite and talc:
2) serpentinization associated with cummingtonite and calcite:
3) replacement by bowlingite and iddingsite.

Olivine pseudomorphs are frequently rimmed by chlorite and talc derived from the intercumulus alteration and replacement of the adjacent plagioclase grains. Chlorite and talc commonly occur also in thin veins in the feldspar. The chlorite is slightly pleochroic, colourless to pale green; the birefringence varies between 0.001 and 0.009 and is probably related to the different iron-magnesium ratios of the chlorites. Concurrently calcium, alkali and aluminium ions released during the replacement of plagioclase by chlorite entered the intercumulus fluids and led to the formation of clinozoisite and calcite. The initial formation of cummingtonite and talc indicates that the earlier stage in the olivine alteration took place at approximately 750°C. (Bowen & Tuttle, 1949; Gillery, 1959), and that later at a temperature between 400° and 500°C, the serpentinization occurred. Thus, since serpentine is much less abundant than cummingtonite or talc, most of the alteration probably took place at relatively high temperatures, above 500°C.

d) Amphiboles

Amphiboles of both primary and secondary origin are present in the rocks of the lower layered series. The primary amphibole is brown in colour and occurs in both euhedral and anhedral grains and is a product of intercumulus crystallization; in some of the cumulates of the Lower Zone B unit the amphibole makes up some 2 per cent by volume of the rock. Although attempts to separate a pure concentrate of the amphibole for analysis have been unsuccessful it is probable that it is hastingsitic in composition. This identification is inferred from the close comparison of its optical properties with those of an amphibole (Table VI) which occurs in a gabbro cumulate xenolith from the syenite-gabbro breccia margin of the Kap Boswell syenite. As volatiles, mainly water, are essential constituents of the amphibole, its crystallization as a primary intercumulus mineral must have taken place at a minimum water vapour pressure of approximately 1000 bars (Boyd, 1959).

Much of the secondary amphibole is derived from the alteration of augite, and consists of masses of small laths and prismatic grains which are paler coloured in the centre and more strongly coloured in the marginal areas of the aggregates. The intercumulus hastingsite also alters to small prismatic laths of a green-blue, green-brown amphibole indistinguishable from the amphibole derived by alteration of the augite. The analysis of a composite sample of these lighter and darker amphiboles in a metamorphosed cumulate 50 m from the contact with Hutchinson Gletscher Syenite II, is given in Table VII.

Table VI. *Amphiboles: Optical Properties*

	1	2	3
α	1.661	1.644	1.664
β	1.672	1.657	1.670
γ	1.681	1.665	1.678
$\gamma:z$	16°	18°	17°
2V α	82°–88°	72°–84°	–
α	light brown	pale brown – green-brown	light brown
β	dark brown	greenish blue – olive green	brown
γ	brown	light blue – greenish blue	brown

1 Brown amphibole, plagioclase – augite – olivine orthocumulate (E.G. 6525). Ridge east of Hutchinson Gletscher Syenite I.

2 Secondary actinolite, plagioclase – augite cumulate (E.G. 3816). West of Kap Deichmann.

3 Hastingsite, gabbro xenolith in syenite (E.G. 3327). Kap Boswell (Lwin, 1960).

Table VII. *Amphibole: Analysis and Comparisons*

	1	2	3	4
SiO_2	47.01	41.82	44.56	54.33
TiO_2	0.88	3.07	1.20	0.29
Al_2O_3	9.03	13.48	11.67	2.68
Fe_2O_3	2.09	2.71	2.03	1.09
FeO	12.06	9.41	9.67	11.68
MnO	0.19	0.12	0.09	0.00
MgO	14.01	12.31	14.68	15.31
CaO	12.20	11.99	10.82	12.46
Na_2O	0.28	2.99	2.78	0.54
K_2O	0.06	0.75	0.86	0.12
H_2O^+	1.93	2.00	1.65	2.04
H_2O^-	0.10	–	0.06	0.20
	99.84	100.65	100.07	100.74

Numbers of ions in the basis of 24 (O:OH).

	1		2		3		4	
Si	6.85	8.00	6.11	8.00	6.51	8.00	7.74	8.00
Al	1.15		1.89		1.49		0.26	
Al	0.40	5.26	0.43	5.05	0.52	5.26	0.19	4.98
Ti	0.10		0.34		0.13		0.03	
Fe^{+3}	0.23		0.30		0.22		0.12	
Mg	3.04		2.68		3.20		3.25	
Fe^{+2}	1.47		1.15		1.18		1.39	
Mn	0.02		0.15		0.11		–	
Na	0.08	2.00	0.85	2.87	0.79	2.64	0.15	2.07
Ca	1.91		1.88		1.69		1.90	
K	0.01		0.14		0.16		0.02	
OH	1.88		1.95		1.61		1.94	

1 Secondary aluminous amphiboles – bulk composition, plagioclase – augite cumulate (E.G. 3816).
West of Kap Deichmann. Anal. D. Abbott.

2 Hastingsite, gabbro xenolith in syenite (E.G. 3327).
Kap Boswell (Lwin, 1960). Anal. M. T. Lwin (Value of H_2O^+ assumed for calculating the numbers of ions).

3 Hastingsite, garnet – hornblende – two pyroxene rock
(Deer *et al.*, 1963, Table 43, No. 11).

4 Actinolite, hornblende – epidote – albite schist
(Deer *et al.*, 1963, Table 38, No. 9).

e) Iron Oxides

The iron oxides consist mainly of magnetite, titanomagnetite and ilmenite. The rocks also contain small amounts of sulphides, largely chalcopyrite, but chalcocite, bornite and pyrrhotite have also been identified (Table VIII). Titanomagnetite contains thin exsolution lamellae of

Table VIII. *Iron Oxides – Volume per cent*

Unit	Height (meters)	Spec. No.	Magnetite	Ilmenite	Sulphides	Ratio Mt/Il
	3850	3997	4.2	1.7	tr	2.5
	3200	6006	–	–	–	–
Lower Zone	2600	6031	0.8	0.4	0.1	2.0
B-type	2050	6517	1.8	0.8	0.2	2.3
cumulates	1750	5620	1.3	1.0	tr	1.3
	1500	3404	8.3	3.0	–	2.8
	1250	6525	3.0	1.1	–	2.7
	750	6537	0.3	0.1	tr	3.0

ilmenite. Under high magnifications (× 450) the areas between exsolution lamellae are seen to consist of a fine intergrowth of two minerals, the one, magnetite, the other probably ulvöspinel. Titanomagnetite and ilmenite occur both as cumulus and intercumulus crystals forming isolated euhedral grains and granular aggregates respectively, the latter sometimes occurring in large growths enclosing feldspar laths. Most of the iron oxide grains are anhedral with "mutual boundary textures" in relation to the silicate phases. Boundaries between the titanomagnetite and ilmenite are smooth and sharp "closed boundaries", indicating that the aggregates are the products of exsolution from high temperature solid solutions which originally separated from the magma as a single crystal phase (VINCENT & PHILLIPS, 1954). Additional evidence of the exsolution relationship between ilmenite and titanomagnetite is shown by the continuity of the ilmenite lamellae in the titanomagnetite with adjacent ilmenite crystals. Moreover some of the oxide grains, euhedral in outline, consist of both ilmenite and titanomagnetite and have formed by exsolution of the two phases from original euhedral gains which crystallized at higher temperatures.

IV. PETROGRAPHY

a) Lower Zone a Cumulates

Rocks of the Lower Zone A unit (Plate 4, Figs. 1, 2) at the base of the lower series have been traced from the ridge bordered by Hutchinson Gletscher Syenites I and II, eastwards for a distance of 5 km to the peninsular, west of Kap Deichmann. On the peninsular the Lower Zone A cumulates are 350 m thick and increase to 650 m at the extreme north-west of the outcrop: the unit has not been identified, and is probably not present, in the western part of the intrusion on Kontaktbjerg and the mountains to the northeast. The Lower Zone A type cumulates are fine-grained rocks with an allivalitic texture in which phenocrysts (~ 2mm) of plagioclase, augite and olivine occur in a groundmass of small (~ 0.5 mm) lath-shaped feldspars. Some of the olivines form elongated crystals, and these and the larger feldspar laths are commonly aligned sub-parallel to the igneous lamination (Plate 6, Fig. 1), but the more olivine- and augite-rich cumulates of the unit do not show allivalitic texture (Plate 10, Fig. 1). In these bands, in which the feldspar is subordinate to the ferromagnesian minerals and interstitial to the olivine and augite crystals, the textures are identical with those of the coarser-grained dark-mineral bands such as the olivine mesocumulates of the Lower Zone B-unit. Near the top of the Lower Zone A cumulates, at 650 m on the ridge west of Hutchinson Gletscher Syenite I, and 350 m along the coast, the number of feldspar laths decreases, the grain size increases and a transition takes place to coarser-grained cumulates of Lower Zone B-type.

The average rock of the Lower Zone A is a plagioclase-augite-olivine orthocumulate. The relative amounts of plagioclase, clinopyroxene and olivine change frequently in the sequence to give extreme feldspar-rich (E.G. 6070, See Plate 7, Fig. 1) and ferromagnesian-rich (E.G. 6075) bands (Table IX). Feldspar-rich bands are more numerous towards the top of the unit, the upper 50 m consists of an anorthosite zone which consists largely of feldspar adcumulates with thin bands of more average rock (Plate 4, Fig. 1 and 2); in the area west of Kap Deichmann the anorthosite zone is narrow and consists only of one or two thin feldspar-rich bands.

Table IX. *Lower Zone A-Type Cumulates – Modal Composition* (alteration products recalculated as primary minerals)

	1	2	3	3a	4	5
Plagioclase	64	37	72	58	94	2
Augite	16	38	25	26	–	5
Olivine	19	25	2	16	–	87
Iron oxides, biotite, hastingsite, clinozoisite	1	–	1	–	6	6

1 "Average" Lower Zone A-type orthocumulate (E.G. 6067) height 500 m.
2 "Average" Lower Zone A-type orthocumulate (E.G. 6087) height 600 m.
3 Feldspar-rich Zone A-type orthocumulate (E.G. 3813) height 250 m.
3a Average composition of 6067, 6087 and 3813.
4 Feldspar adcumulate, Lower Zone A (E.G. 6070) height 600 m.
5 Olivine mesocumulate, Lower Zone A (E.G. 6075) height 600 m.

The feldspar of the Lower Zone A-type cumulates is generally fresh but some incipient alteration is shown by the presence of turbid patches and the formation of sericite. The larger feldspars of the lower levels at 500 m show oscillatory zoning ranging in composition from An_{79} to An_{67}, but in the small crystals of the matrix the intermediate zones are absent and the plagioclase is almost uniform in composition, An_{78-76}. Higher in the unit, at 600 m, both the matrix and the large feldspars are more calcic, An_{82} and An_{75-82} respectively, with reverse zoning in the larger crystals. The clinopyroxene, $Ca_{43}Mg_{44}Fe_{13}$, forms unzoned anhedral crystals and has an ophitic relationship to the plagioclase; the cumulus component of the pyroxene crystals commonly show no feldspar embayments, and it is the marginal intercumulus growth that generally encloses feldspar crystals. The augite is usually unaltered but in some specimens the clinopyroxene is partly replaced by chlorite and a green hornblende. In the lowest rocks of the unit the olivine has a composition of Fo_{77} but in most of the higher rocks it is more iron-rich, and is Fo_{68-67} in composition, and is frequently present in clusters of six or more grains. A few cumulus crystals of magnetite also occur in the rocks of the Lower Zone A unit.

The formation of orthocumulates involves only limited contact between the intercumulus liquid and the overlying magma and results in the crystallization of the intercumulus liquid as successively lower temperature zones around the original cumulus crystals, or in additional phases that formed at lower temperatures (WAGER, BROWN & WADSWORTH, 1960; WADSWORTH, 1961). The feldspar adcumulates formed by a process in which diffusion between the intercumulus liquid and the magma continued after accumulation, with the consequence that the

Table X. *Lover Zone A-Type Cumulates – Analyses*

	1	2	3
SiO_2	46.10	48.12	49.21
Al_2O_3	20.05	25.82	30.16
Fe_2O_3	2.69	1.30	1.44
FeO	4.81	3.68	0.35
MgO	10.02	4.02	0.08
CaO	11.92	12.74	14.05
Na_2O	1.73	2.57	3.21
K_2O	0.43	0.14	0.40
H_2O^+	1.41	0.75	0.75
H_2O^-	0.36	0.16	0.31
TiO_2	0.25	0.77	0.24
MnO	0.08	0.09	0.01
P_2O_5	0.14	0.10	0.01
	99.99	100.26	100.22

1 Plagioclase-augite-olivine orthocumulate (E.G. 6067) Ridge south of Hutchinson Gletscher Syenite I. height 500 m.
2 Feldspar-rich orthocumulate (E.G. 3813) west of Kap Deichmann height 250 m.
3 Feldspar adcumulate (E.G. 6070) Ridge south of Hutchinson Gletscher Syenite I height 600 m.
Anal. W. A. Deer.

adcumulus growth of feldspar occurred at similar temperatures to that of the original cumulus crystals. As a result the plagioclase of the matrix and at the margins of the large plagioclase crystals have the same composition, *i.e.* An_{82}. In these adcumulate conditions the amount of the pore liquid was small and this crystallized mainly as poikilitic augite. In other layers, in which olivine is the chief cumulus phase, the amount of the pore liquid was greater and the rocks are mesocumulates (*e.g.* Table IX No. 5). In some of the more olivine-rich layers the cumulus olivine is surrounded by augite and plagioclase, similar in composition to the cumulus plagioclase of adjacent layers, and these rocks have an heteradcumulate texture.

Three rocks were analyzed from the Lower Zone A unit and represent successive stages in the enrichment of the cumulates in plagioclase. The first was collected as "average olivine gabbro" and is a plagioclase-augite-olivine orthocumulate (Tables X, XI, No. 1). The second is a feldspar-rich olivine-poor orthocumulate (No. 2) and the third a feldspar adcumulate (No. 3). The change in the relative proportions of the main minerals which gives rise to the feldspar adcumulate is shown in the analyses by increases in the SiO_2, Al_2O_3, CaO and Na_2O and decreases in

Table XI. *Lower Zone A-Type Cumulates – Norms and Modes*

		1		2		3	
Or		2.54		0.83		2.36	
Ab		14.64		21.75		25.94	
An		45.68		58.51		66.71	
Ne		–		–		0.66	
Diop.	Wo	5.24	9.99	1.69	3.27	0.23	0.43
	En	3.79		1.08		0.20	
	Fs	0.96		0.50		0.00	
Hyp.	En	4.72	5.92	4.99	7.27	–	
	Fs	1.20		2.28			
Oliv.	Fo	11.52	14.75	2.76	4.15	–	
	Fa	3.23		1.39			
Mt		3.90		1.88		0.47	
Il		0.47		1.46		0.46	
Ap		0.33		0.24		0.02	
Wo		–		–		0.71	
Hm		–		–		1.12	
		$Or_{4.0}Ab_{23.3}An_{72.7}$		$Or_{1.0}Ab_{26.8}An_{72.2}$		$Or_{2.5}Ab_{27.3}An_{70.2}$	
		$Wo_{52.5}En_{37.0}Fs_{9.6}$		$Wo_{51.7}En_{33}Fs_{15.3}$		$Wo_{53.5}En_{46.5}$	
		$En_{80}Fs_{20}$		$En_{66.5}Fs_{33.5}$		–	
		$Fo_{78}Fa_{22}$		$Fo_{66.5}Fa_{33.5}$		–	
		Modes					
Plagioclase		64		72		94	
Augite		14		12		0	
Olivine		8		0		0	
Iron oxides		1		tr.		1	
Clinozoisite		tr.		0		2	
Chlorite		2		13		0	
Altered olivine		11		2		0	
Actinolite		tr.		1		3	

the FeO and MgO contents. The plagioclase-augite-olivine cumulate (E.G. 6067) has a higher Al_2O_3 content than the overlying Lower Zone B-type rocks and, in conformity with their earlier accumulation, has a lower iron-magnesium ratio.

b) Lower Zone B-Type Cumulates

Lower Zone B-type cumulates are well developed on the ridge to the southwest of the contact with Hutchinson Gletscher Syenite I, where some 1400 m of the layered sequence is exposed; the total thickness of the unit is approximately 3200 m. The thickness of the lower layered series in the western part of the intrusion cannot be estimated with any

Table XII. *Lower Zone B-Type Cumulates – Modal Composition* (alteration products recalculated as primary minerals)

	1	2	3	4	5
	N.W. Kap Deichmann	W. Kap Deichmann	N.W. Area		
Plagioclase	50	58	52	53	58
Augite	40	32	28	33.5	26
Olivine	7	6	13	9	16
Iron oxides	3	3	6	4	1
Hastingsite, biotite, clinozoisite, calcite	–	1	–	0.5	

1 Average of five plagioclase-augite-olivine orthocumulates.
2 Average of seven plagioclase-augite-olivine orthocumulates.
3 Average of three plagioclase-augite-olivine orthocumulates.
4 Average modal composition of Lower Zone A-type cumulates.
5 Average modal composition of Lower Zone B-type cumulates.

certainty, due to the injection of the extensive zone of syenite-gabbro breccia and hydrid, but probably was originally of comparable thickness.

The average rock of the Lower Zone B-unit is, in the main, a plagioclase-augite-olivine orthocumulate (Table XII), in which the proportions of the chief constituents vary to give contrasted layers of darker, more ferromagnesian-rich and lighter coloured, more feldspar-rich layers some 6 to 10 m in thickness (Plate 5, Fig. 1). Variation in mineral content within the major darker and lighter coloured layers gives rise to thinner bands of less contrasted composition between 2 cm and 1 m thick (Plate 5, Fig. 2). Because of the precipitous nature of the western face of the north-south ridge, west of Hutchinson Gletscher Syenite I, individual layers have not been traced eastwards and it is possible that some lateral variation occurs. The plagioclase-augite orthocumulates at the base of the Lower Zone B sequence west of Kap Deichmann provide an example of such local variation. Here the first 150 m of the Lower Zone B-type cumulates are olivine-free and coarser-grained than their counterparts on the ridge to the southwest of Hutchinson Gletscher Syenite I, and the underlying Lower Zone A-type cumulates.

In the average Lower Zone B-type cumulate, plagioclase forms euhedral to subhedral laths approximately 2 mm in length; some incipient alteration of the plagioclase is evident from the presence of turbid patches, the formation of sericite and the occurrence of small grains of epidote (α 1.744) adjacent to the turbid feldspar. In the lowest rocks of the unit the plagioclase is zoned from An_{67} to An_{64} (Plate 7, Fig. 2 and

Table XIII – *Lower Zone B-Type Cumulates – Analyses*

	1	2	3	4	5	6	7	8
SiO_2	47.85	47.66	47.96	45.26	47.34	48.11	49.08	47.79
Al_2O_3	17.40	18.55	16.59	17.72	17.28	21.43	21.30	17.78
Fe_2O_3	2.12	1.86	2.62	4.46	4.11	2.31	1.68	1.34
FeO	4.83	5.43	5.46	8.09	6.50	4.47	4.23	7.85
MgO	9.33	9.17	8.29	7.23	6.10	5.50	6.35	10.14
CaO	14.27	12.95	15.03	12.00	13.42	14.22	13.73	11.38
Na_2O	2.11	2.19	2.05	2.13	2.72	2.32	2.42	2.02
K_2O	0.20	0.27	0.18	0.37	0.40	0.33	0.09	0.10
H_2O^+	1.04	1.34	0.82	0.92	0.91	0.42	0.39	0.41
H_2O^-	0.27	0.18	0.11	0.17	0.13	0.17	0.10	0.19
TiO_2	0.58	0.58	1.00	1.90	1.42	0.58	0.84	1.03
MnO	0.08	0.08	0.07	0.07	0.12	0.08	0.06	0.14
P_2O_5	0.05	0.28	0.03	0.05	0.11	0.03	0.02	0.03
	100.13	100.54	100.21	100.37	100.56	99.97	100.29	100.20
$\frac{(Na_2O+K_2O+CaO)}{(Na_2O+K_2O)}$	16	16	13	17	19	16	15	16
$\frac{(FeO+Fe_2O_3)}{(FeO+Fe_2O_3+MgO)}$	43	44	49	63	66	55	48	48

1 Plagioclase-augite-olivine orthocumulate (E.G. 3218) West Kap Deichmann, height 700 m.
2 Plagioclase-augite-olivine orthocumulate (E.G. 6537) Ridge west of Hutchinson Gletscher Syenite I height 750 m.
3 Plagioclase-augite-olivine orthocumulate (E.G. 6524) Ridge west of Hutchinson Gletscher Syenite I height 1250 m.
4 Plagioclase-augite-olivine orthocumulate (E.G. 6517) Ridge west of Hutchinson Gletscher Syenite I height 2050 m.
5 Plagioclase-augite-olivine orthocumulate (E.G. 6031) West of Kap Deichmann, height 2600 m.
6 Plagioclase-augite-olivine orthocumulate (E.G. 6006) West of Kap Deichmann, height 3200 m.
7 Plagioclase-augite-olivine orthocumulate (E.G. 3976) West of Kap Deichmann, height 3800 m.
8 Plagioclase-augite-olivine orthocumulate (E.G. 3997) West of Kap Deichmann, height 3850 m.
Anal. W. A. DEER.

Plate 8, Fig. 1). At a height of 1250 m in the layered series, the plagioclase is zoned from An_{81} to An_{65}, and then becomes increasingly more sodic at higher levels in the series, and at 2050 m the plagioclase is zoned from An_{67} to An_{54}. Thereafter the plagioclase again becomes more calcic and at the 3800 m level is zoned from An_{77} to An_{65} (Plate 9, Fig. 2). Augite, some of which is altered to chlorite and green hornblende, occurs mainly as euhedral crystals which commonly show a subpoikilitic or

Table XIV. *Lower Zone B-Type cumulates – Norms and Modes*

		1		2		3		4		5		6		7		8	
Or		1.18		1.60		1.06		2.19		2.36		1.95		0.53		0.59	
Ab		16.88		18.53		16.24		18.02		20.83		19.63		20.48		17.09	
An		37.42		39.99		35.54		37.70		33.76		47.09		46.99		39.15	
Ne		0.53		–		0.60		–		1.18		–		–		–	
Diop.	Wo	13.80		9.36		16.21		8.98		13.40		9.71		8.77		7.14	
	En	9.89	26.37	6.45	17.97	11.36	31.06	5.77	17.37	8.77	25.87	6.43	18.72	6.08	16.81	4.55	13.83
	Fs	2.68		2.16		3.49		2.62		3.70		2.58		1.96		2.14	
Hyp.	En	–		2.07	2.76	–		2.37	3.45	–		0.32	0.45	4.47	5.91	7.25	10.66
	Fs	–		0.69		–		1.08		–		0.13		1.44		3.41	
Oliv.	Fo	9.35	12.15	10.03	13.72	6.51	8.71	6.91	10.36	4.50	6.60	4.86	7.01	3.69	5.00	9.43	14.31
	Fa	2.80		3.69		2.20		3.45		2.10		2.15		1.31		4.88	
Mt		3.07		2.70		3.80		6.47		5.96		3.35		2.44		1.94	
Il		1.10		1.10		1.90		3.61		2.70		1.10		1.60		1.96	
Ap		0.12		0.66		0.07		0.12		0.26		0.07		0.05		0.07	
Feld.	Or	2.1		2.7		2.0		3.8		4.1		2.8		0.8		1.0	
	Ab	30.4		30.8		30.7		31.1		36.6		28.6		30.1		30.1	
	An	67.5		66.5		67.3		65.1		59.3		68.6		69.1		68.9	
Diop.	Wo	52.3		52.1		52.2		51.7		51.8		51.9		52.2		51.6	
	En	37.5		35.9		36.6		33.2		33.9		34.3		36.1		32.9	
	Fs	10.2		12.0		11.2		15.1		14.3		13.8		11.7		15.5	
Hyp.	En	–		75		–		68.7		–		71.1		75.6		68.0	
	Fs	–		25		–		31.3		–		28.9		24.4		32.0	
Oliv.	Fo	77		73.1		74.7		66.7		68.2		69.3		73.8		65.9	
	Fa	23		26.9		25.3		33.3		31.8		30.7		26.2		34.1	

Table XV. *Western and Northwestern Area Lower Zone B Cumulates Analyses*

	1	2	3
SiO_2	40.86	47.00	46.52
Al_2O_3	16.19	18.54	13.95
Fe_2O_3	8.21	3.12	1.32
FeO	8.85	5.35	9.58
MgO	7.09	9.76	15.06
CaO	12.72	12.92	10.66
Na_2O	1.65	2.03	1.88
K_2O	0.13	0.17	0.12
H_2O^+	0.89	0.25	0.61
H_2O^-	0.27	0.25	0.00
TiO_2	3.24	0.98	0.50
MnO	0.11	0.07	0.18
P_2O_5	0.02	0.05	0.03
	100.23	100.49	100.41

1 Magnetite-ilmenite-rich plagioclase-augite-olivine orthocumulate (E.G. 3404). Southern side Kontaktbjerg.
Anal. W. A. DEER.

2 Plagioclase-augite-olivine orthocumulate, (E.G. 3253). Northeastern tip of mountain north of Kontaktbjerg.
Anal. W. A. DEER.

3 Ferromagnesian-rich plagioclase-augite-olivine orthocumulate (E.G. 7200). Small nunatak, south side Hutchinson Gletscher.
Anal. J. H. SCOON.

subophitic relationship with the plagioclase. The composition of the clinopyroxene varies from $Ca_{43}Mg_{44}Fe_{13}$ to $Ca_{43}Mg_{41}Fe_{16}$ (DEER & ABBOTT, 1965), and the most iron-rich augite is present in the cumulates at the 2050 m level (Plate 9, Fig. 1). Olivine forms rounded crystals approximately 1 mm in diameter; the variation in composition, from Fo_{67} to Fo_{70}, is comparable with that of the clinopyroxene. In some of the rocks the olivine is extensively altered to cummingtonite, talc and to a lesser extent, bowlingite and iddingsite (Plate 8, Fig. 2).

Small quantities of hypersthene (Fs_{25}) and magnetite are present as narrow discontinuous reaction rims around some of the olivine crystals. Hypersthene is more abundant in the metamorphosed cumulates of the western and northwestern area where it occurs as clouded grains, 1–2 mm in size, intergrown with clinopyroxene. Titanomagnetite and ilmenite occur as intercumulus minerals but some iron oxide of early crystallization is also present. Chromite of early crystallization occurs as rounded or euhedral grains in some olivines and there are small amounts of intercumulus hastingsite and biotite.

Table XVI. *Western and Northwestern Area Lower Zone B Cumulates Norms and Modes*

		1		2		3	
Or		0.77		1.00		0.71	
Ab		13.96		17.09		15.91	
An		36.29		41.02		29.27	
Diop.	Wo	11.10	21.17	9.50	18.11	9.78	18.88
	En	8.09		6.96		6.38	
	Fs	1.98		1.65		2.72	
Hyp.	En	0.47	0.58	2.62	3.24	0.07	0.10
	Fs	0.11		0.62		0.03	
Oliv.	Fo	6.38	8.10	10.32	13.02	21.77	32.01
	Fa	1.72		2.70		10.24	
Mg		11.90		4.52		1.91	
Il		6.15		1.86		0.95	
Ap		0.05		0.12		0.07	
		$Or_{1.5}Ab_{27}An_{71.5}$		$Or_{1.7}Ab_{28.9}An_{69.4}$		$Or_{1.5}Ab_{34.7}An_{63.8}$	
		$Wo_{52.4}En_{38.2}Fs_{9.4}$		$Wo_{52.5}En_{38.4}Fs_{9.1}$		$Wo_{51.8}En_{32.8}Fs_{14.4}$	
		$En_{81}Fs_{19}$		$En_{80.9}Fs_{19.1}$		$En_{70}Fs_{30}$	
		$Fo_{79}Fa_{21}$		$Fo_{79.3}Fa_{20.7}$		$Fo_{68}Fa_{32}$	
Modes							
Plagioclase		50*		57		48	
Augite		28*		31		26	
Olivine		8*		8		25	
Iron oxides		14		4		1	

* Includes alteration products of the plagioclase, augite and olivine respectively.

Small lenses and more irregular patches of gabbro pegmatite, generally conformable with the layering, are common in the banded rocks in the area west of Kap Deichmann, The pegmatites consist of large plagioclase and augite crystals, 10–20 mm in size, with minor amounts of magnetite, epidote, apatite and quartz. The augite from a pegmatite lens at the 400 m level south of the contact with Hutchinson Gletscher Syenite II has the composition $Ca_{43.5}Mg_{43}Fs_{13.5}$.

The chemical composition of the Lower Zone B-type cumulates, except for that of CaO, show a relatively smooth and progressive variation from the lowest exposed members of the series to the 2000 to 2600 m level (Tables XIII, XIV) at which the most differentiated part of the sequence occurs. From the base of the Lower Zone B-type cumulates to this level there is an increase in Fe_2O_3 + FeO, Na_2O and TiO_2, and a decrease in the percentage of Al_2O_3 and MgO. The lowest cumulates in the sequence have a mafic index of 16 and a felsic index of 43, both indices increase with height in the layered series and at 2600 m are 19 and 66 respectively. From the 2600 m level to the highest exposed cumulates of the lower layered series these trends are reversed; the percentages of total iron oxides, CaO and TiO_2 decrease and those of Al_2O_3 and MgO increase. The content of Na_2O unlike the iron oxides and TiO_2, shows only a small decrease due to the compensating effect of the larger content of plagioclase in the higher cumulates, a factor which also contributes to the marked increase in Al_2O_3 in these rocks. The apparent anomalous behaviour of the CaO content as well as the rapid decrease in the percentage of Al_2O_3, in the earlier cumulates of Lower Zone B-type, is due also to a change in the relative proportions of the main constituents in the cumulates and is essentially related to the higher content of augite in the cumulates between 1250 m and 2050 m.

The chemical composition, norms and modes of three Lower Zone B-type cumulates from the western and northern western area of the lower layered series are given in Tables XV and XVI.

V. RHYTHMIC LAYERING AND MINOR VARIATION

Convection currents were shown by WAGER and DEER (1939) to have had an important role in the formation of the layered series of the Skaergaard intrusion. Subsequently a similar mechanism has been invoked to account for some or all the features of other layered intrusions. Rhythmic banding may also be produced by undercooling during magmatic crystallization (WAGER, 1959; VAN ZYL, 1959) and, as with the Rhum ultrabasic complex, by successive additions of new magma (BROWN, 1956). The zoning of the feldspars of the lower layered series of the Kap Edvard Holm complex cannot be explained by any of these processes operating singly, and all three factors, convective cumulation, undercooling and the influx of new magma each appear to have been contributing factors in the formation of the lower layered series. The injection of new influxes of magma will disrupt convective circulation and lead to periods in which the magmatic currents are arrested, or considerably reduced in velocity, so that conditions of less active and more active movement will be intermittent. The nature of the zoning in the plagioclase demonstrates that undercooling was an important factor during the early stages of the formation of the lower layered series, including that of the anorthosite zone, consequent on a period of rapid heat loss during which the thermal gradient in the country rocks was re-established after the emplacement of the magma. In this initial period, crystallization began slowly with the formation of relatively few crystals of plagioclase, olivine and augite which accumulated towards the floor of the intrusion and formed the phenocrystal component of the allivalitic cumulates of Lower Zone A-type. Olivine and augite accumulated more rapidly than the plagioclase, probably in a marginal area of the intrusion that was subsequently destroyed by the injections of the later Hutchinson Gletscher Syenites I and II, leading to the formation of a zone enriched in feldspar on the site now occupied by the lower layered series. The period of strong under cooling was subsequently replaced by a rapid increase in feldspar nucleation which gave rise to the smaller feldspar crystals of the allivalitic cumulates.

During the formation of the lowest cumulates of this period of crystallization the smaller feldspar crystals mixed with the earlier larger crystals of olivine, augite and plagioclase to give the gabbro cumulates of allivalitic texture, and in the higher zone of slower accumulation, layers rich in feldspar were formed. Here slow accumulation, together with effective diffusion between accumulating crystals and the overlying magma gave rise to the feldspar adcumulates of the anorthosite zone. Thus during the period of undercooling plagioclase, An_{75}, crystallized and was followed, on establishment of equilibrium at a higher temperature, by a zone An_{82}, in composition. Later, conditions of crystallization changed, super-saturation was reduced, and the temperature raised towards equilibrium. As a result more normal crystallization of the coarse grained Lower Zone B-type cumulates followed.

To evaluate the extent of the minor variation, the modes were recalculated after converting secondary products into original constituents. The recalculated values, expressed in volume per cent are plotted on a diagram showing modal variation with height in the intrusion (Fig. 5). Although the crystallization of basaltic magma can begin with the precipitation of either pyroxene, olivine or feldspar (YODER & TILLEY, 1962), olivine was probably the first to precipitate from the magma of the lower layered series of Kap Edvard Holm. This is indicated by the textural relationships of the phases in the gabbros, and is in accord with the earlier experimental work of OSBORN and TAIT (1952). YODER & TILLEY have shown, however, that all the major phases appear over a small temperature range of less than 80°C and that the three phases crystallize together in the range of approximately between 1155°C and 1170°C. These temperatures are lowered, and the range extended, by increasing oxygen fugacities. With falling temperature the amount of olivine precipitating decreased and the percentage of olivine changes from 20 per cent at the 500 m to less than 1 per cent at the 2050 m level. Concurrently, nucleation of pyroxene and iron oxides increased and that of feldspar diminished so that the maximum concentration of augite is 50 per cent in the cumulates at 1750, and of iron oxides is 6 per cent in those at 2050 m (Fig. 5). The period of crystallization which gave rise to the cumulates from the 2050 m to the 3900 m level was probably associated with new additions of magma, and in consequence with crystallization at increasingly higher temperatures, with the result that the compositional trends and balance between nucleation rates for the different minerals were reversed. Olivine and feldspar crystallized in increasing quantities towards the top of the series while that of pyroxene and iron oxides decreased, and the final cumulates, at 3850 m, to form from the Lower Series magma, contain 61 per cent plagioclase, 20 per cent augite, 18 per cent olivine and 1 per cent iron oxides.

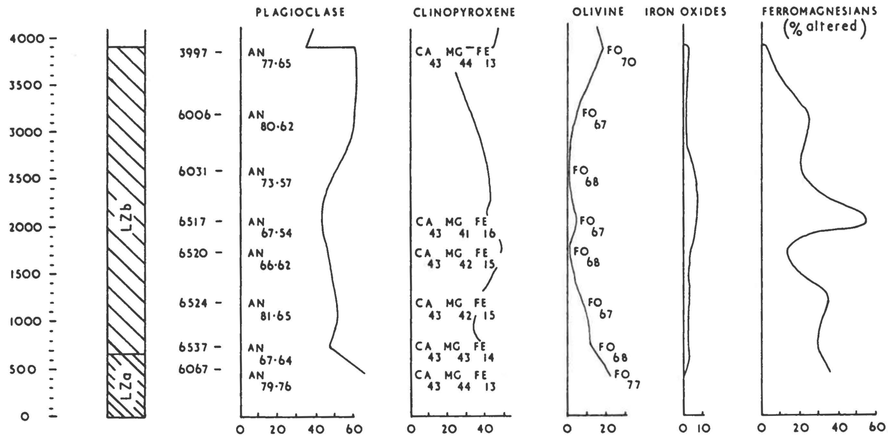


Fig. 5. Variation in the modal percent of plagioclase, clinopyroxene, olivine and iron oxides with height in the lower layered series. (alteration products converted into primary constituents). The extreme right of the figure shows the percentage of altered ferromagnesian constituents.

The complimentary variation in the relative abundance between feldspar and pyroxene was probably due in part to the effect of the oxygen fugacity on the crystallization. Yoder (1954) has shown that in the system diopside-anorthite an increase in vapour pressure inhibits the crystallization of feldspar in relation to that of the pyroxene. The variation in the proportions of hydrous phases in the cumulates indicates that oxygen fugacity was probably at a maximum during the formation of the iron-rich cumulates at the 2000 m level (Fig. 5), and in these rocks too, the percentage of feldspar is smaller particularly in relation to that of the pyroxene.

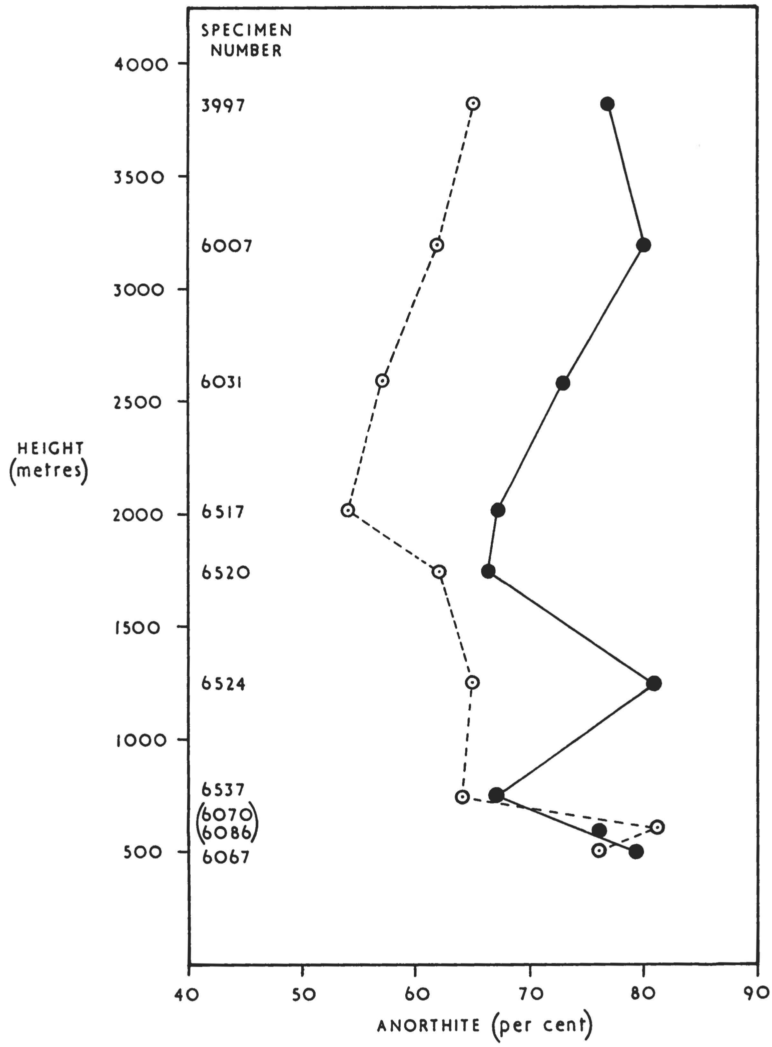


Fig. 6. Variation in plagioclase composition with height in the cumulates of the Lower Layered Series. Solid line, core composition. Broken line, marginal compositions

VI. VARIATION IN COMPOSITION OF MINERALS AND CUMULATES WITH FRACTIONATION

The variation in composition of the plagioclase with height in the layered series is shown in Fig. 6. In the Skaergaard intrusion the formation of the layered sequence by bottom accumulation gave rise to successive layers formed at lower temperatures, and as a result the feldspars are progressively more sodic and the ferromagnesian minerals richer in iron in the later differentiates. In the lower layered series of the Kap Edvard Holm complex, fractionation was uninterrupted until after the accumulation of the relatively highly differentiated layers at approximately the 2000 m level where the feldspar is zoned from An_{67-54}, the clinopyroxene $Ca_{43}Mg_{41}Fe_{16}$ and the olivine Fo_{67} in composition. During the period of fractionation which gave rise to the layers above the 2050 m level, several limited influxes of new magma occurred. These raised the temperature of the crystallizing liquid with the result that the cumulates consist of higher temperature phases which, at the 3900 m level, consist of plagioclase An_{77-65}, augite $Ca_{43}Mg_{44}Fe_{13}$ and olivine Fo_{70} in composition.

Fig. 7, in which some of the oxide percentages are plotted against height in the layered series, shows a comparable variation with that of the composition trends of the individual minerals. Thus the more highly

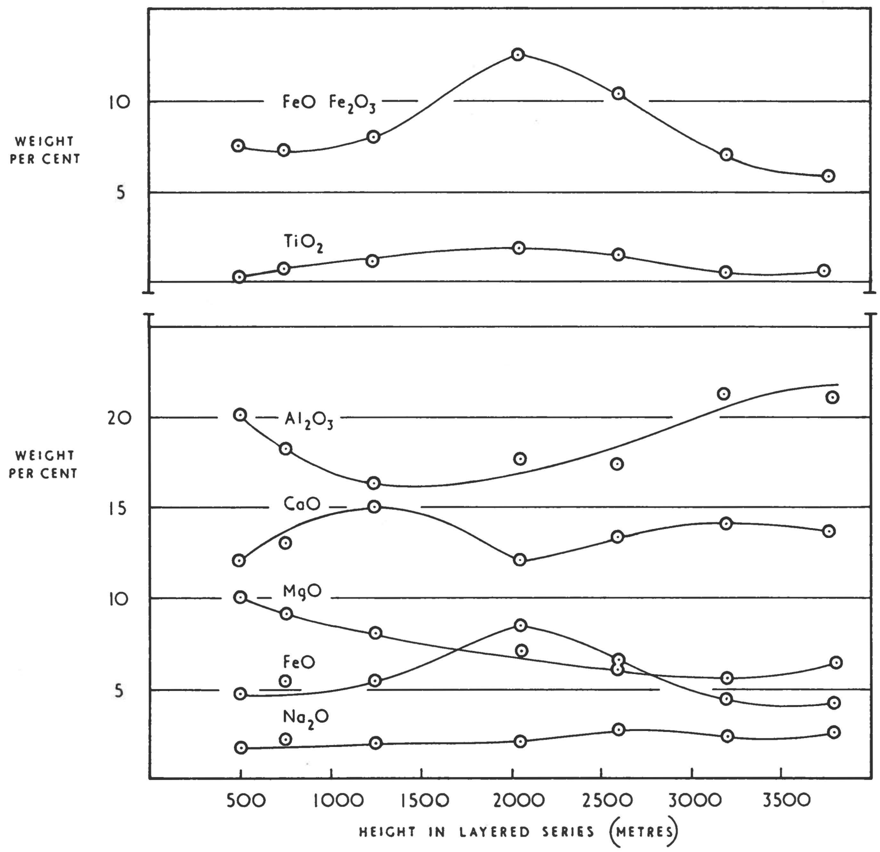


Fig. 7. Variations in oxide percentages in the cumulates with height in the Lower Layered Series.

fractionated iron-enriched horizon in the series, as represented by the rocks 6520 and 6517 occurs between the 1750 and 2000 m levels. The variations in oxide contents of the rocks between the bottom of the Lower Zone B-type cumulates and the 2000 m level are consistent with a process of crystal fractionation. Above this level later influxes of undifferentiated magma, as has previously been deduced from the compositional variations of the constituent minerals, firstly arrested and then reversed the trend.

VII. FRACTIONAL CRYSTALIZATION

The trend in differentiation of basic magma to form iron-rich cumulates is due to the separation, in the early stages of crystal fractionation, of magnesian olivine and pyroxene and calcic plagioclase so that successive liquids and crystal phases are enriched in iron and alkalis relative to magnesium and calcium. As Fe^{+2} replaces Mg^{+2} in successive lower temperature ferromagnesian phases and alkalis replace Ca in plagioclase, the differentiation of basic magma can be expressed in terms of the ferromagnesian and feldspar components as shown by variations in the mafic index, 100 $(FeO + Fe_2O_3)/(FeO + Fe_2O_3 + MgO)$, and the felsic index 100 $(Na_2O + K_2O)/(Na_2O + K_2O + CaO)$ (Fig. 8). The trend in the composition of the lower layered series is not progressive and indicates that the fractionation history of the lower rocks of the Kap Edvard Holm complex was more complex than that of the Skaergaard intrusion. Thus the trend of enrichment in iron was continuous until the 2050 level where the mafic index is 63 (Fig. 9). During this period of fractionation the variation in the felsic index is slight and indicates that only small changes occurred in the calcium-alkali ratio of the feldspars. Above the 2050 level there is a reversal in the trend of crystallization (Fig. 8, nos. 6 and 8), and the mafic and felsic indices decrease from 63 and 19 to 44 and 15 respectively. This reversal in trend is the most distinctive feature of the fractionation and has been correlated with successive small influxes of undifferentiated magma after the formation of the cumulates at the 2050 level. The magma additions were not sufficiently large to disrupt repeatedly the fractionation process but had an accumulative effect in gradually raising the temperature of the crystallizing magma from which phases of an increasingly higher formation temperature were precipitated.

The limited iron enrichment of the cumulates of the lower layered series, compared with that shown by the rocks of the Skaergaard layered series is thus due in part to the peculiar cooling history of Kap Edvard Holm magma. Here, fractionation and the trend to iron enrichment were interrupted by the addition of new magma which resulted in the accumulation of successively higher temperature phases above the 2050 ft. level. In addition higher oxygen fugacity also contributed to the lower rate of iron enrichment as shown by the presence, in the rocks of the Lower

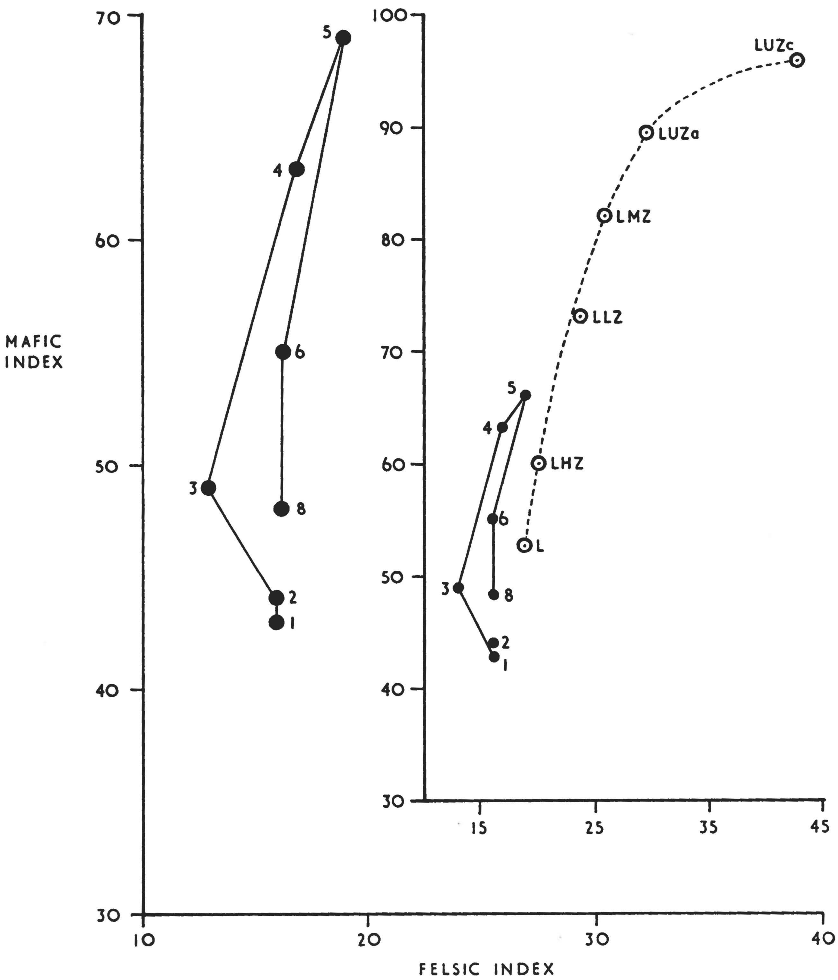


Fig. 8. Variation of the mafic and felsic indices in the cumulates of the Lower Layered Series.

(Nos. 1–8 refer to the 700, 750, 1250, 2050, 2600, 3200 and 3860 m. levels respectively). Inset shows the variation of the mafic and felsic indices of the Lower Layered Series compared with the successive stages in the trend of the liquid compositions in the Skaergaard Intrusion.

Layered Series, of hydrous phases among the products of intercumulus crystallization. Experimental studies have shown that iron enrichment is suppressed if oxygen fugacities are buffered at a sufficiently high value. Under these conditions the field of spinel is enlarged (PRESNALL, 1966), and the presence of a small amount of spinel in some of the lower cumulates is consistent with this hypothesis.

The earliest cumulates of the Lower Layered Series are not exposed and from the petrographic and chemical evidence more than one magma-

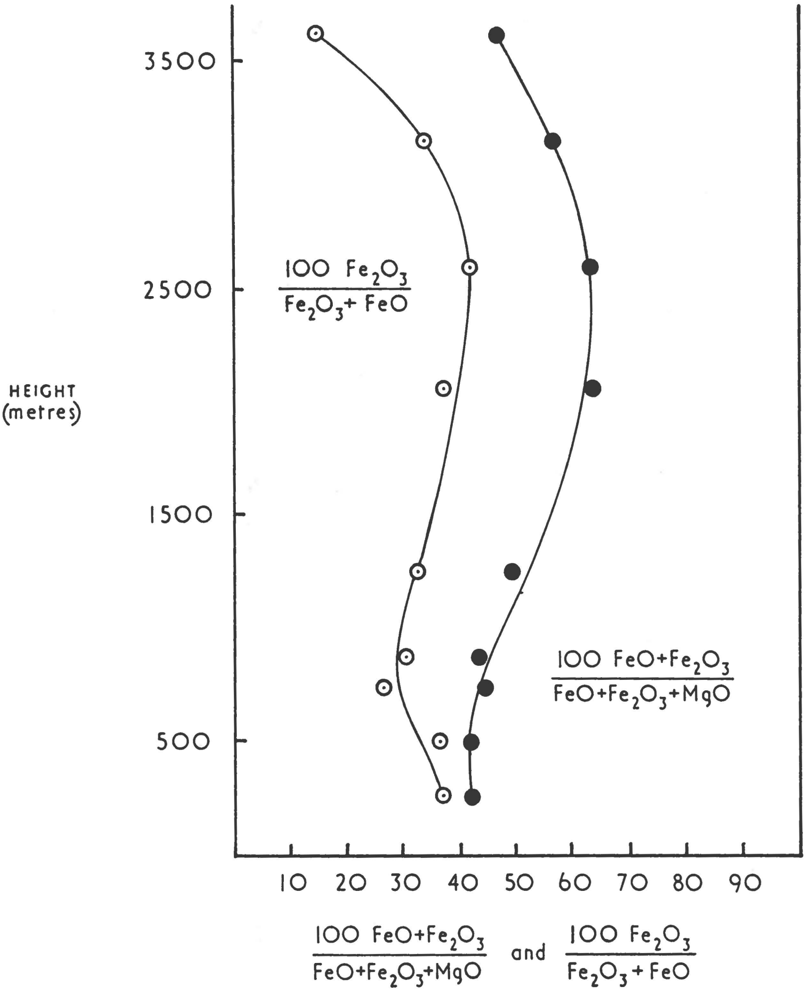


Fig. 9. Variation of the ratios $100(FeO+Fe_2O_3)/(FeO+Fe_2O_3+MgO)$ and $100\ Fe_2O_3/(Fe_2O_3+FeO)$ with height in the Lower Layered Series.

tic surge was involved in their formation. Due to this factor and the absence of marginal chilled liquid it is not possible to make a precise comparison of the Lower Layered Series liquid with the original composition of the Skaergaard magma. The latter was tholeiitic in composition and its crystallization was characterized, during the formation of the early and middle cumulates, by the formation of both clino-and orthopyroxene. An approximation to the composition of the Lower Layered Series magma, derived by taking the mean of seventeen analyses of the cumulates of the series, is shown in Table XVII. Comparison with the analysis and norm of the chilled marginal gabbro of the Skaergaard intrusion shows that the main composition difference is the ferric: ferrous iron ratio, and that normatively the Lower Layered Series cumulates

Table XVII. *Composition of the Cumulates of the Lower Layered Series and the Skaergaard Magma*

	1	2			1	2
SiO_2	47.60	48.08	Or		1.56	1.48
TiO_2	1.00	1.17	Ab		20.08	20.05
Al_2O_3	18.87	17.22	An		40.06	35.62
Fe_2O_3	2.66	1.32				
FeO	5.83	8.44	Diop.	Wo	9.48	8.43
MnO	0.09	0.16		En	6.37	5.02
MgO	7.55	8.62		Fs	2.38	2.98
CaO	12.77	11.38	Hyp.	En	2.36	4.78
Na_2O	2.37	2.37		Fs	0.88	2.85
K_2O	0.26	0.25				
H_2O^+	0.82	1.01	Oliv.	Fo	7.01	8.18
H_2O^-	0.18	0.05		Fa	2.12	5.36
P_2O_5	0.09	0.10		Mt	3.87	1.91
	100.09	100.17		Il	1.90	2.22
				Ap	0.20	0.24
$\frac{100\ (FeO+Fe_2O_3)}{(FeO+F_2O_3+M_gO)}$	53	53	Plagioclase		An_{67}	An_{64}
$\frac{100\ (Fe_2O_3)}{(Fe_2O_3+FeO)}$	31	13.5	Diopside		Wo_{52} En_{35} Fe_{13}	Wo_{51} En_{31} Fs_{18}
$\frac{100\ (Na_2O+K_2O)}{(Na_2O+K_2O+CaO)}$	17	19	Orthopyroxene		En_{73} Fs_{27}	En_{27} Fs_{37}
			Olivine		Fo_{77} Fa_{23}	Fo_{60} Fa_{40}

1 Average composition of seventeen cumulates of the Lower Layered Series.
2 Chilled marginal gabbro, Skaergaard intrusion (WAGER & BROWN, 1968).

contain a considerably small percentage of orthopyroxene. Although the two compositions are not strictly comparable they support the conclusion, based on the mineralogical characteristics of the cumulates of the two intrusions, that the Lower Layered Series magma is less tholeiitic than that of the Skaergaard, and that it has affinities with transitional alkali olivine basalt magma.

The mafic and felsic indices of the estimated composition of the Lower Layered Series magma, and that of the chilled marginal Skaergaard magma, indicate that the differentiation of the two liquids at the time of intrusion was comparable. Thus the mafic and felsic indices are 53 and 17 and 53 and 19 respectively for the initial Lower Layered Series and the Skaergaard magma. There is, however, a marked contrast in their oxidation state, *i.e.* 31 and 13.5, and it is this factor that led to the subsequent divergence of the differentiation products of the two liquids.

REFERENCES

BOWEN, N. L., & TUTTLE, O. F. 1949. The system $MgO\text{-}SiO_2\text{-}H_2O$. *Bull. Geol. Soc. Amer.*, vol. **60**, p. 439–460.

BOYD, F. R., 1959. Hydrothermal investigation of amphiboles. *Researches in Geochemistry*, Edit. P. H. ABELSON, Wiley and Sons, New York. p. 377–396.

BROWN, G. M., 1956. The layered ultrabasic rocks of Rhum, Inner Hebrides. *Phil. Trans. Roy. Soc. Lond.*, Ser. B, vol. 240, p. 1–53.

— 1957. Pyroxenes from the early and middle stages of fractionation of the Skaergaard intrusion, East Greenland. *Min. Mag.*, vol. **31**, p. 511–543.

CARR, J. M., 1954. Zoned plagioclases in layered gabbros of the Skaergaard intrusion, east Greenland. *Min. Mag.*, vol. **30**, p. 367–375.

DEER, W. A., & ABBOTT, D., 1965. Clinopyroxenes of the gabbro cumulates of the Kap Edvard Holm complex, East Greenland. *Min. Mag.*, Tilley Volume, p. 177–193.

DEER, W. A., HOWIE, R. A., & ZUSSMAN, J., 1963. *Rock Forming Minerals.* vol. **2**, Longmans, London.

ELSDON, R., 1969. The structure and intrusive mechanism of the Kap Edvard Holm layered gabbro complex, East Greenland. *Geol. Mag.*, vol. **106**, p. 45–56.

GILLERY, F. H., 1959. X-ray study of synthetic Mg-Al serpentines and chlorites. *Amer. Min.*, vol. **44**, p. 143–152.

KEMPE, D. R. C., DEER, W. A., & WAGER, L. R., 1970. Geological investigations in East Greenland Part VIII. The petrology of the Kangerdlugssuaq alkaline intrusion, East Greenland. *Meddr Grønland*, **190**, 2, p. 1–49.

KEMPE, D. R. C., & DEER, W. A., 1970. Geological investigation in East Greenland Part IX. The mineralogy of the Kangerdlugssuaq alkaline intrusion, East Greenland. *Meddr Grønland*, **190**, 3, p. 1–95.

ELSDON, R., 1971. Clinopyroxenes from the Upper Layered Series, Kap Edvard Holm, East Greenland. *Min. Mag.* Vol. 38, p, 49–57.

LEWIN, M. T., 1960. Mineralogical study of the syenites of the Kap Edvard Holm complex, East Greenland. M.sc thesis, Univ. Manchester.

MURRAY, R. J., 1954. The clinopyroxenes of the Garbh Eilean Sill, Shiant Isles, *Geol. Mag.*, vol. **91**, p. 17–31.

OSBORN, E. F., & TAIT, D. B., 1952. The system diopside-forsterite-anorthite. *Amer. Journ. Sci.*, Bowen Volume, p. 413–433.

PRESNALL, D. C., 1966. The join forsterite-diopside-iron oxide and its bearing on the crystallization of basaltic and ultramafic magmas. *Amer. Journ. Sci.*, vol. **264**, p. 753–809.

SIMPSON, E. S. W., 1954. On the graphical representation of differentiation trends in igneous rocks. *Geol. Mag.*, vol. **91**, p. 238–244.

VINCENT, E. A., and PHILLIPS, R., 1954. Iron titanium oxide minerals in layered gabbros of the Skaergaard intrusion, east Greenland, Part I. Chemistry and ore microscopy. *Geochim. cosmochim. Acta.*, vol. **6**, p. 1–26.

WADSWORTH, W. J., 1961. The layered ultrabasic rocks of southwest Rhum, Inner Hebrides. *Phil. Trans. B*, vol. **244**, p. 21–64.

WAGER, L. R., 1959. Differing powers of crystal nucleation as a factor for producing diversity in layered igneous intrusions. *Geol. Mag.*, vol. **96**, p. 75–80.

— 1965. The form and internal structure of the alkaline Kangerdlugssuaq intrusion, East Greenland. *Min. Mag.*, Tilley vol., p. 487–497.

WAGER, L. R., & DEER, W. A., 1938. A dyke swarm and crustal flexure in East Greenland. *Geol. Mag.*, vol. **75**, p. 39–46.

— — 1939. Geological investigations in East Greenland, Part III. The petrology of the Skaergaard intrusion, Kangerdlugssuaq. *Meddr Grønland.* **105**, 4, p. 1–352.

WAGER, L. R., and BROWN, G. M., 1968. Layered Igneous Rocks. Oliver and Boyd, Edinburgh.

WAGER, L. R., BROWN, G. M., & WADSWORTH, W. J., 1960. Types of igneous cumulates *Journ. Petr.*, vol. **1**, p. 73–85.

YODER, H. S., 1954. The system diopside-anorthite-water. Geophys. Lab. Carnegie Inst., Washington. *Ann. Rep.* 1953–54. p. 106–107.

YODER, H. S., and TILLEY, C. E., 1962. Origin of basalt magmas: An experimental study of natural and synthetic rock systems. *Journ. Petr.*, vol. **3**, 342–532.

VAN ZYL, C., 1959. An outline of the geology of the Kapalagulu complex. Kungwe Bay, Tanganyika Territory, and aspects of the evolution of layering in basic intrusions. *Trans. Geol. Soc. S. Africa*, vol. **62**, p. 1–30.

Færdig fra trykkeriet den 30. december 1971.

PLATES

Plate 1

Fig. 1. Northern part of the Kap Edvard Holm complex from the southeast. Air photograph by H. G. WATKINS, August 1930.

Fig. 2. Kap Deichmann Syenite (bottom right) and Hutchinson Gletscher Syenites I and II. (Centre) Part of the lower layered series of the Kap Edvard Holm complex from the east. Air photograph by H. G. WATKINS. August 1930.

Fig. 1.

Fig. 2.

Plate 2

Fig. 1. Western end of Kontaktbjerg showing contact between the marginal gabbro and the metamorphic complex. Lower Zone B-type cumulates overlie the marginal gabbro in the top left hand of the photograph.

Fig. 2. Contact of Lower Zone A cumulates with Hutchinson Gletscher Syenite I.

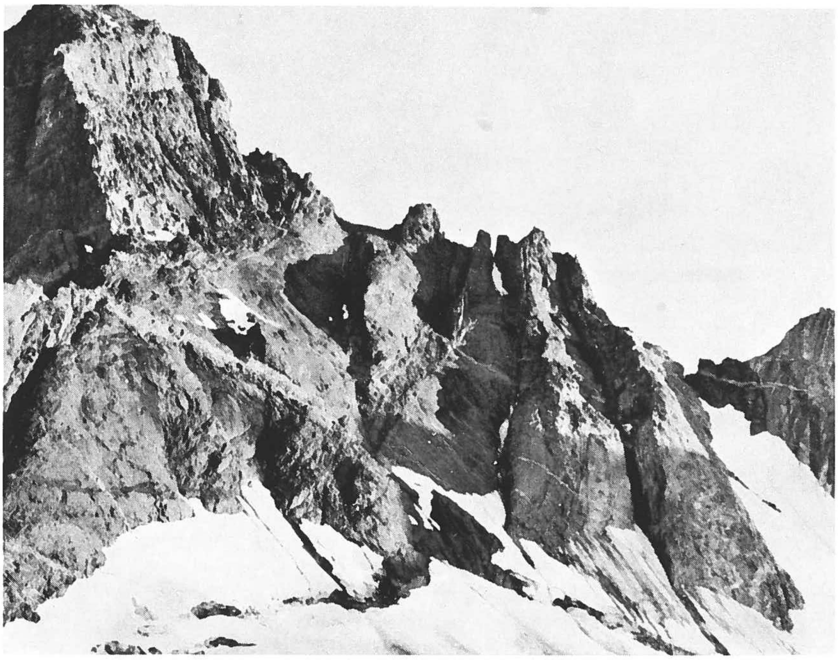


Fig. 1.

Fig. 2.

Plate 3

Fig. 1. Lower Zone A cumulates. South of Hutchinson Gletscher Syenite I and II. Note prominent feldspar-rich band in upper middle section of the photograph.

Fig. 2. Lower Zone B cumulates extensively veined by the quartz-syenite of the zone of igneous breccia, north face of Kontaktbjerg.

Fig. 1.

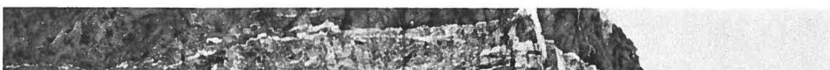


Fig. 2.

Plate 4

Fig. 1. Lower Zone A rhythmic banding. South of contact with Hutchinson Gletscher Syenite I.

Fig. 2. Lower Zone A rhythmic banding, showing development of prominent feldspar-rich band. South of Hutchinson Gletscher Syenite I.

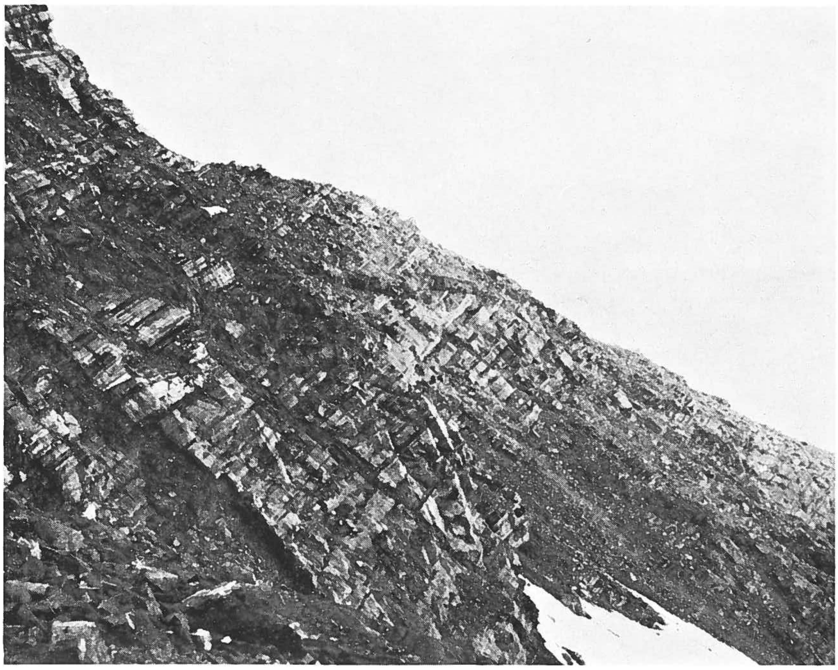


Fig. 1.

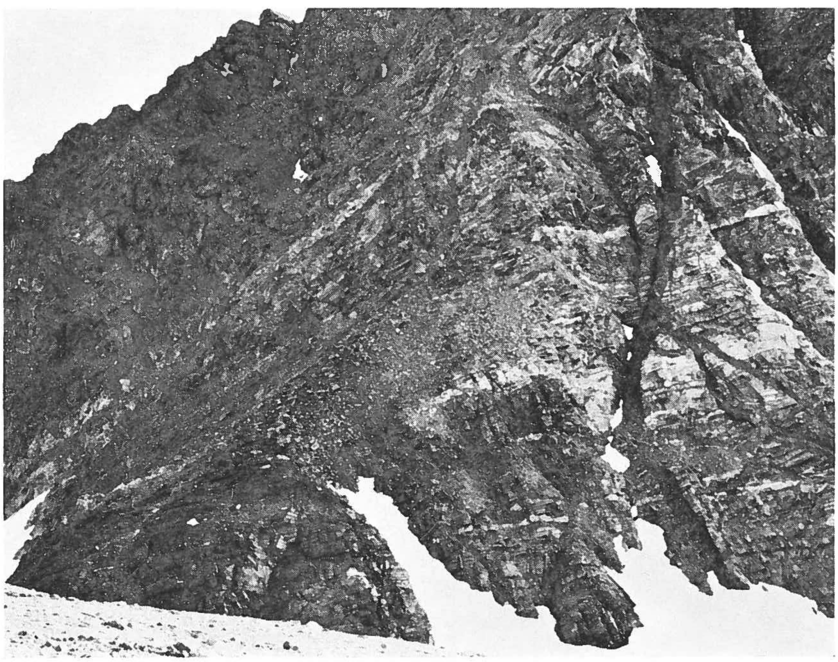


Fig. 2.

Plate 5

Fig. 1. Lower Zone B, large scale rhythmic banding. Individual bands vary in thickness between 6 and 10 m. Height of the ridge is approximately 350 m. Ridge west of Hutchinson Gletscher Syenite I.

Fig. 2. Lower Zone B, small scale rhythmic banding. Ridge west of Hutchinson Gletscher Syenite I.

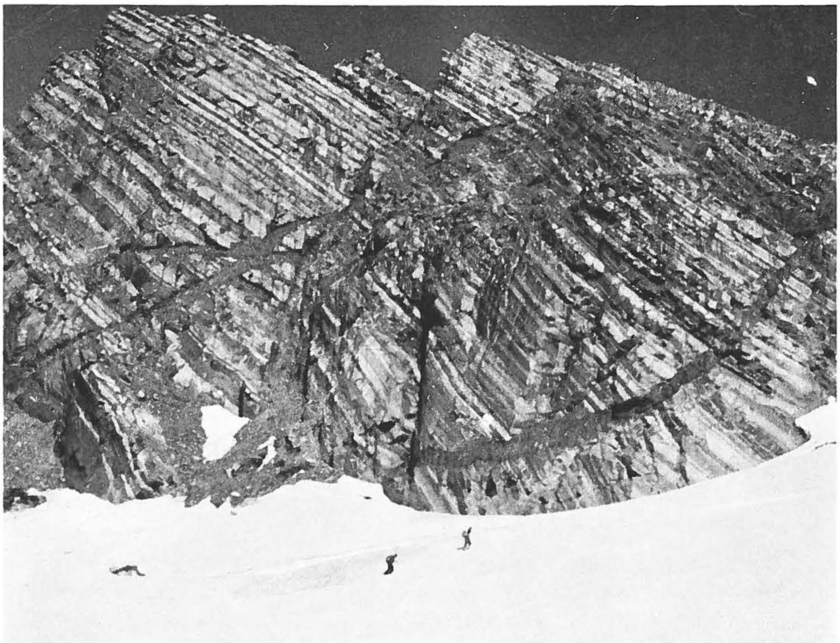


Fig. 1.

Fig. 2.

Plate 6

Fig. 1. Lower Zone A, plagioclase-augite-olivine-orthocumulate (E.G. 6067), height 500 m. Note elongated olivine and larger plagioclase laths aligned subparallel to the igneous lamination. Ridge south of Hutchinson Gletscher Syenite I. Crossed polarisers, x 25.

Fig. 2. Lower Zone A, plagioclase-augite-olivine orthocumulate (E.G. 6067), height 500 m. Note large olivine crystals showing some intercumulus growth, and smaller augite in matrix of small plagioclase laths. Ridge south of Hutchinson Gletscher Syenite I. Plane polarized light. x 25.

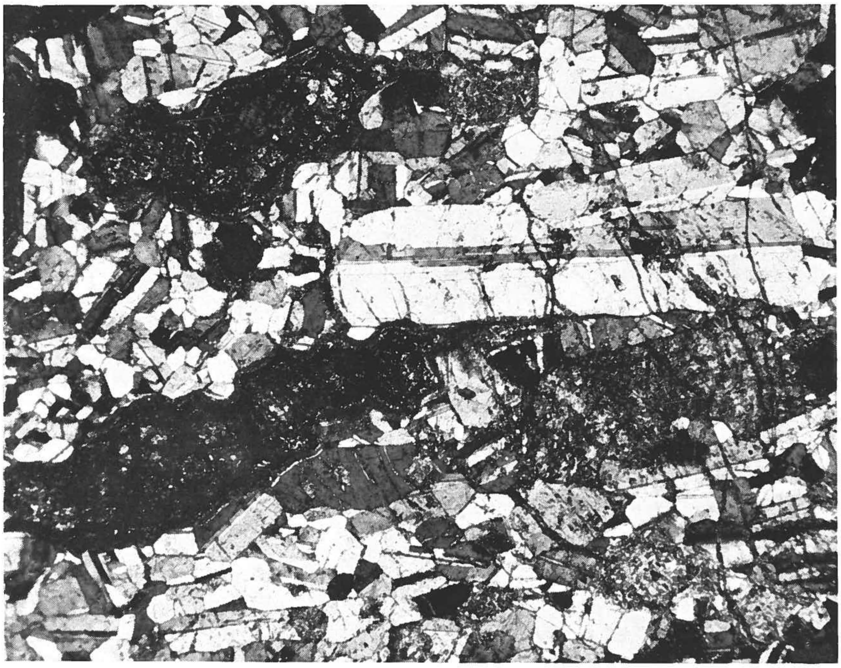


Fig. 1.

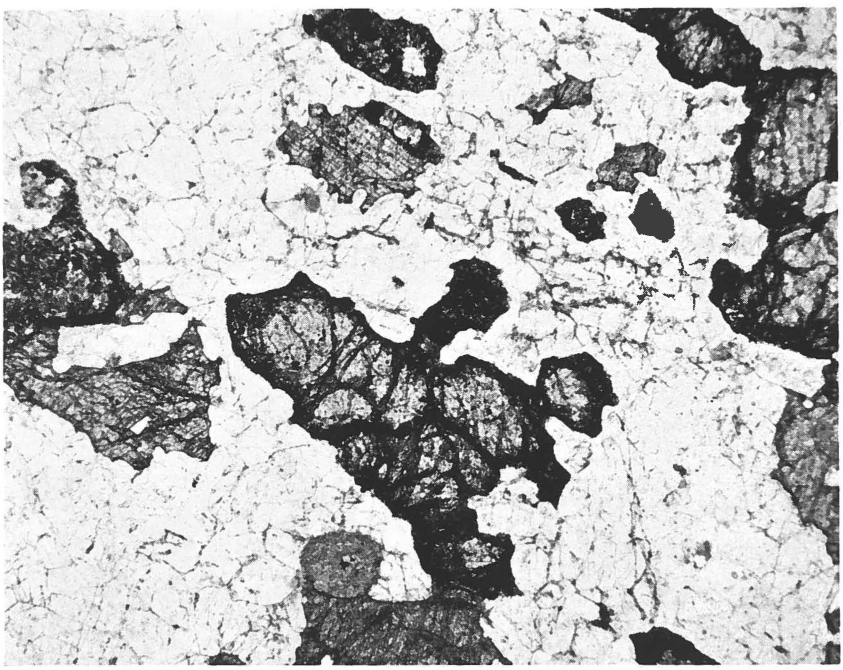


Fig. 2.

Plate 7

Fig. 1. Lower Zone A, feldspar adcumulate (E.G. 6070), height 600 m. Note large plagioclase enclosed in matrix of smaller plagioclase laths. Ridge south of Hutchinson Gletscher Syenite I. Crossed polarizers, x 25.

Fig. 2. Lower Zone B, plagioclase-augite-olivine orthocumulate (E.G. 5637) height 750 m. Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

Fig. 1.

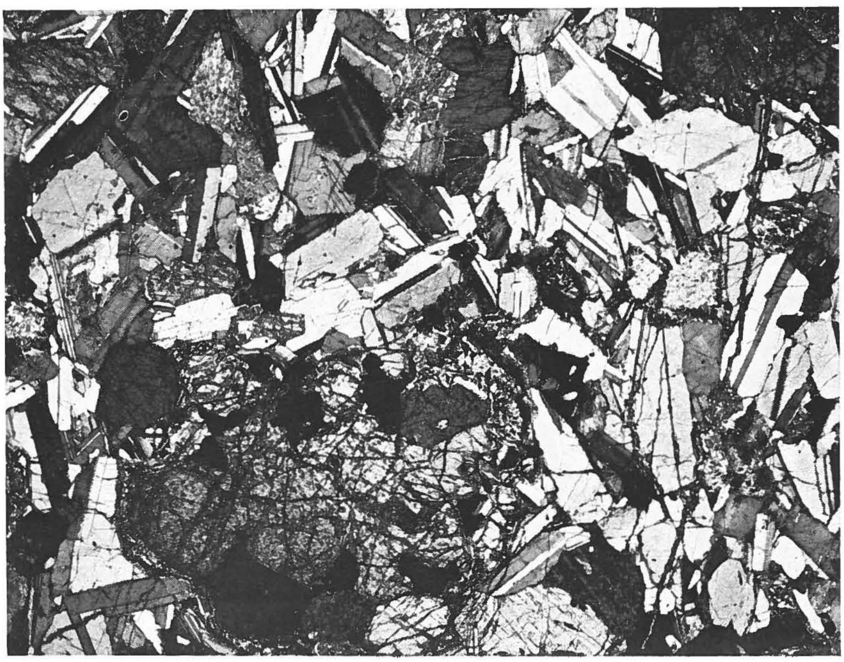


Fig. 2.

Plate 8

Fig. 1. Lower Zone B, plagioclase-augite-olivine orthocumulate. More ferromagnesian-rich band adjacent to E.G. 6537 (note sub-alignment of plagioclase laths). Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

Fig. 2. Lower Zone B, plagioclase-augite-olivine orthocumulate (E.G. 6520), height 1750 m. Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

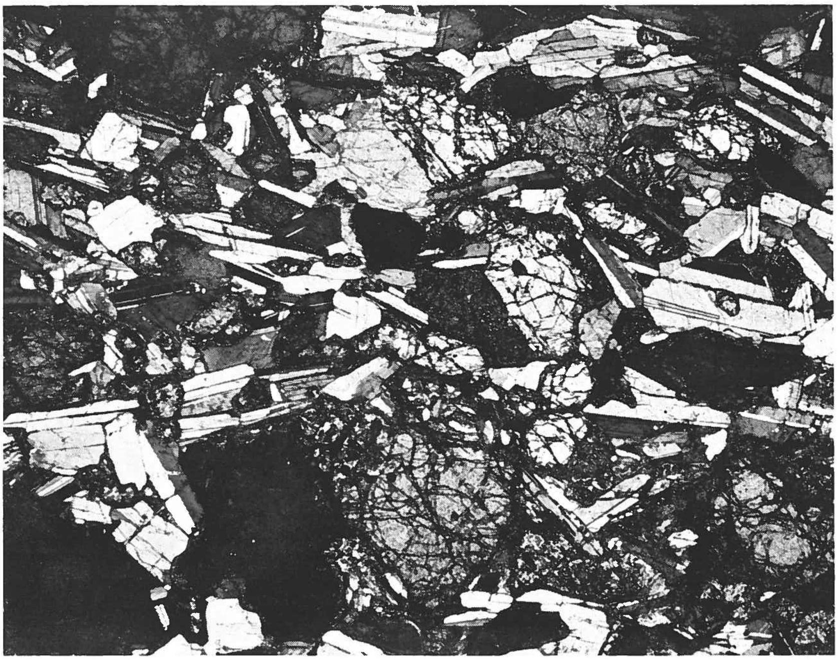


Fig. 1.

Fig. 2.

Plate 9

Fig. 1. Lower Zone B, plagioclase-augite-olivine orthocumulate (E.G. 6517) height 2050 m. Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

Fig. 2. Lower Zone B, plagioclase-augite-olivine orthocumulate (E.G. 3997) height 3850 m. Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

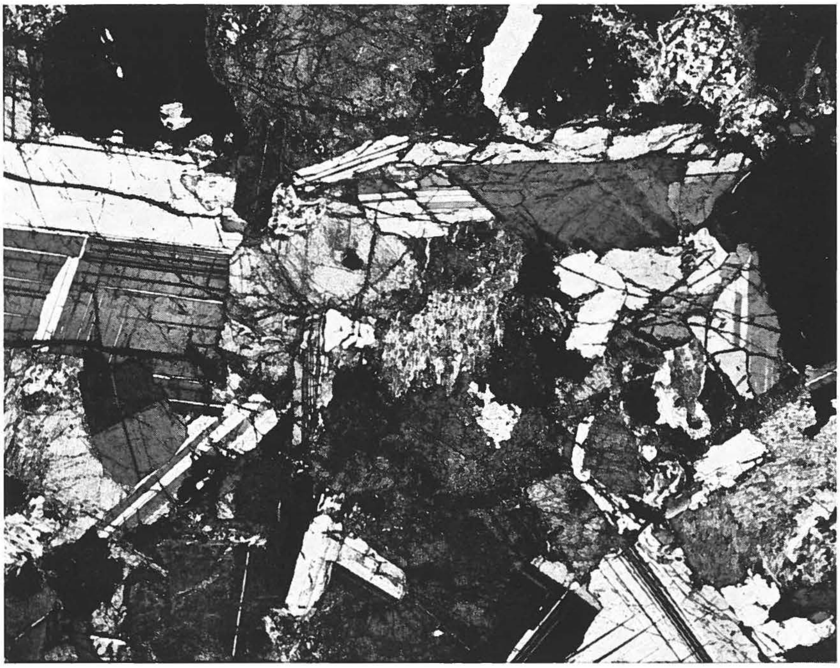


Fig. 1.

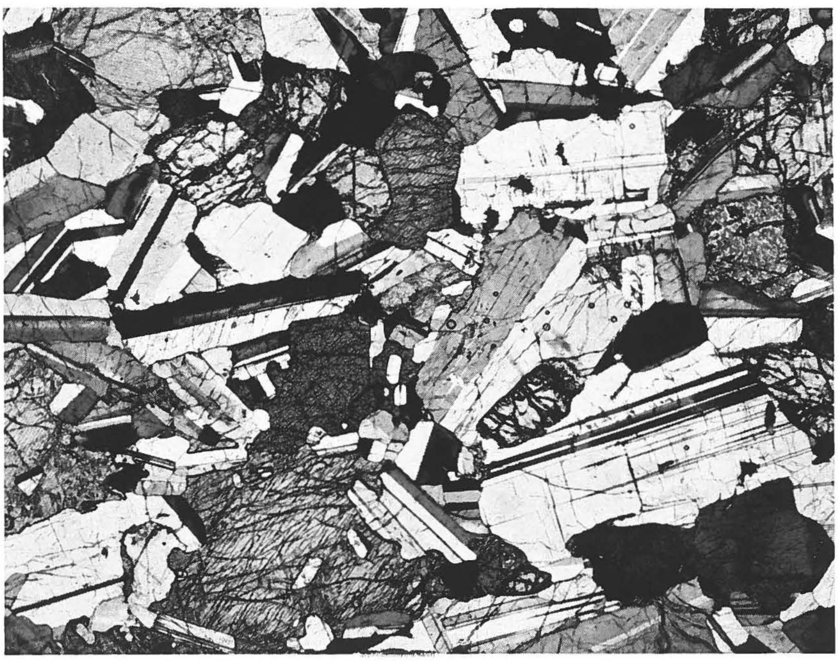


Fig. 2.

Plate 10

Fig. 1. Lower Zone A, ferromagnesian-rich cumulate (E.G. 3967) height 450 m. Crossed polarizers, x 12.

Fig. 2. Lower Zone B, ferromagnesian-rich cumulate (E.G. 6534) height 1000 m. Ridge west of Hutchinson Gletscher Syenite I. Crossed polarizers, x 12.

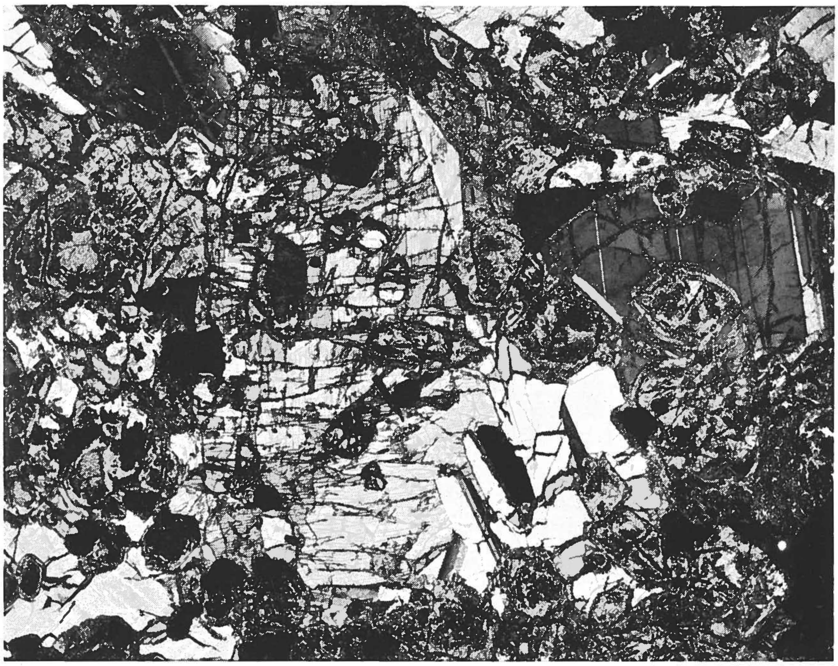
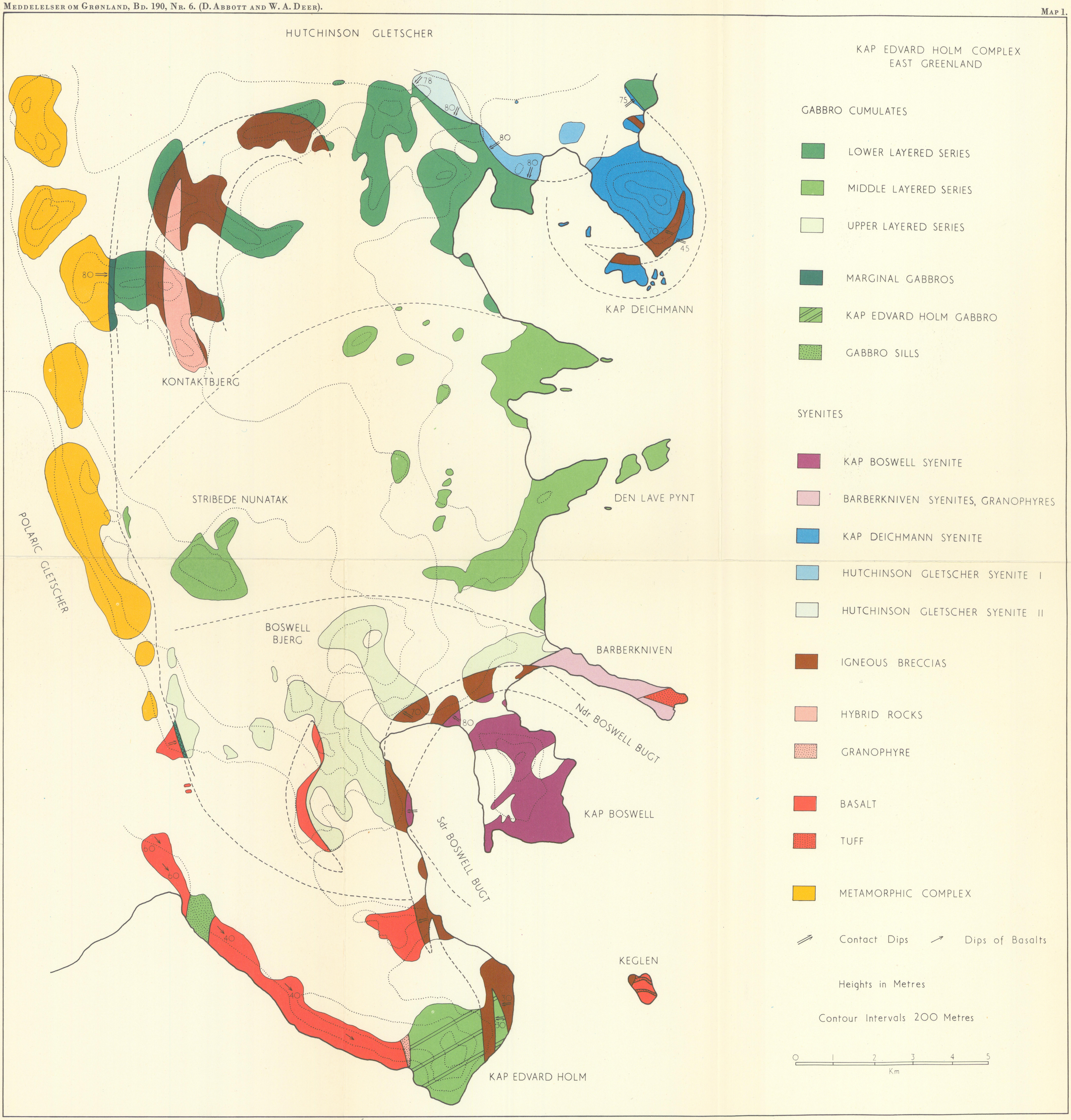


Fig. 1.

Fig. 2.


KAP EDVARD HOLM COMPLEX
EAST GREENLAND
GABBRO CUMULATES
LOWER LAYERED SERIES
MIDDLE LAYERED SERIES
UPPER LAYERED SERIES
MARGINAL GABBROS
KAP EDVARD HOLM GABBRO
GABBRO SILLS
SYENITES
KAP BOSWELL SYENITE
BARBERKNIVEN SYENITES, GRANOPHYRES
KAP DEICHMANN SYENITE
HUTCHINSON GLETSCHER SYENITE I
HUTCHINSON GLETSCHER SYENITE II
IGNEOUS BRECCIAS
HYBRID ROCKS
GRANOPHYRE
BASALT
TUFF
METAMORPHIC COMPLEX
Contact Dips
Dips of Basalts
Heights in Metres
Contour Intervals 200 Metres
0 1 2 3 4 5
Km
HUTCHINSON GLETSCHER
KAP DEICHMANN
KONTAKTBJERG
STRIBEDE NUNATAK
DEN LAVE PYNT
POLARIC GLETSCHER
BOSWELL BJERG
BARBERKNIVEN
Ndr BOSWELL BUGT
KAP BOSWELL
Sdr BOSWELL BUGT
KEGLEN
KAP EDVARD HOLM