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CHEMICAL PETROLOGY OF TERTIARY FLOOD BASALTS FROM THE SCORESBY SUND AREA

BY

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WITH ELECTRON PROBE ANALYSES BY
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WITH 13 FIGURES AND 7 TABLES IN THE TEXT,
2 APPENDICES AND 2 PLATES

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

Sequences of basalts have been sampled in a number of profiles in the upper part of the basalt plateau of Kong Christian IX's Land. The flows are faulted and tilted near the coast but apparently undisturbed inland. Nowhere in the investigated area were intrusives found, but sediments and pyroclastic horizons (including a palagonitic brecceia) were observed in a few localities. The bulk of the flows are subacrial. These basalts are seen under the microscope to be typical tholeiites, being made up of plagioclase (labradorite), clinopyroxene and opaque oxides. Olivine may be present occasionally and pigeonite sporadically. The glassy breccia contains two types of glass (fresh and hydrated) with olivine and plagioclase microphenocrysts. Chemically the lavas form an extremely homogeneous group and have with one exception quartz and hypersthene in the norm. The fact that this one exception is the most reduced of the analyses suggests that the appearance of normative quartz may be secondary and that the magmas originally were olivine-hypersthene normative. Specific chemical characteristics of these lavas include high iron and TiO_2 contents, and low K_2O. They differ from the Skaergaard magma in that they are not high-alumina types and they do not have such a high magnesium content. Comparisons have been drawn with ocean-floor tholeiites and tholeiites from other regions of the North Atlantic province, and although systematic geographic differences may exist in this province they are minor, with better data than available at present being required to confirm them.

A large number of mineral analyses, especially of pyroxenes, has been carried out by electron microprobe. The pyroxenes show extensive variation both of a normal fractional crystallization type and various "quench" trends towards sub-calcic augites although certain observations do not favour the interpretation of these trends as being due to metastable crystallization. The feldspars show relatively restricted variation in spite of the complex zoning shown by many of the phenocrysts. Coexisting oxide phases give, in general, values of PO_2 and temperature similar to that found by other workers although some samples have suffered reequilibration and are anomalous. Interstitial glass has undergone hydration and does not appear to have the composition of a late differentiate.

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PREFACE

The Oxford University Expedition to East Greenland (1965) was carried out at the suggestion of the late Professor L. R. Wager who had long regarded a detailed investigation of the Tertiary flood basalts of this area as an important task but had himself been prevented from this by his other researches, notably on the Skaergaard and Kangerdlugssuaq intrusions, which have formed the subjects for some of the earlier publications in this series. We gratefully acknowledge his inspiration and encouragement together with his permission to draw on an unpublished manuscript devoted to the geomorphology of this part of Greenland. We also thank our three colleagues of the expedition, especially D. C. Rex who collaborated in earlier investigations on the collection, and R. J. Norris who made many of the observations recorded in figure 3. Lastly, we thank the various organizations, which have been listed earlier (Rucklidge & Brooks, 1966), whose financial support made the expedition possible.

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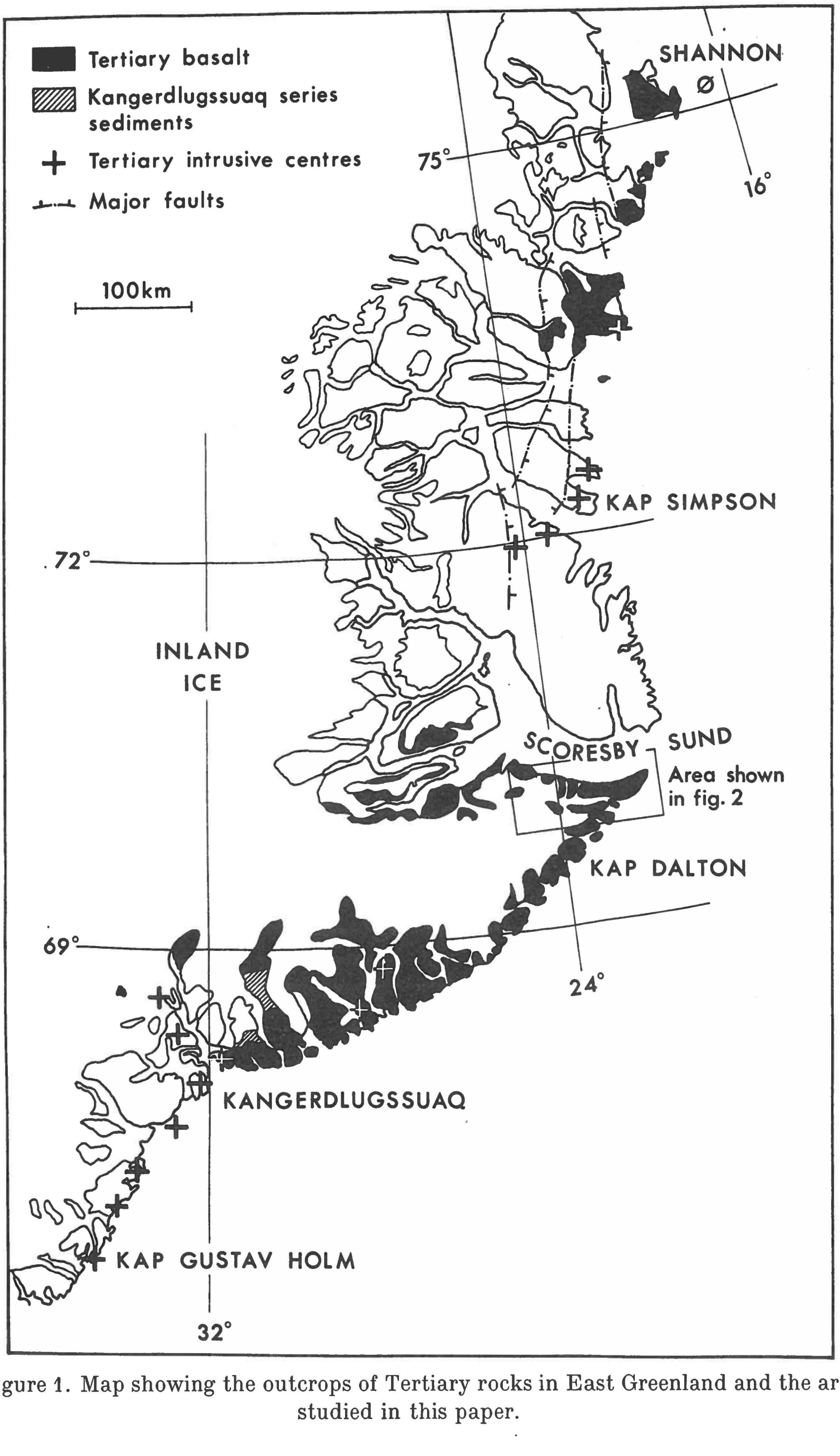

Figure 1. Map showing the outcrops of Tertiary rocks in East Greenland and the area studied in this paper.

INTRODUCTION

The six man expedition from Oxford University which visited the south side of Scoresby Sund, East Greenland in the summer of 1965 had as its task the description and sampling of the succession of flood basalts which covers almost all the land along the ca. 500 km coast between Scoresby Sund and Kangerdlugssuaq (figure 1). The presence of basalts in this area was first reported by SCORESBY (1823) but apart from relatively brief descriptions (HOLMES, 1918; WAGER, 1934, 1947; WATT & WATT, 1971) the area remained relatively unknown until recently. The Oxford Expedition, which has been described by RUCKLIDGE & BROOKS (1966) and FAWCETT, RUCKLIDGE & BROOKS (1966), resulted in a large collection from the northern part of this extensive basalt area on which palaeomagnetic measurements (TARLING, 1967) and K-Ar age determinations (BECKINSALE, BROOKS & REX, 1970) have already been published. Glaciological observations have also been reported by RUCKLIDGE (1966). The present paper describes field relations and discusses the chemistry of the lava flows and their constituent minerals. The great extent of the lava field should, however, be borne in mind and the results given here, which refer only to the northern part and the top of the sequence, cannot be safely extrapolated to the entire area which stretches hundreds of kilometers to the south and is as much as 7 km in thickness.

There is relatively little information available on compositional variations in the vast flood basalt accumulations throughout the world. Although they are commonly regarded as tholeiitic basalts, exhibiting only limited variations in composition throughout the lava pile, the data to support this supposition are surprisingly scarce. The Columbia River and Snake River plateau lavas are described by WATERS (1961) and the Deccan accumulation by WASHINGTON (1922) and WEST (1958).

The North Atlantic Tertiary region has provided chemical and mineralogical data that proved to be the basis of most discussions of the petrogenesis of basic igneous rocks between 1924 and 1960 (for a summary see TURNER & VERHOOGEN, 1960, p. 221 *et seq.*). Such data were acquired largely from sills, dykes and plutonic bodies with only a small proportion related directly to the lava flows. In parts of the Hebridean region extensive alteration of lava flows place severe restrictions on any interpretation of chemical data obtained from the majority of lava flows (Fawcett, 1965). Tilley & Muir (1962) have given an analysls of an unaltered flow from Mull but many of the earlier analyses appear to have been carried out on altered material. The data of Patterson (1952) and Patterson & Swaine (1955) on Antrim basalts and Anderson & Dunham (1966) on Skye may be combined to give a picture of the gross variations within the lava accumulations of the Scottish area. More recently data have been reported for carefully controlled material from the Small Isles of Inverness-shire (Ridley, 1971). F. Walker & Davidson (1936), Rasmussen & Noe-Nygaard (1969, 1970) and Noe-Nygaard & Rasmussen (1968) have discussed data from the Faeroes while a considerable amount of scattered information exists for Icelandic lavas which has, in part, been summarized by Jakobsson (1972). Apart from Clarke's (1970) work on the lavas of Svartenhuk, West Greenland and Cape Dyer, Baffin Island, the more westerly segment of the North Atlantic Province is not well-represented in terms of petrographic and analytical data. Relations in Greenland with special reference to distribution of magma types and their connections with the events in the opening history of the North Atlantic have been discussed by Brooks (1972). In East Greenland analyses from widely scattered localities have been presented by Backlund & Malmquist (1932), Katz (1952) Wager (1934, 1935), Wager & Deer (1939), Krokström (1944) and by Haller (1956). However, as Wenk (1961a) states "Little is known about the petrographic succession of the lavas". From the limited amount of data available it is certain that there are considerable variations in the composition of volcanic rocks in East Greenland. Tholeiitic basalts are described from Kong Christian IX's Land by Wager (1934, 1947) and Wager & Deer (1939) but more alkalic varieties appear to occur in the upper part of the sequence in the vicinity of the Prinsen af Wales Bjerge (Anwar, 1955). Highly undersaturated lavas were discovered in Hobbs Land by Katz (1952) that are similar to some of the pebbles discovered in the sediments of Kap Dalton by Wager (1935). There is no evidence of any alkaline basaltic rocks in the area visited by this expedition. A number of boulders found in Bopladsdalen at Kap Brewster may have been derived from an undersaturated magma but there are no clues as to the location of the parent body. This paper provides new data on the petrographic, chemical and mineralogical features of the upper part of the succession in Kong Christian IX's Land to be viewed in conjunction with the K-Ar age studies (Beckinsale *et al.*, 1970) and palaeomagnetic observations (Tarling, 1967) which were carried out on the same collection.

FIELD OBSERVATIONS

Samples were mainly collected from a series of traverses on the sides of nunataks located on the north side of Torvgletscher. In addition further sampling was carried out near the edge of the icecap, on the west side of Kamelgletscher and in the vicinity of the expedition base camp at Bopladsdalen (figure 2). A brief account of the field relations was presented in an earlier paper (Fawcett, Rucklidge & Brooks, 1966).

The lava flows are virtually horizontal over most of the area examined but towards the east, between Roma Gletscher and Kap Brewster dips of up to 18° were observed, generally towards the Denmark Strait, but in a few places with a northerly component (figure 3).

The area is also cut by a number of faults, very few of which were directly observed. The area consists largely of isolated nunataks which rise to the maximum height of about 2000 m represented by the level of the snow-covered plateau inland and it was difficult to make good correlations between the various vertical sections measured owing to the absence of good marker horizons. However, in a number of cases distinctive groups of flows or prominent columnar flows could be used as such and disclosed the presence of faults in narrow gulleys or ice-filled valleys along the north side of Torvgletscher. Only in a few cases was it possible to determine the relative movement on the faults and the minimum displacement was then found to range between 70 and 500 m. All observed and inferred faults are shown in figure 3 where it can be seen that they lie in two directions: ENE-WSW, or approximately parallel to the coast of the Denmark Strait, and WNW-SSW or approximately at right angles to this. Just as the dips increase in magnitude on approaching the coast so the faults increase in number in the same direction. This impression is supported by the lack of reports of faulting in the more westerly basalt exposures in Milne Land and Gåseland (Watt & Watt, 1971). The coast-parallel faults are normal faults generally down-throwing on the coastal side, but with isolated cases of downthrow the other way being recorded. The cumulative south-eastward downthrow appears to be considerable. The structure is thus one of block faulting which is concentrated in the coastal regions, apparently dying-out inland. It therefore contrasts with the structure of the coast in the Kangerdlugssuaq region

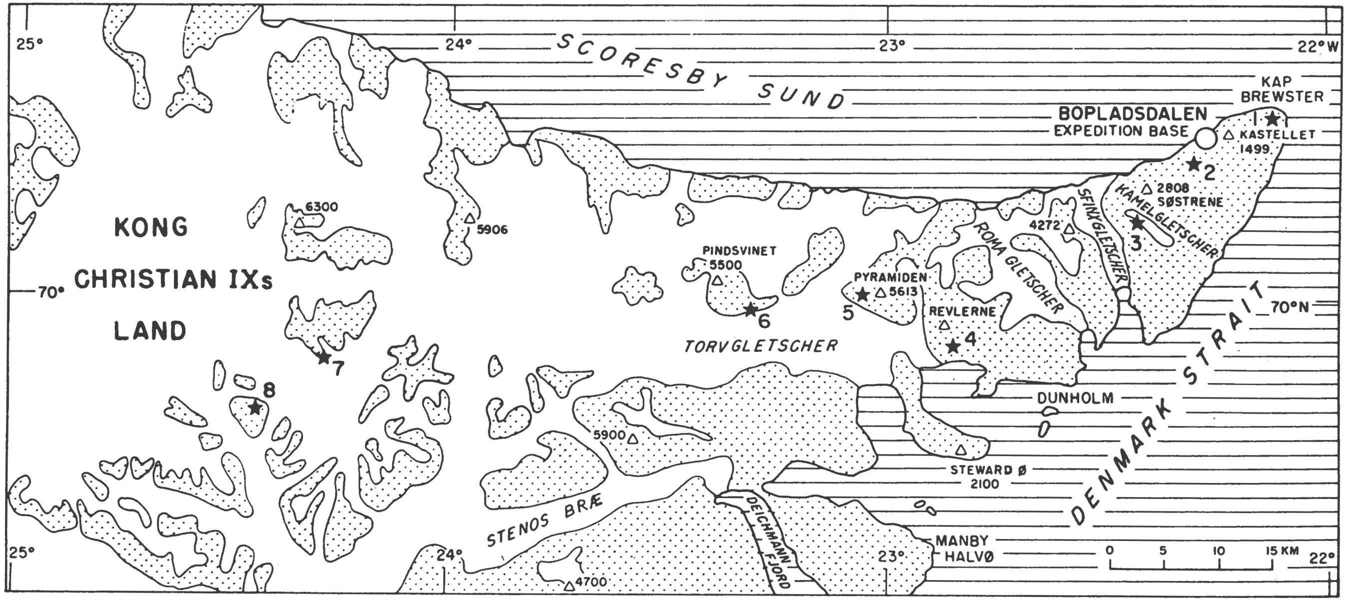

Figure 2. Map showing the area in which specimens were collected. The dotted areas are rock and the white areas are ice-covered. Collections were made at each of the eight localities indicated by stars. For the distribution of sample numbers between the numbered localities see table 1.

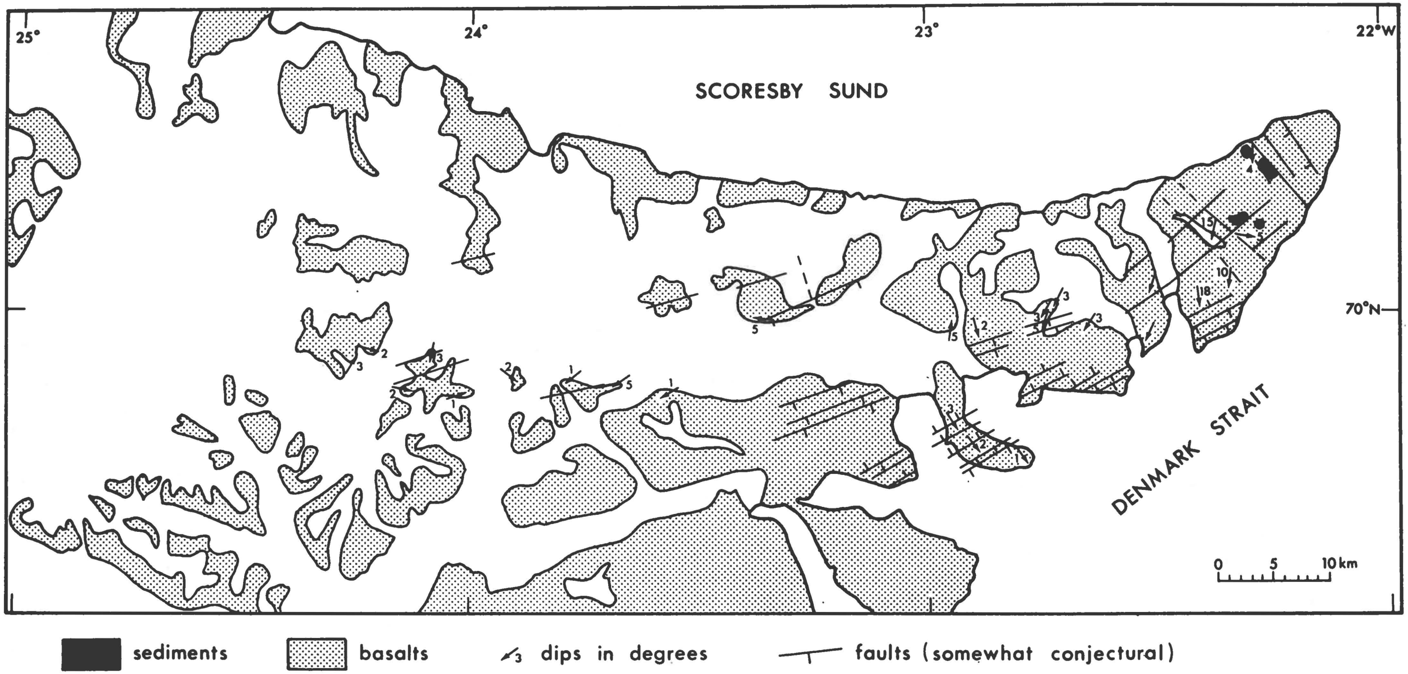

Figure 3. Map covering the same area as figure 2 showing faults and dips in the lavas together with the localities in which sediments were observed.

to the south where WAGER (1947) has described a flexure associated with little faulting. WAGER (1935) has however described similar faulting at Kap Dalton, much closer to the area described in this investigation, which has preserved a small area of sedimentary rocks in the same way as those at Kap Brewster. Each set of samples collected at the locations shown in figure 2 has been treated as an independent series of flows but, owing to the lack of detailed correlation between these localities, it is possible that some traverses overlap. It is perhaps significant that all the lavas from this collection whose palaeomagnetic properties were measured (TARLING, 1967) proved to be reversely magnetized, while WATT & WATT (1971) using a primitive field method found some normally magnetized horizons in the Gåseland and Milne Land successions.

The majority of flows show the typical three-fold vertical division of vesicular base, massive, often columnar central part and vesicular top which is generally of the blocky or aa type. Whenever possible, samples were collected from the centres of the massive zones. Occasional red soil horizons are usually less than 2 feet thick and indicate a subaerial environment. However, marine fossil-bearing, sedimentary horizons are intercalated with the lava flows in the Kap Brewster area (HASSAN, 1953) and a single occurrence of pillow lava was encountered at an elevation of 220 m on the traverse at Muslingehjørnet. One carbonaceous sedimentary horizon was found at an elevation of 130 m on the Kap Brewster traverse and similar material occurs on Pindsvinet at an elevation of 1380 m. Silicified wood is relatively common on the nunataks north of Torvgletscher, but was not seen in place. Pyroclastics are easily missed as they tend to weather readily to a slope of fine gravelly material in the same way as the vesicular flow tops, but coarse volcanic breccia was observed in the stream bed in Bopladsdalen and thin flaggy tuffs are present between the flows at heights of about 1400 and 1300 m on Pindsvinet and Pyramiden respectively. A prominent gravelly scree at an approximate height of 1000 m on the west shoulder of Pyramiden proved to be a hyaloclastic horizon.

There is a striking absence of any type of intrusive rock in the area covered, especially when compared to the intense dyke and sill swarms reported from other parts of East Greenland (WAGER, 1947). Dykes have also been reported in Milne Land and Gåseland by WENK (1961b) and WATT & WATT (1971) and become numerous to the south on Turner Ø (WATT, personal communication).

The general aspect of the area is shown in plate 1, which shows the faulted and dipping basalts in the coastal area, and plate 2, which shows the dissected, undisturbed plateau of the inland areas, whose upper surface is believed to be very close to that of the original surface.

Table 1. *Relation of sample numbers to the localities shown on figure 2.*

Locality number:	Field number designation[1])	Specimen numbers[2]):
1	K	EG 7147 to EG 7160B
2	M	EG 7183 to EG 7206
3	WK	EG 7165 to EG 7182
4	E	EG 7122 to EG 7136B
5	A	EG 7108 to EG 7120
6	D	EG 7094 to EG 7105
7 and 8	HL	EG 7208 to EG 7220

[1]) as used by TARLING (1967).
[2]) L. R. WAGER collection, Oxford.
All profiles are numbered successively from the base up.

The sample numbers used earlier (TARLING, 1967) are the field numbers and consist of a letter designating the traverse together with the number in that traverse. Their relation to the collection numbers used in this paper are shown in table 1. Samples are housed in the L. R. WAGER Collection at Oxford University, and duplicates in the Moorhouse Collection at the University of Toronto where analysed powders and the polished thin sections used for electron-probe analyses are also located.

PETROGRAPHY

The great majority of lava flows were sampled at only one location, frequently with only a single hand specimen. In one instance, however, a single flow was sampled at fourteen separate locations to test for possible variations within the flow. This flow in the Kap Brewster section, was about 54 m thick and all but one of the fourteen samples were collected at various heights in the massive central layer of the flow. As the thin sections showed no significant variations other than grain size the single specimen collected from other lava flows is considered to be typical of the entire flow. The K-Ar age studies (BECKINSALE *et al.*, 1970) have, however, shown considerable systematic vertical variations in the retentivity for Ar within this flow while recent studies of intra-flow variations by WATKINS, GUNN & COY-YLL (1970) and HART, GUNN & WATKINS (1971) place some restrictions on the interpretation of single samples from lava flows.

The lava flows examined in thin section are typically aphyric, but occasional flows contain phenocrysts of plagioclase up to 5 mm long which may be clustered into star- or rosette-shaped glomeroporphyritic aggregates. The general impression gained in field work is that plagioclase-porphyritic varieties are more common in the upper parts of the main traverses. These phenocrysts are zoned in a complex manner but, as will be shown later, the compositional range of the zoning is fairly small. The maximum grain size of feldspars in the groundmass is 0.2–0.3 mm long and about .02 mm wide. Groundmass feldspar is usually euhedral to subhedral consisting of three or four albite twin lamellae. Normal progressive zoning is present in all feldspar crystals but optical determinations on a flat stage suggest it is entirely within the labradorite compositional range.

Only one type of pyroxene was ever detected in each thin section during the routine thin section examinations. It is a colourless clinopyroxene with variable 2V, suggesting a range of composition in the augite to subcalcic augite range. This was later confirmed by electron probe analyses. There is a range of textures in the pyroxenes, varying from subhedral granular crystals to subophitic plates in some of the sporadic microphenocrysts. Grain sizes show a similar range to the plagioclase feldspar crystals.

Fresh olivine is not a common constituent of the lavas but pseudomorphs of serpentine or "iddingsite" (GAY & LE MAITRE, 1961) form up to about 5% of some sections. Magnetite and ilmenite are present in subhedral crystals in the groundmass and many flows have a very fine grained interstitial matrix. This often has the appearance of "quench" products formed during rapid cooling of the lava flow. Zeolites are usually confined to the upper vesicular layer of the flows where, together with calcite and quartz, they often completely fill the amygdales. Identification of the zeolites by X-ray diffraction techniques showed the presence of stilbite, phillipsite, mesolite, chabazite, thomsonite, heulandite, wairakite and mordenite. There is an indication of vertical zoning in the zeolite assemblages as discussed by WALKER (1960) in Eastern Iceland but the faulting in the area prevents accurate correlation of the various traverses. It is probably significant, however, that the flows at the top of the stratigraphic column contained no zeolites in the amygdales. The topography suggests that these samples (localities 7 and 8, figure 2) were collected from the top flows of the total lava accumulation. This provides a further analogy with the lavas of Eastern Iceland.

ROCK ANALYSES

Samples collected on a traverse at locality 4 on figure 2 gave the greatest single vertical thickness of flows encountered in the area (970 m—17 distinct flows). Each of these samples was analysed together with 32 lava flows from other traverses in the area.

Chemical analyses shown in table 2 and 3 were carried out by three different techniques. The first 32 analyses table 2 (group 1) were carried out by Mrs. D. DVORAK and Mr. C. PARRISSIS, under the supervision of Professor J. C. VAN LOON using atomic absorption techniques, in the Department of Geology, University of Toronto. Analyses 33 to 37 (group 2) were carried out by classical techniques at Loomis Laboratories Ltd, California. Analyses in table 3 (group 3) were completed by Miss E. L. GASPARRINI on glasses prepared by fusing rock powders (RUCKLIDGE, GIBB, FAWCETT & GASPARRINI, 1970) though ferrous iron was determined independently. C. I. P. W. norms in table 2 were calculated by computer with a program written by WENBAN-SMITH (1966). Table 3 does not show norms as the values for H_2O^+ are not available and results would not be comparable with those of table 2.

A comparison of the analyses (recalculated to 100 % water free) made by the three different methods shows significant differences in TiO_2 (average for group 1 analyses: 1.74, for group 2: 2.95 and for group 3: 2.84), and K_2O (group 1: 0.25, group 2: 0.42 and group 3: 0.18). Our latest experience with control analyses indicates that the TiO_2 values of the group 1 analyses may be low. Part of these differences may be due to real differences in the samples, but it is apparent from table 2 that there is poor duplication in certain cases between the various methods of analysis.

With these reservations in mind a number of interesting points are revealed by the analyses: Firstly, the total range of each constituent determined is rather small (i.e. SiO_2: 46.16 % to 49.60 %, Al_2O_3: 12.30 % to 14.97 %), suggesting that all lavas have had a similar origin and low pressure fractionation processes have been limited.

Secondly, oxidation state is one of the most striking features of the table 2 analyses. With the exception of number 35 all analyses in tables 2 and 3 show high values for Fe_2O_3 as well as, in many instances, high

Table 2. *Chemical analyses of rock samples.*

	1	2	3	4	5	6	7	8	9
EG number	7122	7123	7124	7125	7126	7127	7128	7129	7130
SiO_2	48.20	48.00	48.50	49.20	49.20	49.00	48.60	48.40	48.50
TiO_2	2.01	1.65	1.58	1.97	1.78	1.42	1.30	1.47	1.20
Al_2O_3	13.00	13.20	13.60	13.20	13.00	13.90	13.20	13.60	13.20
Fe_2O_3	7.25	5.08	5.80	5.40	5.95	5.48	5.31	5.94	7.41
FeO	8.23	8.66	8.00	8.76	8.85	7.74	8.22	7.88	6.61
MnO	0.20	0.18	0.19	0.20	0.20	0.18	0.20	0.19	0.18
MgO	5.86	7.08	7.00	6.67	6.43	7.28	6.90	7.03	7.08
CaO	10.50	11.30	11.40	11.20	10.50	11.10	11.30	11.40	11.50
Na_2O	2.30	2.15	2.09	2.20	2.32	2.18	2.17	2.14	2.16
K_2O	0.12	0.15	0.15	0.13	0.20	0.19	0.19	0.18	0.17
H_2O^+	2.01	2.08	1.20	0.80	0.91	1.27	2.46	1.24	1.41
P_2O_5	0.33	0.26	0.20	0.19	0.23	0.21	0.22	0.24	0.27
Total	100.01	99.79	99.71	99.92	99.57	99.95	100.07	99.71	99.69
CIPW weight norm									
Q	6.69	2.80	4.04	4.70	5.16	3.79	3.56	3.68	5.23
Or	0.71	0.89	0.89	0.77	1.18	1.12	1.12	1.06	1.00
Ab	19.46	18.19	17.68	18.61	19.63	18.44	18.36	18.10	18.27
An	24.78	15.91	27.27	25.75	24.46	27.57	25.71	26.96	25.81
Wo } Di	10.55	11.93	11.74	11.99	10.96	10.96	12.13	11.76	12.37
En } Di	6.87	7.32	7.57	7.36	6.66	7.17	7.48	7.63	8.95
Fs } Di	2.90	3.87	3.32	3.87	3.64	2.96	3.89	3.26	2.22
En } Hy	7.73	10.31	9.86	9.25	9.35	10.96	9.70	9.87	8.68
Fs } Hy	3.27	5.44	4.32	4.86	5.12	4.52	5.04	4.22	2.15
Fo } Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa } Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt	10.51	7.37	8.41	7.83	8.63	7.95	7.70	8.61	10.74
Il	3.82	3.14	3.01	3.75	3.39	2.70	2.47	2.80	2.28
Ap	0.79	0.62	0.48	0.46	0.55	0.50	0.53	0.58	0.65

(continued)

Table 2 (cont.)

		10	11	12	13	14	15	16	17	18
EG number		7131	7132	7133	7134	7135 A	7135 B	7136 A	7136 B	7195
SiO_2		49.60	48.60	48.70	48.70	48.30	49.20	48.80	48.40	47.76
TiO_2		1.27	1.62	1.97	1.71	1.92	1.63	2.14	2.08	2.10
Al_2O_3		13.30	12.90	12.30	13.20	12.50	12.60	12.50	13.60	14.25
Fe_2O_3		5.38	6.24	5.65	5.26	7.01	5.03	5.94	3.92	8.48
FeO		7.44	8.75	10.46	9.39	9.56	9.82	9.62	10.16	5.57
MnO		0.17	0.20	0.22	0.20	0.29	0.20	0.21	0.18	0.16
MgO		7.01	6.56	5.75	6.35	5.47	6.30	6.16	6.39	6.03
CaO		11.60	10.90	10.30	10.60	10.20	11.10	10.30	10.60	11.42
Na_2O		2.00	2.31	2.37	2.53	2.27	2.30	2.52	2.54	2.07
K_2O		0.09	0.20	0.30	0.29	0.18	0.16	0.26	0.19	0.23
H_2O^+		1.24	1.18	1.30	1.12	1.45	1.18	1.03	1.22	1.78
P_2O_5		0.16	0.30	0.28	0.32	0.34	0.32	0.32	0.41	0.2
Total		99.26	99.76	99.60	99.68	99.49	99.84	99.80	99.69	100.05
CIPW weight norm										
Q		5.75	4.22	4.48	2.62	6.61	4.03	4.26	1.57	7.64
Or		0.53	1.18	1.77	1.71	1.06	0.95	1.54	1.12	1.36
Ab		16.92	19.54	20.05	21.40	19.20	19.46	21.32	21.49	17.51
An		27.04	24.23	22.03	23.80	23.38	23.57	22.02	25.14	28.90
Wo	Di	12.36	11.70	11.43	11.20	10.49	12.33	11.32	10.39	11.09
En		8.03	7.19	6.06	6.41	5.98	6.80	6.60	5.63	9.52
Fs		3.42	3.78	4.95	4.24	4.00	5.01	4.13	4.35	0.03
En	Hy	9.42	9.15	8.26	9.40	7.64	8.89	8.74	10.29	5.49
Fs		4.01	4.82	6.74	6.21	5.12	6.54	5.48	7.96	0.02
Fo	Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt		7.80	9.05	8.19	7.63	10.16	7.29	8.61	5.68	12.30
Il		2.42	3.08	3.75	3.25	3.65	3.10	4.07	3.96	3.99
Ap		0.38	0.72	0.67	0.77	0.81	0.77	0.77	0.98	0.48

(continued)

Table 2 (cont.)

	19	20	21	22	23	24	25	26	27
EG number	7196	7197	7159	7160 A	7160 B	7161	7162	7165	7166
SiO_2	49.25	48.72	47.24	48.23	47.33	47.63	46.14	47.86	47.00
TiO_2	2.09	1.98	2.08	1.74	1.88	2.36	2.36	1.85	1.76
Al_2O_3	13.88	13.35	13.64	14.90	14 76	13 65	12.52	13.65	14.75
Fe_2O_3	7.08	7.45	6.06	7.65	7.41	8.21	8.32	5.60	5.45
FeO	5.66	5.95	8.05	6.03	5.82	7.24	8.16	8.26	7.28
MnO	0.15	0.16	0.51	0.17	0.25	0.28	0.20	0.19	0.18
MgO	6.43	7.44	6.23	5.88	6.60	5.49	6.63	7.05	7.45
CaO	11.20	11.03	11.33	10.93	11.83	11.09	10.46	11.10	11.16
Na_2O	2.28	2.48	2.19	2.32	2.14	2.28	2.23	2.22	2.28
K_2O	0.24	0.29	0.12	0.23	0.12	0.16	0.33	0.49	0.30
H_2O^+	1.37	1.11	1.11	1.40	1.37	1.34	1.40	1.09	1.33
P_2O_5	0.19	0.20	0.18	0.20	0.22	0.21	0.18	0.21	0.14
Total	99.82	100.16	99.59	99.68	99.73	99.94	99.06	99.57	99.08
CIPW weight norm									
Q	7.32	4.47	3.73	6.29	4.81	6.84	3.99	1.83	0.58
Or	1.42	1.71	0.71	1.36	0.71	0.95	1.95	2.90	1.77
Ab	19.29	20.98	18.53	19.63	18.10	19.29	18.87	18.78	19.29
An	26.92	24.43	27.02	29.55	30.30	26.53	23.17	25.82	29.12
Wo	11.50	12.16	11.75	9.80	11.31	11.38	11.56	11.69	10.63
En Di	9.29	9.74	7.45	8.93	8.93	8.34	8.21	7.51	7.27
Fs	0.79	0.94	3.49	1.13	1.04	1.91	2.28	3.35	2.46
En Hy	6.73	8.78	8.06	7.07	7.50	5.34	8.30	10.05	11.28
Fs	0.57	0.85	3.78	1.06	0.88	1.22	2.30	4.48	3.83
Fo Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt	10.27	10.80	8.79	11.09	10.74	11.90	12.06	8.12	7.90
Il	3.98	3.77	3.96	3.31	3.58	4.49	4.49	3.52	3.35
Ap	0.46	0.48	0.43	0.48	0.53	0.50	0.43	0.50	0.34

(continued)

Table 2 (cont.)

	28	29	30	31	32	33	34	35	36	37
EG number	7167	7214	7216	7218	7220	7108	7112	7113	7133	7136 B
SiO_2	48.07	48.81	48.81	48.43	48.19	48.53	47.69	47.29	47.25	46.91
TiO_2	1.59	1.42	1.31	0.89	0.75	2.25	2.56	3.23	3.21	3.41
Al_2O_3	14.97	12.95	13.45	14.46	13.49	14.16	13.71	14.75	13.49	14.89
Fe_2O_3	5.76	7.73	7.85	6.65	9.41	5.46	4.73	1.91	4.23	3.79
FeO	7.28	8.01	7.18	6.10	6.48	7.96	9.10	10.94	11.20	9.45
MnO	0.16	0.22	0.20	0.17	0.21	0.22	0.22	0.20	0.25	0.21
MgO	6.57	6.43	6.82	6.88	6.81	5.93	6.69	6.45	5.30	6.19
CaO	11.65	9.95	10.05	11.32	10.57	11.42	11.26	10.91	10.23	10.92
Na_2O	2.31	2.35	2.20	2.06	2.35	2.39	2.24	2.52	2.52	2.41
K_2O	0.13	0.53	0.46	0.57	0.54	0.48	0.38	0.43	0.45	0.37
H_2O^+	1.03	0.87	1.22	1.80	0.90	0.59	1.04	0.80	1.15	0.90
P_2O_5	0.10	0.18	0.15	0.20	0.13	0.25	0.23	0.32	0.32	0.35
Total	99.62	99.45	99.03	99.37	99.83	99.64	99.85	99.75	99.60	99.80
CIPW weight norm										
Q	2.65	5.21	5.14	3.94	4.35	3.25	1.74	0.00	1.67	0.69
Or	0.77	3.13	2.72	3.37	3.19	2.84	2.25	2.54	2.66	2.19
Ab	19.54	19.88	18.61	17.43	19.88	20.22	18.95	21.32	21.32	20.39
An	30.08	23.21	25.46	28.51	24.66	26.48	26.22	27.65	24.16	28.71
Wo	11.35	10.48	9.83	11.05	11.30	11.97	11.78	10.23	10.31	9.75
En Di	7.56	6.92	6.93	7.91	8.48	7.62	7.19	5.36	5.20	5.79
Fs	2.90	2.76	2.00	2.10	1.64	3.52	3.87	4.52	4.81	3.42
En Hy	8.80	9.10	10.05	9.23	8.48	7.14	9.48	6.62	8.00	9.62
Fs	3.38	3.63	2.90	2.45	1.64	3.30	5.11	5.59	7.40	5.68
Fo Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.66	0.00	0.00
Mt	8.35	11.21	11.38	9.64	13.64	7.92	6.86	2.77	6.13	5.50
Il	3.02	2.70	2.49	1.69	1.43	4.28	4.87	6.14	6.11	6.35
Ap	0.24	0.43	0.36	0.48	0.31	0.60	0.58	0.77	0.74	0.81

Table 3. *Chemical analyses of rock samples by electron microprobe.*

	1	2	3	4	5	6	7
EG number	7183	7184	7185	7186	7187	7188	7189
SiO_2	50.33	49.66	50.67	49.76	50.66	50.30	50.99
TiO_2	2.39	2.54	2.61	2.52	2.54	2.45	2.45
Al_2O_3	15.54	14.75	14.57	14.24	14.50	14.75	15.16
Fe_2O_3	5.24	5.53	6.09	3.98	4.77	6.23	5.42
FeO	6.07	5.78	5.01	5.76	5.31	5.72	5.68
MnO	0.15	0.18	0.20	0.23	0.17	0.19	0.17
MgO	7.20	6.56	6.43	7.33	6.47	7.66	7.09
CaO	10.69	13.20	12.72	13.86	12.25	11.33	12.44
Na_2O	1.96	2.32	2.16	2.14	2.25	2.07	2.16
K_2O	0.21	0.14	0.14	0.14	0.14	0.13	0.15
Total	99.98	100.66	100.60	100.96	99.06	100.83	101.71

	8	9	10	11	12	13	14
EG number	7190	7191	7192	7193	7194	7118 (a)	7118 (b)
SiO_2	51.01	50.13	49.36	50.09	51.03	47.38	45.03
TiO_2	3.71	3.63	3.57	2.89	2.79	3.76	5.66
Al_2O_3	14.08	14.37	13.72	14.60	15.21	13.31	11.73
Fe_2O_3	3.78	5.82	6.07	5.90			
FeO	8.84	7.85	7.51	6.28	11.09	13.75	7.83
MnO	0.23	0.25	0.19	0.17	0.17	0.26	0.14
MgO	6.01	6.12	5.69	6.82	6.66	6.21	2.53
CaO	10.96	10.74	11.14	11.24	11.83	11.21	10.74
Na_2O	2.54	2.47	2.69	2.43	2.49	2.74	0.06
K_2O	0.23	0.25	0.26	0.17	0.20	0.46	0.29
Total	101.39	101.63	100.20	100.59	101.46	98.96	84.00

Analyses 13 and 14 of basaltic glass from locality 5. No. 13 is of fresh, brown glass and no. 14 of orange, hydrated glass.

Table 4. *Recalculation of the olivine tholeiite analysis (EG 7113) to show the effect of secondary oxidation on the normative composition.*

	1		2	
SiO_2	47,29		–	
TiO_2	3.23		–	
Al_2O_3	14.75		–	
Fe_2O_3	1.91		5.22	
FeO	10.94		7.90	
MnO	0.20		–	
MgO	6.45		–	
CaO	10.91		–	
Na_2O	2.52		–	
K_2O	0.43		–	
H_2O+	0.80		–	
P_2O_5	0.32		–	
Q	–		1.32	
Or	2.54	51.51	2.54	51.51
Ab	21.32		21.32	
An	27.65		27.65	
Wo	10.32	20.20	10.32	18.56
En	5.36		6.00	
Fs	4.52		2.24	
En	6.62	12.21	9.90	12.94
Fs	5.59		3.04	
Fo	2.86	5.52	–	–
Fa	2.66		–	
Mt	2.77		7.66	
Il	6.14		6.14	
Ap	0.77		0.77	

Column 1: Analysis of EG 7113 reproduced from table 2, with $Fe_2O_3/FeO = 0.17$.
Column 2: Analysis of EG 7113 with Fe_2O_3/FeO recalculated to an arbitrary value of 0.66, i.e. similar to that found in the other samples.

values for total iron. Undoubtedly this oxidation results in the appearance of high percentage of quartz in the norms (up to 5.64 %). In contrast, the only analysis with a low Fe_2O_3 value (number 35) has hypersthene and olivine in the norm but, of course, no quartz. The effect of a hypothetical oxidation on the norm of analysis 35 is shown in table 4 where the analysis and norm are reproduced together with an arbitrary set of new values for FeO and Fe_2O_3. The increase in Fe_2O_3 from 1.90 % to 5.22 % and consequent decrease in FeO from 10.89 to 7.90 % results in the removal of 5.5 % olivine from the norm and the appearance of 1.32 % quartz together with changes in the normative pyroxene and magnetite. Consequently, although the oxidation of the lavas has undoubtedly exaggerated the tholeiitic characteristics of the norms, the evidence of analysis 35 suggests that the primary composition, before oxidation was definitely tholeiitic.

Thirdly, the East Greenland basalts are low in K_2O (ca. 0.2 $^0/_0$ as compared to 0.8 $^0/_0$ for the average quartz basalt by Manson, 1967) as well as being high in total iron as mentioned above. It also appears that they are TiO_2 rich. These characteristics are shared with certain other rocks from the North Atlantic area, namely those of the Greenland-Iceland-Faeroes-Scotland aseismic ridge system. The compositions of basaltic rocks from this area have been discussed and compared with basalt compositions from the mid-ocean rift system by Noe-Nygaard (1966) who attempted to show, on the basis of very sparse data, that a difference existed. These results, which compare closely with those recently obtained for basalts of N. W. Iceland by J. Bailey (personal communication), confirm Noe-Nygaard's suggestions and give further support to the suggestion of Brooks (1972) that volcanic rocks in this belt, which were generated during a prolonged period of ocean-floor spreading in a region of abnormal heat-flow, might be expected to show chemical characteristics diagnostic of an unusual temperature-pressure regime.

Table 5. *Comparative analyses of other basalts from Kong Christian IX's Land.*

	1	2	3	4	5	6
SiO_2	47.89	47.61	48.89	47.26	47.81	48.08
TiO_2	1.74	1.58	2.64	2.69	2.51	1.17
Al_2O_3	14.36	10.92	13.60	14.17	13.64	17.22
Fe_2O_3	1.63	3.80	4.72	4.68	4.50	1.32
FeO	10.14	7.25	9.65	8.32	8.84	8.44
MnO	0.19	0.19	0.24	0.19	0.22	0.16
MgO	7.28	13.49	4.54	6.65	6.51	8.62
CaO	10.51	8.07	10.09	10.64	11.29	11.38
Na_2O	3.01	2.74	2.74	2.30	2.54	2.37
K_2O	0.22	0.10	0.30	0.81	0.35	0.25
H_2O^+	2.76	3.62	1.38	1.45	0.76	1.01
H_2O^-	0.10	0.58	0.14	0.90	1.26	0.05
P_2O_5	0.18	0.17	0.39	0.23	0.24	0.10

1. EG 383: altered variolitic basalt, Kangerdlugssuaq area
2. EG 1519: altered olivine basalt, Kangerdlugssuaq area
3. EG 1057: tholeiitic basalt, Kap Dalton
4. EG 1093: olivine basalt, Barclay Bugt
5. EG 1112: olivine basalt, Kap Daussy
6. EG 4507: Skaergaard chilled margin

Analyses 1–5 Wager & Deer (1939)
6 Wager & Brown (1968)

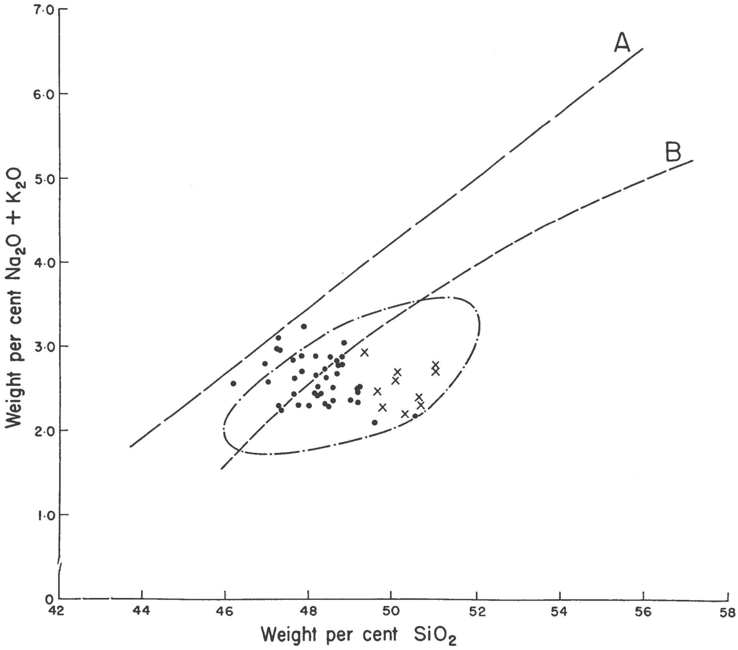

Figure 4. Plot of total alkalis against silica for the new analyses in tables 1 and 2. Solid circles are the complete analyses of table 1 and x symbols are for analyses in table 2 that show only the composition of the anhydrous glass made from the rock powder. All constitutents in these latter analyses are consequently somewhat higher than analyses showing H_2O^+ values. The dashed line A was shown by MACDONALD & KATSURA (1964) as separating the fields of alkali and tholeiitic basalts and the line B is the tholeiitic trend of Thingmuli volcano (CARMICHAEL, 1964).

Table 5 shows the available earlier analyses of basalts from Kong Christian IX's Land which conform in general to those analyses reported here. Analyses 1 and 2 (table 5) are described as altered, and may therefore not be reliable, but analysis 2 is considerably more MgO-rich than any of the new analyses. Also shown in table 5 is the preferred value for the Skaergaard intrusion initial liquid from the analysis of chill sample EG 4507. It is immediately apparent that no sample of extrusive rock from this area has been reported which approaches the high Al_2O_3 content of this rock. As remarked by WAGER & BROWN (1968), this rock is also unusually reduced; it has a Fe_2O_3/FeO ratio appreciably lower than the most reduced sample (EG 7113) of the present study. Further, but less striking, differences include lower iron and TiO_2 together with higher MgO in the Skaergaard analysis. In view of the importance of the Skaergaard intrusion, it will be of interest in further work to see to what extent this composition is represented in the area.

Figure 4 shows the distribution of analyses on TILLEY's (1950) total alkalis/SiO_2 plot. The line A is MACDONALD & KATSURA's (1964) dividing

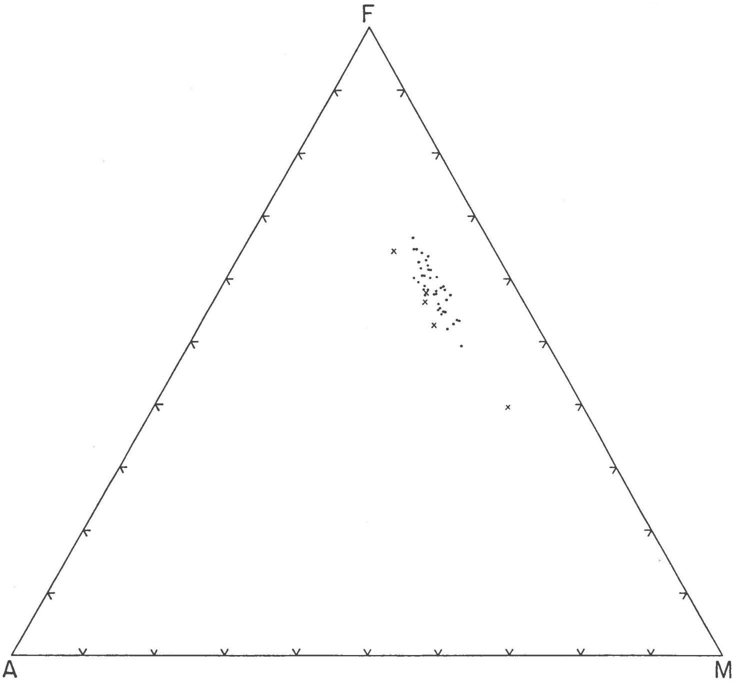

Figure 5. A-F-M plot of the analyses of tables 1 and 2 (solid circles) Crossed symbols are the analyses of East Greenland basalts presented by WAGER & DEER (1939).

line between the fields of alkali and tholeiitic basalts. The line B is the trend of tholeiitic differentiation in Thingmuli volcano, Iceland (CARMICHAEL, 1964). The area encircled by the dashed line includes the major concentration of Hawaiian tholeiites (MACDONALD & KATSURA, 1964).

All analyses are clearly tholeiitic although there is a considerable variation in the degree of tholeiitic affinity.

The range of SiO_2 content from 46 to over 49.5 % suggests some degree of differentiation in the magma chamber. This view is reinforced by the spread of points on the AFM diagram of figure 5. The trend is consistent with the normal trends expected from the differentiation of tholeiitic magma.

There are no significant trends of oxide variation with respect to position in the stratigraphic column. This contrasts with the work of WATKINS & GUNN (1969) on the Tertiary lavas from Oregon.

One specimen (EG 7118, locality 4, figure 2) consisting largely of glass, was collected at an elevation of about 1100 m. It consists of pale brown glass that is rimmed by orange/yellow glass at the contact with cracks and vesicles. About 20 % of the section consists of small subhedral plagioclase laths and subhedral olivine crystals; pyroxene is completely absent. Electron probe analyses of the brown and orange/yellow glasses are given in table 3, analyses 13 and 14 respectively. The balance of the analyses totals can be assumed to consist almost exclusively of H_2O for both analyses. No significant variations are visible between the analysis of the brown (and presumably fresh) glass and the whole rock analyses of tables 2 and 3 and it plots within the fields of the whole rock analyses in figures 4 and 5. Clearly precipitation of plagioclase (An_{88}) and olivine (Fo_{75}) and minor opaque phases has been in such proportions that there is little significant change in the composition of the remaining liquid but the possible significance of these phases is discussed below. The analysis of the orange glass (table 3, anal. 14) shows that the major change is one of hydration (judging by the totals, an increase from ca. 1 % H_2O to ca. 16 % H_2O) but other significant redistributions of oxides have also taken place. This is particularly noticeable in the removal of Na_2O, MgO and iron and the concentration of TiO_2 (presumably the reason for the distinctive colour). In a study of a basaltic glass which had been hydrated from 1 % H_2O to 8 % H_2O, MUFFLER, SHORT, KEITH & SMITH (1969) noted a slight increase in TiO_2 and pronounced decreases in iron, MgO and CaO with only a minor decrease in Na_2O. In general, however, the patterns of change are similar.

Comparisons with other areas

In the fjord district lying to the north of Scoresby Sund scattered outcrops of Tertiary tholeiitic basalts occur for which a number of older analyses are available. An average for 6 of these recalculated to 100 % water-free is given in column 2 of table 6 and may be compared with column 1, which is the average, similarly recalculated, for analyses 1–37 in table 2 of this paper. Significant differences exist for TiO_2, K_2O and P_2O_5 as well as in oxidation state but in view of the age of the analyses averaged in column 2 it is doubtful if any great significance should be attached to these differences. It should also be noted that a number of these samples were taken from the abundant minor intrusives of the region and are designated as dolerites rather than basalts.

Of the other analyses in table 6, from other areas of the North Atlantic Province, the similarities are striking and many of the differences may well be accounted for by experimental errors. It appears that in West Greenland more picritic compositions occur which cannot be matched by any samples from the Scoresby Sund area. The Antrim and Northern England tholeiites are both higher in SiO_2 and K_2O and lower in total iron; differences which may perhaps be explained by their position, relatively far removed from the continental margin. Contamination seems more likely than differentiation due to their low iron contents but of course these differences may also be connected with differences at the

Table 6. *Average compositions of some tholeiites from other areas, compared to the Scoresby Sund average.*

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	49.0	48.8	49.3	48.0	54.5	51.7	49.9	48.6	47.4	52.0	49.0
TiO_2	1.9	2.9	2.3	1.5	1.1	1.4	2.2	2.9	1.3	1.6	1.7
Al_2O_3	13.8	12.7	14.5	13.2	14.9	14.3	14.3	12.8	14.8	16.5	15.6
Fe_2O_3	6.2	3.2	4.4	3.0	2.8	3.5	4.1	7.6	4.1	3.2	2.6
FeO	8.2	10.7	8.1	8.2	6.7	8.6	10.2	8.3	8.6	7.4	8.8
MnO	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2
MgO	6.6	6.4	5.9	11.5	5.9	5.9	5.8	5.9	9.5	5.6	8.5
CaO	11.1	11.6	12.0	11.9	10.3	10.3	9.7	10.4	11.8	9.9	10.4
Na_2O	2.3	2.3	2.6	2.1	2.3	2.7	2.3	2.4	1.8	2.5	2.3
K_2O	0.3	0.7	0.4	0.3	1.3	0.9	0.9	0.4	0.3	0.8	0.6
P_2O_5	0.2	0.5	0.3	0.2	0.1	0.3	0.3	–	–	0.2	0.2

1. Average of analyses 1–37 in table 2.
2. Average of tholeiitic basalt analyses from the areas north of Scoresby Sund comprising the following:
   Krokström (1944), dolerite, p. 18, plagioclase porphyrite, p. 28 (TiO_2 content of 6.59 appears anomalously high and is not included in average) and basalt, p. 42.
   Tyrrell (1932), dolerite.
   Backlund & Malmquist (1932), dolerite p. 24 and plagioclase basalt p. 32.
3. Average of 14 feldspar-phyric lavas from Svartenhuk, West Greenland (Clarke, 1970).
4. Average of 10 olivine tholeiites from Svartenhuk (Clarke, 1970).
5. Average of 8 tholeiitic dolerites from the North of England Holmes & Harwood (1929).
6. Average of 9 tholeiites from the Antrim plateau NE Ireland, Patterson & Swaine (1955).
7. Average Spitzbergen dolerite calculated from 4 analyses of Tyrrell & Sandford (1933).
8. Average of 24 aphyric quartz tholeiites from the Faeroe Islands lower lava series, Rasmussen & Noe-Nygaard (1969).
9. Average of 22 olivine tholeiites from the Faroe Islands upper lava series, Rasmussen & Noe-Nygaard (1969).
10. Average of 715 quartz tholeiites with world-wide distribution, Manson (1967).
11. Average of 182 olivine tholeiites with world-wide distribution Manson (1967).

source regions in the mantle. The West Greenland feldspar-phyric basalts, the Faeroe Islands basalts and the Spitsbergen dolerites all differ only in minor points from the analyses reported here and confirm the unity of these rocks as belonging to a single petrographic province having been formed by similar processes throughout. Very similar compositions have been reported for post-glacial lavas in Iceland (Heier, Chappell, Arriens & Morgan, 1966) indicating that the same processes have continued to recent times.

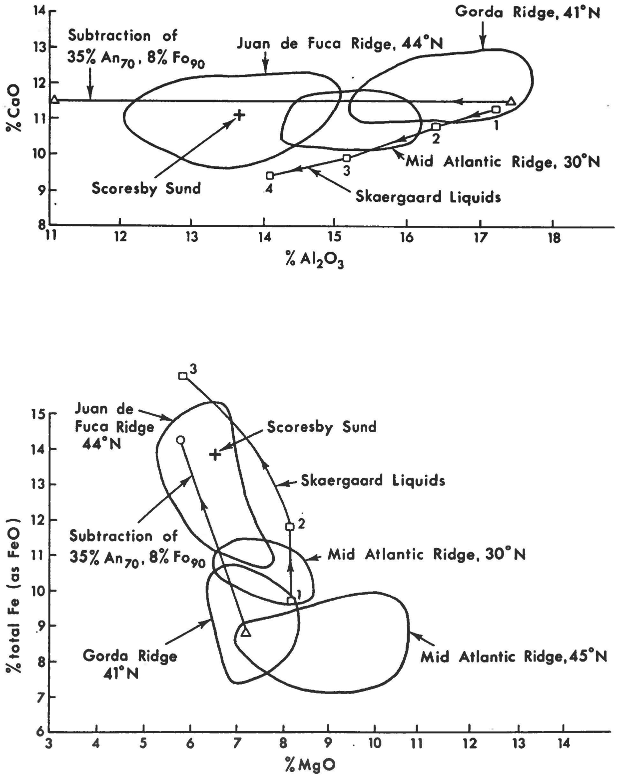

Figure 6. Plots of weight percent CaO against Al_2O_3 (above) and total FeO against MgO (below). The fields of ocean-ridge tholeiites from various localities, the trend of the Skaergaard liquids and the effect of removal of 35 % plagioclase (An_{70}) and 8 % olivine (Fo_{90}) are taken from KAY *et al.* (1970) while the average composition of the Scoresby Sund tholeiites has been added. Note how this composition might be derived from a parental liquid similar to the Skaergaard initial liquid (which in turn resembles certain ocean-ridge tholeiites) by a process of olivine/plagioclase fractionation as suggested by KAY *et al.* (Numbers on the Skaergaard trends refer to the initial liquid and the liquids after 35 %, 76 % and 88 % crystallization, in that order).

Comparisons with world-wide average for tholeiites are also given in table 6 (columns 10 and 11) which show that the world-wide averages are higher in Al_2O_3 and K_2O and lower in total iron than the typical North Atlantic composition.

ENGEL, ENGEL & HAVENS (1965) attempted to show that basalts from the mid-ocean ridge systems have a characteristic chemical composition, their low K_2O and high Al_2O_3 contents being especially noteworthy. Many of the Scoresby Sund basalts show K_2O contents down to the level of ENGEL *et al.*'s ocean tholeiites, but Al_2O_3 contents are also low. More recently, ocean-ridge tholeiites have been shown to cover a fairly broad spectrum of compositions, with, for example Al_2O_3 ranging from 12 to

18⁰/₀ (Kay, Hubbard & Gast, 1970) and other elements, particularly certain trace elements, must be taken into account when characterizing ocean tholeiites. Of the ocean-ridge tholeiite analyses reported by Kay *et al.* (1970), those from the Juan de Fuca ridge most closely resemble those reported here. It was shown by these authors that such iron-rich, alumina-poor compositions could arise by high-level olivine and plagioclase fractionation from the more characteristic high-Al_2O_3 ocean tholeiite and this mechanism could well have operated widely throughout the North Atlantic province (figure 6). That olivine and plagioclase are liquidus phases is confirmed by their presence as the only crystals in the hyaloclastite described above. It is however surprising that, if this is the case, the high-Al_2O_3 Skaergaard liquid, which closely resembles the supposedly more primitive ocean-ridge compositions, is so rare.

Comparative discussions of this type are greatly limited by inadequate data and for many of the regions discussed here observations are either too sparse or of too poor quality. Our final answers regarding the exact distribution of different basalt types must wait, not only until this situation has been remedied but also until investigations have been extended to the less abundant elements. These reservations must also apply to the observations of Noe-Nygaard (1966) already referred to.

MINERAL ANALYSES

a. Pyroxenes

Pyroxene analyses were carried out on polished thin sections from 29 lava flows, whole rock analyses being available for most of these flows. In order to obtain a sample of the range of pyroxene composition in any one thin section a random selection of about 30 points was analysed in seven specimens and an average of 18 points per sample analysed in all 29 flows. Thus a total of about 550 individual analyses of pyroxenes have been completed. The data are too voluminous for publication in full but copies of the data are available from the authors.

Figure 7 shows the compositions of about 160 pyroxenes plotted on the normal pyroxene quadrilateral. The additional 390 unplotted analyses serve to reinforce the pattern on figure 7 but also make it unduly crowded. This wide range of pyroxene compositions revealed by electron probe analyses contrasts markedly with composition estimates available from minerals separated from the parent rock for chemical analyses (see for instance, Deer, Howie & Zussman, 1963, Vol. 2, p. 127). Figure 7

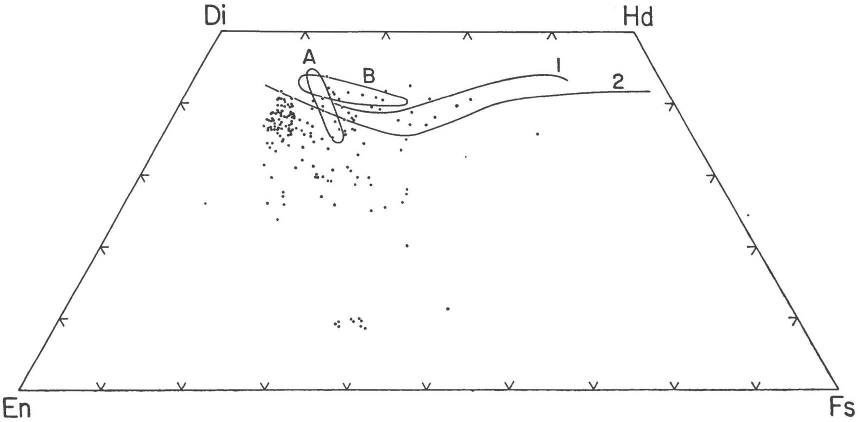

Figure 7. Plot of pyroxene analyses from 29 lava flows. The points plotted are representative of 550 pyroxene analyses, many analyses duplicate the points shown here. The line 1 is the augite trend in some tertiary acid glasses (Carmichael, 1960) and line 2 the augite trend in Skaergaard (Wager & Brown, 1967). Areas A and B are the two pyroxene trends presented by Smith & Lindsley (1971).

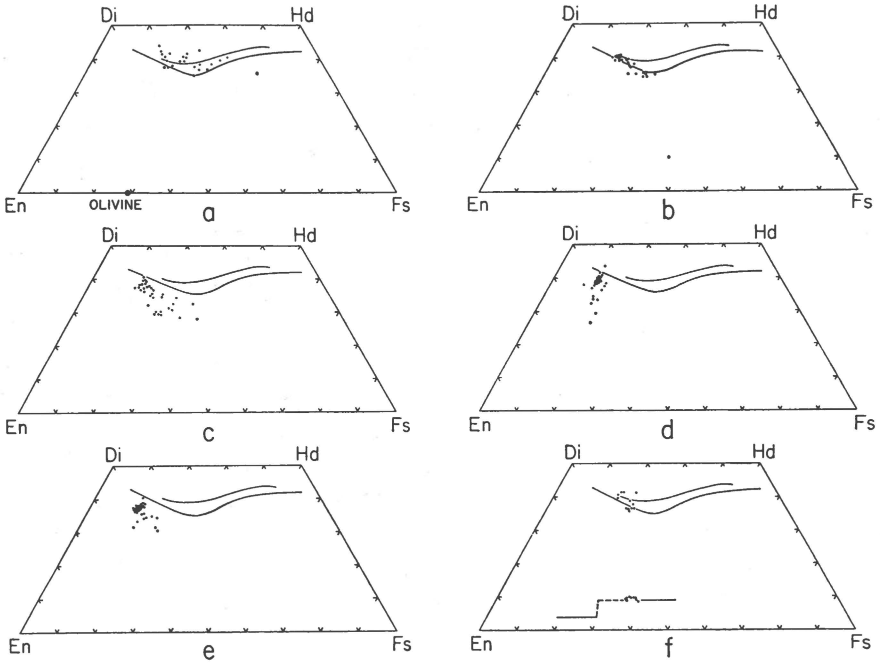

Figure 8. Pyroxene analyses from six lava flows. Augite trend lines are the same as in figure 7 and the pigeonite trend in 8f is from WAGER & BROWN (1967).
a-EG 7113, b-EG 7167, c-EG 7200, d-EG 7186, e-EG 7184, f-EG 7108
Individual analyses for these pyroxenes are shown in appendix 1.

is a composite diagram, in that the data points are taken from several lava flows. Figure 8 illustrates typical pyroxene assemblages in six single lava flows. The wide compositional range of pyroxenes in a single lava flow is immediately apparent. Data points on each of the six pyroxene quadrilaterals of figure 8 were collected from a single polished thin section for each specimen and the analyses from which these diagrams were plotted are given in appendix 1. This range of composition was first reported by us in 1968 (FAWCETT, RUCKLIDGE & GASPARRINI, 1968) and also by EVANS & MOORE (1968). It has subsequently been reported from the intensive studies of lunar samples (see, for example: *Science*, volume 167 no. 3918 and *Geochimica et Cosmochimica Acta*, vol. 34, Supplement 1, for several papers on this topic) and also in other terrestrial materials (SMITH & LINDSLEY, 1971). Also plotted on figures 7 and 8 are the "augite" trends in the Skaergaard intrusion (WAGER & BROWN, 1968), line 2, the augite trend found in some Tertiary acid glasses by CARMICHAEL (1960), line 1, and quench and "normal" trends in a single basalt flow reported by SMITH & LINDSLEY (1971), areas A and B respectively.

The great majority of pyroxene compositions fall in the augite and subcalcic augite range with a small number in the pigeonite and ferroaugite fields. Pigeonite was encountered in only four specimens, despite the fact that most of the augites are less calcic than those from other areas that are plotted on both figures. Smith & Lindsley pointed out that their "quench" trend crossed the Skaergaard trend for augites and attributed this to metastable crystallisation in the normal two pyroxene field. It is difficult to apply this reasoning to the pyroxenes analysed in this study where, for many rocks, all pyroxenes are less calcic than those of the Skaergaard. Textural evidence does not suggest that all these pyroxenes are quench products. In specimen EG 7184, for instance, (figure 8 e), all analysed pyroxenes are less calcic than those of the Skaergaard trend, yet the thin section examination shows microphenocrysts of subophitic augite up to 0.5 mm across and granular subhedral groundmass augites about 0.1 mm across. It must be inferred that the microphenocrysts are not quench products yet the analyses apparently plot in the two pyroxene field. If these microphenocrysts precipitated at temperatures very close to the basalt liquidus they may well represent an equilibrium crystallisation. This explanation relies on the experimental observation that the two pyroxene field narrows with increasing temperature.

Other trends illustrated in figure 8 show a variety of characteristics ranging from an apparent equilibrium trend (figure 8 b) to what may be an extreme example of a quench trend (8 d) with two trends (8 c and 8 e) intermediate between these two. Only the specimens plotted in figures 8 b and 8 f show the presence of pigeonite. If pigeonite has a patchy distribution in these lava flows as implied by Smith & lindsley (1971, p. 227) for the Columbia River basalts then it may be present in other parts of these lava flows. It is interesting to note that augite in the samples containing pigeonite plots fairly close to the Skaergaard trend. Each of these two specimens (EG 7167 and EG 7108, figures 8 b and 8 f) shows evidence of a considerable degree of normal crystal/liquid fractionation (best shown in the augite of EG 7167 and the pigeonite of EG 7108). Specimens EG 7200, EG 7186 and EG 7184 (figure 8 c, d and e) show no pigeonite and a "quench" augite trend. The sixth specimen, EG 7113 (figure 8 a) is rather difficult to interpret in terms of the normal and quench trends of augite. It has a wide range of Mg-Fe ratios but also a considerable scatter in the Ca content and is the only sample in figure 8 with a Ca content that is usually higher than that of the Skaergaard augites. The rather random scatter of points on figure 8 may be due to variations in liquid composition in the neighbourhood of the growing crystal as suggested by Evans & Moore (1968). The thin sections of the specimens illustrated in figure 8 were reexamined in the hope that they would show some textural differences. Unfortunately no such differences were observed. Specimens of figure 8 c and d (specimens EG 7186 and EG 7200) that best illustrate the quench trend, have partially devitrified brown glass in the groundmass but so also has EG 7167 (figure 8 b) that shows the best approach to a "normal" trend. Specimen EG 7184 (figure 8 e) also contains devitrified glass in the groundmass but glass is absent in EG 7108 and EG 7113 (figures 8 f and 8 a). In each specimen the pyroxene occurs in rare subhedral microphenocrysts up to 0.5 mm across and subhedral granular groundmass crystals. Specimen EG 7113 (figure 8 a) contains phenocrysts of plagioclase and minor olivine that are absent in other flows; the olivine is unzoned (Fo_{71}).

With the exception of EG 7113 the pyroxene trends in all specimens illustrated in figure 8 can probably be adequately explained on the basis of variable rates of cooling. It should be emphasised that although Smith & Lindsley (1971) define two augite trends characteristic of the chilled margin and the interior of a single flow, the augites throughout the flow may be expected to show compositions at any point between these two trends. The pyroxenes plotted in figure 7, from a variety of locations in several flows, show the scatter to be expected in a group of specimens with different cooling histories.

An examination of the detailed pyroxene analyses in appendix 1 provides further support for Smith & Lindsley's (1971) argument that ferric iron in tetrahedral coordination is not likely to be the cause of the quench trend (Kuno, 1955). Without exception, there is sufficient Si + Al + Ti to fill the tetrahedral sites in the analysed pyroxenes. Indeed for most analyses the tetrahedral sites are filled by Si and Al. There is a

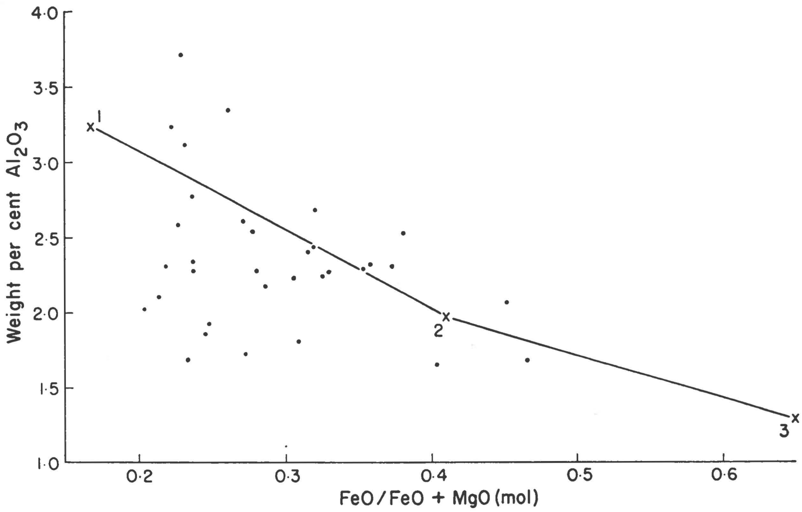

Figure 9. Plot of the Al_2O_3 content against the molecular FeO/FeO + MgO ratio for specimen EG 7200. Points 1, 2 and 3 are for pyroxenes from the Skaergaard intrusion (Wager & Brown, 1967).

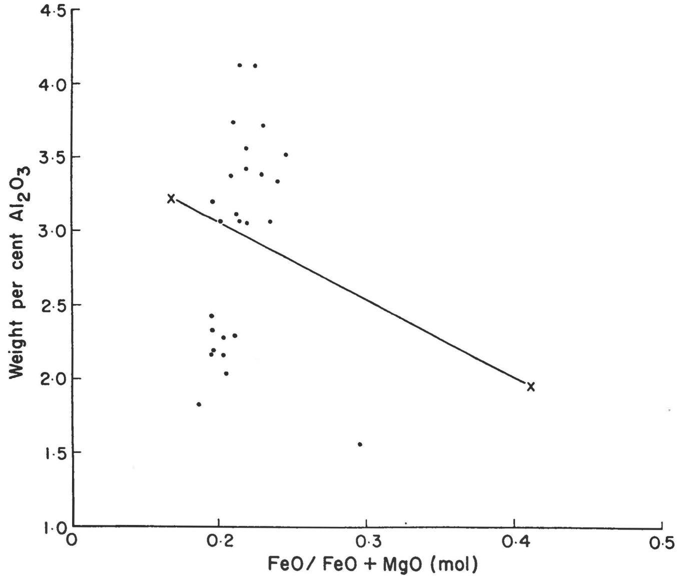

Figure 10. Pyroxenes from specimen EG 7184 plotted on the same basis as for figure 9.

considerable range in the Al_2O_3 content of the augites (from about 1.5 to 4.1 wt $^0/_0$) but the systematic variation with iron content, such as that shown by SMITH & LINDSLEY's samples is not shown. The more iron-rich augites do tend to show lower Al_2O_3 values but there is a wide scatter in the more magnesian augites (figures 9 and 10). TiO_2 and MnO percentages are much more constant than those for Al_2O_3 and no systematic trends can be postulated for these constituents.

b. Plagioclase feldspar

Analyses of plagioclase feldspar were carried out by determining SiO_2, Al_2O_3, CaO, K_2O and Na_2O on twenty to thirty points in a single section. Points were selected from many separate crystals and also on different positions in a single grain. Oxide totals for these analyses are not quite as good as for other minerals but the relative proportions of Ab, An and Or calculated from the analyses show normal trends and suggest that the analyses are reliable.

Plagioclase sometimes occurs as phenocrysts as well as in the groundmass and all crystals show some zoning. Phenocrysts often have a complex appearance under crossed nicols and show both oscillatory and normal zoning. The complex zoning in the phenocrysts does not necessarily reflect wide compositional changes, and differences in the spread of anorthite values does not vary very much from groundmass to phenocrysts

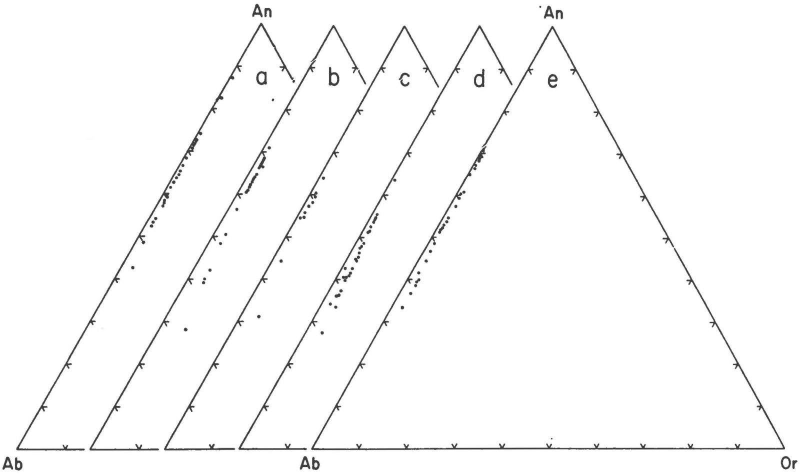

Figure 11. Plot of the feldspar compositions in molecular proportions for five lava flows
a-EG 7189, b-EG 7196, C-EG 7207, d-EG 7204, e-EG 7198

in a single flow; in some specimens there being no significant difference in the compositional range of the two. Consequently no distinction between phenocryst and groundmass crystals has been made in the presentation of feldspar analyses. Feldspars were analysed in twenty five specimens and, unlike the pyroxenes, showed little variation from one flow to another. The maximum range of composition encountered in the entire group is An_{87} $Ab_{12.5}$ $Or_{0.5}$ to $An_{27.3}$ $Ab_{69.3}$ $Or_{3.4}$. Electron probe analyses have been recalculated into molecular proportions of An, Ab and Or and five typical results are shown in figure 11.

It is considered likely that oscillatory zoning of the phenocrysts with small compositional variation has arisen by the process of diffusion – controlled growth described by Bottinga, Kuno & Weill (1966).

c. Oxide phases

Two oxide phases, a magnetite solid solution and an ilmenite solid solution, are present in all samples analysed. They can usually be distinguished in thin section by their contrasting habit, magnetite occurring in irregular, roughly-equant, rectangular grains and ilmenite in elongate, needle-shaped grains. The spinels are roughly 0.2 mm across and the ilmenites 0.2 mm long but only 0.02 mm wide. Some of the spinels have undoubtedly been oxidized and, under reflected light, show a variety of exsolution textures. Such crystals were avoided during the electron probe analytical work. Buddington & Lindsley (1964) developed a

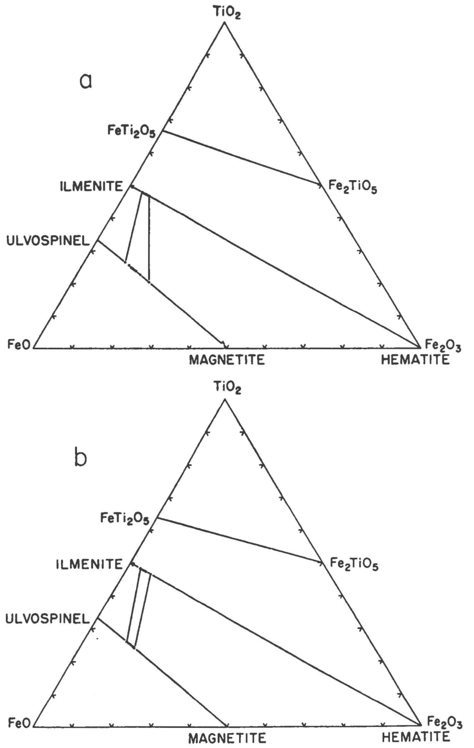

Figure 12. Analyses of coexisting iron-titanium oxides in two specimens plotted in terms of molecular percent FeO, Fe_2O_3 and TiO_2 (based on the recalculation method of CARMICHAEL (1967). Lines joining the spinel solid solution and rhombohedral solid solution are not true tie lines but indicate compositional limits for each phase. a-EG 7176, b-EG 7183

correlation between the composition of coexisting oxides and the temperature and oxygen fugacity of crystallisation. This technique has been applied by several authors to the determinations of the physical conditions of oxide precipitation in volcanic rocks (e.g. CARMICHAEL, 1967). The high oxidation state indicated in the whole rock analyses suggested that analyses of the oxide phases would be useless, but, in fact, this is not entirely the case. Analytical results for two typical specimens are listed in appendix 2 and plotted, after recalculation by the method of CARMICHAEL (1967), in figures 12 and 13. The "tie lines" in figure 12 do not indicate the composition of coexisting phases as all spinel$_{ss}$ and ilmenite$_{ss}$ points plotted occur in one thin section; instead they delimit the range of compositions found in each specimen.

In specimen EG 7176 (figure 12 a) there is a fairly wide range of spinel compositions Usp$_{62}$ to Usp$_{77}$) but only a relatively small range in

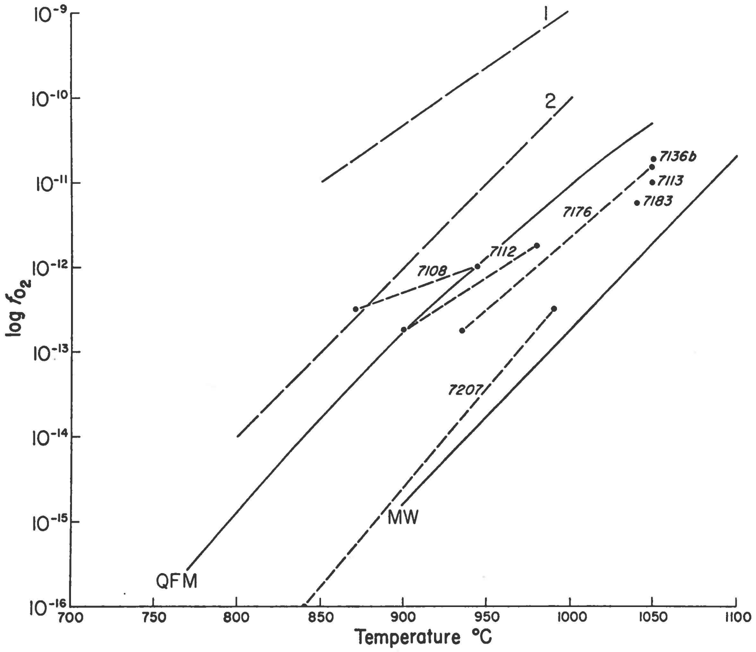

Figure 13. Plot of log fo_2 against temperature for seven specimens (the prefix EG has been omitted from sample numbers appearing on the diagram). Lines labelled QFM and MW are for the quartz-fayalite magnetite and magnetite-wustite buffers. Dashed lines 1 and 2 represent values of magnetite-ilmenite equilibration for assemblages coexisting with olivine (1) and orthopyroxene (2) (CARMICHAEL, 1967).

the coexisting rhombohedral phase (Ilm_{74} to Ilm_{96}). In contrast, specimen EG 7183 (figure 12 b) shows a relatively small range of composition for both phases (spinel—Usp_{74-79}; rhombohedral phase-Ilm_{94-96}). For the purpose of translating this compositional data to values of f_{O_2} and temperature from the BUDDINGTON & LINDSLEY curves, data analogous to that for specimen EG 7183 (small compositional range in both phases) has been averaged to give a single set of values, while data analogous to that for specimen EG 7176 (wide compositional range) has been arbitrarily divided and f_{O_2} and temperature determined for the limits of the compositional range. The data thus obtained are presented for these and other specimens in figure 13. Three specimens each give a single set of results at about 1050°C and log f_{O_2} about 10^{-11} (EG 7113, 7183 and 7136 b). In addition, one of the extreme values for a specimen (EG 7176) showing a range of compositions, plots with these three specimens. This temperature and oxygen fugacity is consistent with known temperatures of basaltic magma and with experimentally determined melting relations of basic compositions (YODER & TILLEY, 1962).

Four of the analysed samples show a range of compositions that give temperature and oxygen fugacity values significantly lower than those mentioned above (note that BUDDINGTON & LINDSLEY claim an accuracy of ± 50° C for their geothermometer). The extreme values for each specimen are connected by a dashed line on figure 13. There appear to be two possible explanations for these results. The first is that the oxide phase changes in composition as the lava flow cooled. A second possibility is that the oxides partially reequilibrated after burial by lava accumulation (burial metamorphism). There does not appear to be any unequivocal way of deciding between these alternatives. WAGER (1934, p. 31) observed features in the basalts to the south which he ascribed to burial metamorphism but this was at a stratigraphic level which is believed to lie several kilometers beneath the level sampled in this investigation.

The presence of zeolites in the area may support the burial metamorphism hypothesis, in a manner analogous to occurrences in Eastern Iceland (WALKER, 1960) but at least one specimen (EG 7183) collected near the base of a succession shows no evidence of reheating. In addition, specimen EG 7207 collected near the top of the entire lava accumulation shows a temperature range of about 150° C. It is unlikely that a flow high in the lava pile would show such pronounced effects of burial metamorphism while many flows lower in the stratigraphic succession remain unaffected and it is therefore concluded that the observed relationships are due to reactions which have taken place during cooling.

d. Interstitial glass

Small amounts of brown to red-brown glass occur in the groundmass of several flows. Some electron probe analyses of these glasses are presented in table 7. Although there is a considerable range of values for each constituent, the analyses show some marked similarities, especially if it is assumed, as seems fairly safe, that the low totals reflect the extent of hydration in the glass, and comparisons are made after the individual analyses have been recalculated to give 100 % totals. There are a number of anomalies in the results, however, that makes a rigid interpretation rather difficult. The compositions have clearly been modified by reaction with water. The material analysed is not a late residual liquid of normal basaltic differentiation processes but appears to be a residual product formed by quenching on extrusion of the flow and subsequently modified by reaction with water. Similarly the anomalous composition is not simply due to the effects of hydration, which has already been clearly demonstrated by the analyses of the EG 7118 glasses (table 3).

Table 7. *Electron probe analyses of natural glasses.*

	1	2	3	4	5	6	7
SiO_2	42.56	46.06	43.98	45.39	44.29	43.74	50.92
TiO_2	0.22	0.04	0.06	0.11	0.17	0.14	0.43
Al_2O_3	5.83	4.44	5.42	5.76	5.58	5.00	6.13
FeO (total)	27.47	16.95	21.00	24.31	26.04	26.87	27.28
MnO	0.22	0.04	0.06	0.13	0.11	0.15	0.13
MgO	6.92	16.17	12.93	11.93	7.61	8.35	12.52
CaO	2.56	1.46	2.45	2.91	2.85	3.29	2.97
Na_2O	0.14	0.05	0.04	0.06	0.03	0.05	0.07
K_2O	0.08	0.15	0.04	0.06	0.03	0.18	0.10
	86.01	85.38	85.98	90.67	86.71	87.77	

Key:

1. EG 7122;
2. EG 7125, core of glass particle;
3. EG 7125, rim of glass particle;
4. EG 7131;
5. EG 7133;
6. EG 7135A;
7. Average of analyses 1–6 after recalculation to 100%.

SUMMARY

Flood basalts exposed in the Scoresby Sund area, which represent the higher levels of the extensive basalt plateau of Kong Christian IX's Land can only be regarded as a monotonous sequence when superficially examined.

However, thin section examination and chemical analysis of the flows and particularly of their constituent minerals show many variations. Of these, analysis of the whole rocks and of the pyroxenes and oxide phases show the greatest potential for selecting marker-horizons. It must however, be emphasized that close control is necessary in the collection of specimens before the pyroxene analyses can be evaluated. A complete range of compositions have been found between quench and normal trends and it may well be that this is governed primarily by positions within the flow. With regard to the establishment of a stratigraphy, palaeomagnetic measurements have not given a satisfactory answer but this might be further pursued to resolve the apparent discrepancy between the results obtained on the rocks discussed here and those further to the west.

All flows appear to have been affected by secondary processes. This is most apparent in the high oxidation ratio of the rock analyses. The presence of zeolites, calcite and quartz in the vesicles of many flows suggests the possibility of burial metamorphism but more detailed and extensive sampling is necessary to examine these assemblages. All flows examined have a tholeiitic composition and in almost all cases are quartz normative, although this may be accentuated by secondary alteration. Conspicuously absent are alkali basalt compositions, picrites, such as occur abundantly in the West Greenland Tertiary or a high-alumina tholeiite corresponding to that of the Skaergaard initial liquid. The close similarity between these basalts and others in the North Atlantic area, together with their resemblance to certain mid-ocean ridge lavas supports the belief that they have been erupted during a period of rifting in the early history of the North Atlantic some 60 m.y. ago when Europe, Greenland and North America were contiguous. They therefore compare closely in mode of origin to the tholeiites presently being extruded along the line of the Mid-Atlantic Ridge in the Icelandic central graben. More detailed work is still required to define possible differences in composition between the basalts of the Greenland-Iceland-Faeroes belt and those of other parts of the mid-ocean rift system such as has been suggested by NOE-NYGAARD (1966).

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Appendix 1. *Electron probe analyses of pyroxenes plotted in figure 8.*

Sample no. EG 7167

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	49.16	50.45	50.75	50.83	50.26	50.91	50.57	50.84	52.13	50.80	51.00	50.94	51.62
Al_2O_3	3.53	2.44	2.57	1.78	1.98	2.49	1.73	2.88	2.56	2.16	2.69	2.74	1.88
TiO_2	0.92	1.18	0.94	1.05	0.86	1.12	0.99	0.85	0.97	0.97	0.98	1.00	0.99
FeO	12.81	12.83	10.12	17.54	13.63	11.18	14.36	10.92	9.73	9.89	10.23	10.61	13.61
MnO	0.41	0.30	0.31	0.44	0.35	0.30	0.43	0.28	0.29	0.28	0.29	0.34	0.39
MgO	14.62	14.81	15.99	12.55	14.15	15.21	15.01	15.50	15.31	15.86	15.31	15.27	15.22
CaO	18.66	19.16	20.30	16.94	18.85	19.97	17.72	19.47	19.94	20.16	20.00	19.89	17.48
Na_2O	0.88	0.50	0.44	0.49	0.68	0.40	0.16	0.44	0.34	0.21	0.48	0.46	0.37
K_2O	0.04	0.06	0.17	0.09	0.16	0.16	0.04	0.37	0.12	0.17	0.16	0.17	0.03
Sum	101.03	101.73	101.59	101.71	100.92	101.74	101.01	101.55	101.39	100.50	101.14	101.42	101.59
Cation contents (12 oxygens)													
Si	3.695	3.758	3.752	3.841	3.792	3.769	3.802	3.765	3.833	3.788	3.781	3.773	3.834
Al	0.305	0.214	0.224	0.159	0.176	0.217	0.153	0.235	0.167	0.190	0.219	0.227	0.165
Al	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.016	0.054	0.0	0.016	0.012	0.0
Ti	0.052	0.066	0.052	0.060	0.049	0.062	0.056	0.047	0.054	0.054	0.055	0.056	0.055
Fe	0.805	0.799	0.626	1.108	0.860	0.692	0.903	0.676	0.598	0.617	0.634	0.657	0.845
Mn	0.026	0.019	0.019	0.028	0.022	0.019	0.027	0.018	0.018	0.018	0.018	0.021	0.025
Mg	1.638	1.644	1.762	1.413	1.591	1.679	1.682	1.711	1.678	1.763	1.692	1.686	1.685
Ca	1.503	1.529	1.608	1.371	1.524	1.584	1.428	1.545	1.571	1.611	1.589	1.579	1.391
Na	0.128	0.072	0.063	0.072	0.099	0.057	0.023	0.063	0.048	0.030	0.069	0.066	0.053
K	0.004	0.006	0.016	0.009	0.015	0.015	0.004	0.035	0.011	0.016	0.015	0.016	0.003
WXY	4.163	4.136	4.147	4.062	4.161	4.109	4.123	4.111	4.033	4.109	4.089	4.093	4.058
Z	4.000	3.972	3.976	3.999	3.968	3.987	3.955	4.000	4.000	3.978	4.000	4.000	3.999
Molecular %													
Fs	20.93	20.50	16.07	28.98	22.07	17.89	23.03	17.57	15.95	15.83	16.59	17.21	22.05
En	41.24	41.19	43.88	36.04	39.81	42.24	41.64	43.32	43.41	43.98	43.02	42.76	42.70
Wo	37.83	38.31	40.05	34.97	38.12	39.87	35.33	39.11	40.64	40.19	40.39	40.03	35.25

VI

Sample no. EG 7113

	1	2	3	4	5	6	7	8	9	10
SiO_2	48.18	48.13	47.15	45.95	48.54	46.57	50.47	48.00	48.80	49.07
Al_2O_3	3.63	2.69	2.54	3.10	3.67	1.85	1.79	2.91	3.33	2.51
TiO_2	2.26	1.75	2.55	2.01	1.76	1.38	1.38	2.11	2.03	1.39
FeO	12.24	17.25	16.06	18.36	10.19	21.78	12.67	15.20	11.00	18.06
MgO	13.75	12.07	10.40	11.68	15.01	8.53	14.73	12.34	14.46	12.60
CaO	20.26	18.31	19.90	19.39	22.53	19.62	19.77	19.69	20.38	17.03
Sum	100.32	100.20	98.60	100.49	101.70	99.73	100.81	100.25	100.00	100.66
Cation contents (12 oxygens)										
Si	3.645	3.710	3.701	3.582	3.612	3.715	3.787	3.680	3.680	3.755
Al	0.324	0.244	0.235	0.285	0.322	0.174	0.158	0.263	0.296	0.226
Al	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti	0.129	0.101	0.151	0.118	0.099	0.083	0.078	0.122	0.115	0.080
Fe	0.774	1.112	1.054	1.197	0.634	1.453	0.795	0.975	0.694	1.156
Mg	1.551	1.387	1.217	1.357	1.665	1.014	1.648	1.410	1.625	1.437
Ca	1.642	1.512	1.674	1.620	1.797	1.677	1.590	1.617	1.647	1.396
WXY	4.096	4.112	4.095	4.291	4.194	4.227	4.110	4.124	4.081	4.070
Z	3.969	3.954	3.936	3.867	3.934	3.889	3.946	3.943	3.976	3.982
Molecular %										
Fs	19.52	27.72	26.73	28.68	15.48	35.06	19.72	24.35	17.49	28.97
En	39.08	34.57	30.85	32.52	40.65	24.47	40.86	35.24	40.98	36.03
Wo	41.40	37.70	42.43	38.80	43.86	40.47	39.42	40.41	41.52	35.00

Sample no. EG 7108

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2......	50.94	50.96	51.24	52.20	51.13	49.95	51.21	51.37	51.92	52.16	52.10	52.25	50.99	51.98
Al_2O_3.....	1.74	2.32	0.99	0.83	0.84	3.37	1.98	1.94	0.95	0.79	0.98	0.99	2.02	0.95
TiO_2......	0.92	0.86	0.47	0.50	0.49	1.35	0.87	0.97	0.54	0.78	0.49	0.49	0.87	0.46
FeO......	13.86	10.62	21.70	23.12	22.24	10.67	13.67	13.56	23.09	23.73	21.87	22.62	13.18	23.01
MnO.....	0.40	0.26	0.57	0.66	0.62	0.23	0.40	0.42	0.70	0.70	0.59	0.62	0.35	0.68
MgO.....	14.12	14.95	20.39	18.72	20.62	14.54	14.90	14.63	19.76	18.77	20.12	19.13	14.13	18.87
CaO......	17.44	19.18	4.55	4.77	4.84	20.00	17.65	17.17	4.30	4.22	4.43	4.65	19.06	4.78
Sum.....	99.42	99.15	99.91	100.80	100.78	100.11	100.68	100.06	101.26	101.15	100.58	100.75	100.60	100.73
Cation contents (12 oxygens)														
Si........	3.869	3.840	3.871	3.927	3.846	3.744	3.838	3.864	3.887	3.916	3.903	3.921	3.832	3.913
Al........	0.131	0.160	0.088	0.073	0.074	0.256	0.162	0.136	0.084	0.070	0.087	0.079	0.168	0.084
Al........	0.024	0.046	0.0	0.000	0.0	0.041	0.013	0.036	0.0	0.0	0.0	0.008	0.011	0.0
Ti........	0.053	0.049	0.027	0.028	0.028	0.076	0.049	0.055	0.030	0.044	0.028	0.028	0.049	0.026
Fe.......	0.880	0.669	1.371	1.454	1.399	0.669	0.857	0.853	1.446	1.490	1.370	1.419	0.828	1.449
Mn.......	0.026	0.017	0.036	0.042	0.040	0.015	0.025	0.027	0.044	0.045	0.037	0.039	0.022	0.043
Mg.......	1.599	1.679	2.296	2.099	2.312	1.624	1.664	1.640	2.205	2.101	2.247	2.140	1.583	2.118
Ca.......	1.419	1.549	0.368	0.384	0.390	1.606	1.417	1.384	0.345	0.339	0.356	0.374	1.535	0.386
WXY....	4.001	4.008	4.099	4.008	4.168	4.031	4.026	3.995	4.070	4.019	4.037	4.008	4.029	4.021
Z........	4.000	4.000	3.959	4.000	3.921	4.000	4.000	4.000	3.971	3.986	3.989	4.000	4.000	3.997
Molecular °/₀														
En.......	40.74	42.91	56.39	52.74	55.84	41.50	41.99	42.02	54.58	52.85	56.03	53.86	39.89	53.00
Fs... ...	23.09	17.52	34.57	37.60	34.74	17.46	22.25	22.54	36.88	38.61	35.10	36.73	21.44	37.35
Wo.......	36.17	39.57	9.05	9.66	9.42	41.04	35.75	35.45	8.54	8.54	8.87	9.41	38.68	9.65

Sample no. EG 7184

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	51.00	49.66	51.28	51.42	49.56	50.81	49.67	50.47	49.91	49.52	50.65	50.25	50.03
Al_2O_3	1.56	3.37	2.27	2.15	3.70	2.03	3.37	3.06	3.51	4.11	3.33	3.10	3.06
TiO_2	0.82	1.14	0.69	0.66	1.20	0.65	1.03	0.89	1.19	1.25	1.15	0.95	0.90
FeO	12.46	8.40	7.85	7.82	8.34	7.74	7.23	8.78	9.60	7.99	9.08	7.80	7.68
MnO	0.35	0.26	0.29	0.26	0.28	0.29	0.25	0.28	0.29	0.28	0.27	0.27	0.27
MgO	17.07	16.33	17.85	17.86	16.23	17.35	15.92	16.44	17.20	16.94	16.83	16.79	16.35
Cr_2O_3	0.12	0.29	0.62	0.65	0.62	0.64	0.99	0.66	0.47	0.98	0.44	0.42	0.98
CaO	15.27	18.62	17.95	18.17	18.40	18.22	19.68	18.31	16.55	17.82	17.24	18.47	18.91
Na_2O	0.36	0.76	0.48	0.50	0.54	0.39	0.52	0.62	0.56	0.58	0.55	0.55	0.68
Sum	99.01	98.83	99.28	99.49	98.87	98.12	98.66	99.51	99.28	99.47	99.54	98.60	98.86
Cation contents (12 oxygens)													
Si	3.849	3.734	3.811	3.815	3.721	3.824	3.735	3.767	3.730	3.687	3.767	3.768	3.754
Al	0.139	0.266	0.189	0.185	0.279	0.176	0.265	0.233	0.270	0.313	0.233	0.232	0.246
Al	0.000	0.032	0.010	0.003	0.048	0.005	0.033	0.036	0.039	0.048	0.059	0.043	0.025
Ti	0.047	0.064	0.039	0.037	0.068	0.037	0.058	0.050	0.067	0.070	0.064	0.054	0.051
Fe	0.786	0.528	0.488	0.485	0.524	0.487	0.455	0.548	0.600	0.498	0.565	0.489	0.482
Mn	0.022	0.017	0.018	0.016	0.524	0.487	0.016	0.018	0.018	0.018	0.017	0.017	0.017
Mg	1.920	1.830	1.977	1.975	1.816	1.947	1.784	1.829	1.916	1.880	1.866	1.877	1.829
Cr	0.007	0.017	0.036	0.038	0.037	0.038	0.059	0.039	0.028	0.058	0.026	0.025	0.058
Ca	1.235	1.500	1.429	1.444	1.480	1.469	1.585	1.464	1.325	1.422	1.374	1.484	1.520
Na	0.053	0.111	0.069	0.072	0.079	0.057	0.076	0.090	0.081	0.084	0.079	0.080	0.099
WX	1.287	1.611	1.499	1.516	1.559	1.526	1.661	1.554	1.407	1.505	1.453	1.564	1.619
Y	2.783	2.489	2.569	2.555	2.510	2.532	2.405	2.520	2.669	2.570	2.596	2.504	2.461
Z	3.988	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Molecular %													
En	48.54	47.46	50.99	50.85	47.83	50.12	47.27	47.92	50.00	50.01	49.17	48.86	48.30
Fs	20.37	14.00	12.82	12.67	13.97	12.77	12.07	14.51	15.91	13.30	15.12	13.01	12.78
Wo	31.10	38.54	36.19	36.48	38.20	37.11	40.66	37.57	34.09	36.69	35.71	38.13	38.92

(continued)

Sampln no. EG 7184 (continued)

	14	15	16	17	18	19	20	21	22	23	24	25	26
SiO_2	48.92	50.49	51.81	51.57	50.15	51.48	49.24	49.83	50.33	50.05	51.11	49.04	51.22
Al_2O_3	4.11	2.41	2.32	2.18	3.55	2.29	3.73	3.04	3.06	3.40	3.19	1.82	2.17
TiO_2	1.18	0.63	0.64	0.73	1.08	0.67	1.46	0.90	0.87	1.00	0.64	0.63	0.64
FeO	8.58	7.37	7.32	7.32	7.96	8.80	7.88	8.15	7.44	8.02	7.44	7.10	7.39
MnO	0.27	0.23	0.25	0.29	0.35	0.33	0.29	0.25	0.21	0.23	0.28	0.13	0.31
MgO	17.13	17.49	17.32	17.34	16.71	19.15	17.20	16.77	17.05	16.64	17.82	17.74	17.75
Cr_2O_3	0.74	0.69	0.63	0.66	0.94	0.60	0.67	0.81	0.82	0.90	0.64	0.05	0.57
CaO	17.05	18.44	18.36	18.35	17.42	15.56	17.54	18.32	18.29	17.77	18.10	18.39	17.74
Na_2O	0.57	0.48	0.43	0.56	0.59	0.42	0.45	0.49	0.48	0.53	0.31	3.16	0.35
Sum	98.55	98.23	99.08	99.00	98.75	99.30	98.46	98.56	98.55	98.54	98.53	98.06	98.14
Cation contents (12 oxygens)													
Si	3.680	3.795	3.846	3.837	3.752	3.814	3.698	3.749	3.769	3.755	3.821	3.735	3.838
Al	0.320	0.205	0.154	0.163	0.248	0.186	0.302	0.251	0.231	0.245	0.179	0.163	0.162
Al	0.044	0.008	0.049	0.028	0.065	0.013	0.029	0.019	0.039	0.056	0.014	0.000	0.029
Ti	0.067	0.036	0.036	0.041	0.061	0.037	0.082	0.051	0.049	0.056	0.036	0.036	0.036
Fe	0.540	0.463	0.454	0.455	0.498	0.545	0.495	0.513	0.466	0.503	0.465	0.452	0.463
Mn	0.017	0.015	0.016	0.018	0.022	0.021	0.018	0.016	0.013	0.015	0.018	0.008	0.020
Mg	1.921	1.959	1.916	1.923	1.863	2.115	1.926	1.881	1.903	1.861	1.986	2.014	1.982
Cr	0.044	0.041	0.037	0.039	0.056	0.035	0.040	0.048	0.049	0.053	0.038	0.003	0.034
Ca	1.374	1.485	1.460	1.463	1.396	1.235	1.412	1.477	1.468	1.429	1.450	1.501	1.424
Na	0.083	0.070	0.062	0.081	0.086	0.060	0.066	0.071	0.070	0.077	0.045	0.467	0.051
WX	1.457	1.555	1.522	1.544	1.482	1.295	1.477	1.549	1.537	1.506	1.495	1.967	1.475
Y	2.633	2.522	2.508	2.504	2.564	2.766	2.590	2.528	2.520	2.544	2.556	2.514	2.564
Z	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	3.898	4.000
Molecular %													
En	50.43	50.47	50.30	50.32	50.03	54.41	50.52	49.03	50.06	49.58	51.15	50.70	51.39
Fs	14.30	12.06	12.11	12.15	13.56	14.32	13.20	13.44	12.29	13.41	12.21	11.58	12.31
Wo	35.27	37.47	37.60	37.52	36.41	31.26	36.28	37.54	37.64	37.00	36.65	37.72	36.30

Sample no. EG 7186

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	52.11	49.96	51.12	50.30	50.75	50.71	50.56	51.71	50.12	51.82	51.63	50.42	50.93	51.58	50.66
Al_2O_3	2.03	3.77	2.61	3.29	3.07	2.74	3.00	2.00	3.35	2.03	1.91	2.93	2.15	2.07	3.21
TiO_2	0.64	1.08	0.84	1.01	0.92	0.99	0.95	0.66	1.00	0.67	0.73	1.19	0.71	0.66	0.95
FeO	8.11	7.35	7.47	7.13	7.39	8.80	6.69	7.11	8.82	8.40	7.14	8.82	9.87	9.04	7.01
MnO	0.24	0.20	0.24	0.22	0.22	0.24	0.20	0.22	0.24	0.29	0.22	0.23	0.24	0.23	0.22
MgO	18.44	16.06	15.94	16.33	16.66	16.05	15.81	17.13	16.03	18.21	16.86	16.56	18.81	17.84	17.57
Cr_2O_3	0.72	1.02	0.91	0.93	0.91	0.36	1.00	0.67	0.44	0.45	0.85	0.49	0.68	0.54	0.94
CaO	17.18	19.60	18.80	19.20	18.62	18.30	20.25	18.85	18.16	16.44	18.67	17.38	14.58	16.05	18.02
Na_2O	0.13	0.26	0.44	0.04	0.39	0.27	0.31	0.28	0.17	0.13	0.42	0.47	0.06	0.18	0.19
Sum	99.60	99.30	98.37	98.46	98.93	98.46	98.77	98.63	98.33	98.44	98.43	98.49	98.03	98.19	98.77
Cation contents (12 oxygens)															
Si	3.845	3.725	3.835	3.769	3.784	3.814	3.783	3.857	3.776	3.864	3.862	3.788	3.827	3.864	3.770
Al	0.155	0.275	0.165	0.231	0.216	0.186	0.217	0.143	0.224	0.136	0.138	0.212	0.173	0.136	0.230
Al	0.022	0.057	0.065	0.059	0.054	0.057	0.048	0.033	0.073	0.043	0.030	0.047	0.017	0.047	0.051
Ti	0.036	0.061	0.047	0.057	0.052	0.056	0.053	0.037	0.057	0.038	0.041	0.067	0.040	0.037	0.053
Fe	0.500	0.458	0.469	0.447	0.461	0.554	0.419	0.444	0.556	0.524	0.447	0.554	0.620	0.566	0.436
Mn	0.015	0.013	0.015	0.014	0.014	0.015	0.013	0.014	0.015	0.018	0.014	0.015	0.015	0.015	0.014
Mg	2.028	1.785	1.782	1.824	1.852	1.800	1.763	1.905	1.800	2.024	1.880	1.855	2.107	1.992	1.949
Cr	0.042	0.060	0.054	0.055	0.054	0.021	0.059	0.040	0.026	0.027	0.050	0.029	0.040	0.032	0.055
Ca	1.358	1.566	1.511	1.542	1.488	1.475	1.624	1.507	1.466	1.314	1.496	1.399	1.174	1.288	1.437
Na	0.019	0.038	0.064	0.006	0.056	0.039	0.045	0.040	0.025	0.019	0.061	0.068	0.009	0.026	0.027
WX	1.377	1.604	1.575	1.548	1.544	1.514	1.669	1.547	1.491	1.332	1.557	1.468	1.183	1.315	1.464
Y	2.643	2.434	2.433	2.456	2.486	2.503	2.355	2.471	2.527	2.673	2.461	2.567	2.840	2.690	2.558
Z	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Molecular %															
En	52.49	47.53	47.93	48.40	49.26	47.12	47.00	49.75	47.27	52.49	49.65	48.91	54.27	51.99	51.51
Fs	13.07	12.13	12.63	11.87	12.27	14.72	11.12	11.70	14.78	13.88	11.85	14.77	16.06	14.92	11.57
Wo	34.44	40.34	39.44	39.73	38.46	38.16	41.87	38.55	37.95	33.63	38.50	36.33	29.67	33.09	36.93

Sample no. EG 7200

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2 . . .	50.74	51.91	51.71	51.69	52.01	51.91	52.62	51.66	50.93	51.77	50.40	50.70	50.52	51.32	50.54	50.26	51.45
Al_2O_3 . .	3.23	1.81	1.92	2.76	2.01	2.17	1.72	2.61	3.34	2.27	1.65	2.27	2.54	2.27	2.32	2.54	2.34
TiO_2 . . .	1.09	0.98	0.88	0.98	0.75	0.91	0.82	1.21	1.48	0.91	1.01	1.23	1.09	0.89	1.24	1.28	0.81
FeO . . .	7.88	13.34	9.36	8.86	7.71	11.38	11.29	10.33	9.65	10.82	17.22	13.77	10.69	8.90	15.06	10.54	9.05
MnO . .	0.24	0.40	0.27	0.25	0.23	0.40	0.35	0.26	0.29	0.31	0.43	0.35	0.35	0.31	0.42	0.32	0.26
MgO . .	15.87	17.30	16.44	16.62	17.74	16.48	17.36	16.10	15.95	16.15	14.66	16.00	16.16	16.71	15.19	15.82	16.99
Cr_2O_3 . .	0.66	0.06	0.20	0.36	0.59	0.08	0.09	0.14	0.49	0.11	0.04	0.04	0.11	0.06	0.05	0.10	0.27
CaO . . .	19.78	14.78	18.61	18.78	18.57	16.93	15.69	18.22	18.45	17.32	13.50	14.87	17.11	17.95	14.52	17.82	17.67
Na_2O . .	0.23	0.23	0.29	0.34	0.23	0.14	0.23	0.32	0.33	0.38	0.28	0.24	0.30	0.39	0.11	0.34	0.14
Sum . . .	99.72	100.81	99.68	100.64	99.84	100.40	100.17	100.85	100.91	100.04	99.19	99.47	98.87	98.80	99.45	99.02	98.98
Cation contents (12 oxygens)																	
Si	3.771	3.847	3.850	3.805	3.838	3.850	3.891	3.812	3.755	3.850	3.861	3.823	3.807	3.842	3.830	3.790	3.841
Al	0.229	0.153	0.150	0.195	0.162	0.150	0.109	0.188	0.245	0.150	0.139	0.177	0.193	0.158	0.170	0.210	0.159
Al	0.054	0.005	0.019	0.045	0.013	0.039	0.041	0.039	0.045	0.049	0.010	0.025	0.032	0.042	0.037	0.015	0.046
Ti	0.061	0.055	0.049	0.054	0.042	0.051	0.046	0.067	0.082	0.051	0.058	0.070	0.062	0.050	0.071	0.073	0.045
Fe	0.490	0.827	0.583	0.545	0.476	0.706	0.698	0.638	0.595	0.673	1.103	0.868	0.674	0.557	0.954	0.665	0.565
Mn	0.015	0.025	0.017	0.016	0.014	0.025	0.022	0.016	0.018	0.020	0.028	0.022	0.022	0.020	0.027	0.020	0.016
Mg	1.758	1.911	1.825	1.824	1.951	1.822	1.914	1.771	1.753	1.790	1.674	1.798	1.815	1.865	1.716	1.778	1.890
Cr	0.039	0.004	0.012	0.021	0.034	0.005	0.005	0.008	0.029	0.006	0.002	0.002	0.007	0.004	0.003	0.006	0.016
Ca	1.575	1.174	1.485	1.481	1.468	1.345	1.243	1.441	1.458	1.380	1.108	1.201	1.381	1.440	1.179	1.440	1.413
Na	0.033	0.033	0.042	0.049	0.033	0.020	0.033	0.046	0.047	0.055	0.042	0.035	0.044	0.057	0.016	0.050	0.020
WX . . .	1.608	1.207	1.527	1.530	1.501	1.365	1.276	1.486	1.505	1.435	1.150	1.237	1.425	1.497	1.195	1.489	1.434
Y	2.416	2.827	2.505	2.505	2.531	2.647	2.726	2.539	2.522	2.589	2.876	2.786	2.612	2.538	2.808	2.557	2.580
Z	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Molecular %																	
En	46.35	48.59	46.83	47.46	50.35	46.80	49.43	45.93	46.25	46.44	42.81	46.26	46.72	48.09	44.31	45.64	48.87
Fs	13.02	21.62	15.30	14.43	12.43	18.73	18.55	16.88	15.92	17.90	28.89	22.88	17.85	14.85	25.30	17.53	14.90
Wo	40.63	29.79	37.87	38.11	37.23	34.47	32.02	37.19	37.84	35.67	28.30	30.86	35.43	37.06	30.39	36.83	36.23

(continued)

Sample no. EG 7200 (continued)

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
SiO_2 . . .	49.85	50.64	50.18	50.75	50.39	52.03	49.73	50.15	51.24	50.69	51.58	49.69	50.22	51.57	49.81	51.09	51.25
Al_2O_3 . .	2.40	2.24	2.43	3.11	3.72	2.23	2.07	1.68	2.58	2.53	2.10	2.28	2.68	1.67	2.30	1.85	2.30
TiO_2 . . .	1.31	1.14	1.29	1.06	1.28	1.13	1.21	0.97	0.86	1.23	0.73	1.31	1.42	0.84	1.30	0.82	0.75
FeO . . .	13.24	13.73	12.38	8.21	8.26	12.75	17.57	19.59	7.95	14.66	7.85	14.44	12.29	8.80	14.82	9.15	7.93
MnO . .	0.40	0.39	0.33	0.25	0.25	0.34	0.41	0.51	0.26	0.32	0.24	0.46	0.33	0.26	0.42	0.29	0.26
MgO . .	16.58	16.43	15.26	15.86	16.07	16.73	12.21	12.97	15.72	13.69	16.77	15.30	15.06	16.77	14.38	16.69	16.62
Cr_2O_3 . .	0.07	0.07	0.07	0.55	0.51	0.09	0.05	0.04	0.48	0.09	0.74	0.04	0.06	0.27	0.04	0.23	0.37
CaO . . .	14.33	13.94	16.66	18.86	18.64	14.42	15.70	13.19	18.88	16.16	18.29	14.88	16.68	17.83	15.67	17.51	18.40
Na_2O . .	0.36	0.10	0.28	0.15	0.26	0.12	0.21	0.22	0.21	0.30	0.41	0.19	0.51	0.33	0.16	0.37	0.28
Sum . . .	98.54	98.68	98.88	98.80	99.38	99.84	99.16	99.32	98.18	99.67	98.71	98.59	99.25	98.34	98.90	98.00	98.16
Cation contents (12 oxygens)																	
Si	3.790	3.837	3.807	3.799	3.751	3.872	3.843	3.876	3.852	3.841	3.854	3.802	3.796	3.876	3.811	3.859	3.850
Al	0.210	0.163	0.193	0.201	0.249	0.128	0.157	0.124	0.148	0.159	0.146	0.198	0.204	0.124	0.189	0.141	0.150
Al	0.005	0.037	0.024	0.073	0.078	0.067	0.032	0.029	0.080	0.067	0.039	0.008	0.035	0.023	0.019	0.024	0.053
Ti	0.075	0.065	0.074	0.060	0.072	0.063	0.070	0.056	0.049	0.070	0.041	0.075	0.081	0.047	0.075	0.047	0.042
Fe	0.842	0.870	0.785	0.514	0.514	0.793	1.136	1.266	0.500	0.929	0.491	0.924	0.777	0.553	0.948	0.578	0.498
Mn	0.026	0.025	0.021	0.016	0.016	0.021	0.027	0.033	0.017	0.021	0.015	0.030	0.021	0.017	0.027	0.019	0.017
Mg	1.879	1.856	1.726	1.770	1.783	1.856	1.407	1.494	1.761	1.546	1.868	1.745	1.697	1.879	1.640	1.879	1.861
Cr	0.004	0.004	0.004	0.033	0.030	0.005	0.003	0.002	0.029	0.005	0.044	0.002	0.004	0.016	0.002	0.014	0.022
Ca	1.167	1.132	1.354	1.513	1.487	1.150	1.300	1.092	1.521	1.312	1.464	1.220	1.351	1.436	1.285	1.417	1.481
Na	0.053	0.015	0.041	0.022	0.038	0.017	0.031	0.033	0.031	0.044	0.059	0.028	0.075	0.048	0.024	0.054	0.041
WX . . .	1.221	1.146	1.395	1.534	1.524	1.167	1.332	1.125	1.551	1.356	1.524	1.248	1.426	1.484	1.309	1.471	1.522
Y	2.831	2.857	2.634	2.465	2.493	2.806	2.675	2.881	2.435	2.639	2.497	2.784	2.614	2.535	2.712	2.560	2.494
Z	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Molecular $^0/_0$																	
En	48.06	47.85	44.46	46.87	47.34	48.65	36.40	38.49	46.77	40.69	49.25	44.56	44.17	48.58	42.09	48.45	48.55
Fs	22.14	23.03	20.73	13.78	13.84	21.30	30.02	33.42	13.49	24.90	13.03	23.33	20.73	14.61	25.00	15.27	13.27
Wo	29.79	29.12	34.81	39.34	38.82	30.05	33.58	28.09	39.74	34.41	37.73	31.11	35.09	36.81	32.92	36.28	38.18

Appendix 2. *Electron probe analyses of opaque phases*

Sample no. EG 7176

Spinel phase

	1	2	3	4	5	6	7	8	9
SiO_2	1.32	1.71	1.91	1.93	0.78	1.19	0.79	1.38	1.18
TiO_2	20.70	26.26	22.99	23.92	21.24	23.12	26.45	24.22	25.72
Al_2O_3	2.16	2.04	2.19	1.90	1.94	1.41	1.76	2.15	1.72
Cr_2O_3	0.26	0.05	0.06	0.05	0.05	0.06	0.06	0.08	0.04
FeO	71.38	62.86	65.44	64.26	69.54	67.38	66.42	65.43	64.29
MnO	0.97	2.49	1.71	2.16	2.03	2.38	1.19	1.75	2.25
MgO	0.79	0.90	0.64	0.67	0.69	0.91	0.90	0.95	0.82
ZnO	0.88	0.32	0.28	0.28	0.28	0.30	0.13	0.24	0.22
Sum	98.46	96.62	95.22	95.17	96.54	96.75	97.71	96.20	96.25
Recalculated Analysis, Ilmenite Basis									
Fe_2O_3	39.01	29.70	32.59	31.59	38.22	35.85	32.08	32.66	31.41
FeO	36.23	36.10	36.08	35.80	35.11	35.09	37.53	36.01	35.99
Total	102.33	99.56	98.45	98.30	100.33	100.30	100.89	99.43	99.36
Recalculated Analysis, Ulvospinel Basis									
Fe_2O_3	24.07	10.72	15.61	13.97	23.39	19.41	13.77	15.32	13.25
FeO	49.69	53.20	51.38	51.68	48.46	49.90	54.01	51.63	52.35
Total	100.85	97.68	96.76	96.55	98.86	98.67	99.08	97.72	97.56
Usp	61.79	80.32	72.74	75.67	62.67	69.47	76.79	73.49	77.32

Rhombohedral phase

	10	11	12	13	14	15	16	17
SiO_2	0.67	0.20	1.64	0.23	0.25	0.32	0.25	0.28
TiO_2	50.28	50.30	48.33	50.27	49.30	50.26	51.12	49.96
Al_2O_3	0.21	0.16	0.38	0.22	0.03	0.29	0.11	0.20
Cr_2O_3	0.24	0.01	0.02	0.00	0.00	0.00	0.01	0.02
FeO	48.38	48.11	46.44	48.23	47.59	48.02	48.10	48.56
MnO	0.53	0.54	0.47	0.52	0.55	0.66	0.53	0.53
MgO	0.92	0.91	1.22	1.03	0.71	0.85	0.89	0.83
ZnO	0.67	0.05	0.02	0.04	0.03	0.03	0.06	0.03
Sum	101.91	100.28	98.52	100.54	98.47	100.43	101.08	100.41
Recalculated Analysis, Rhombohedral Basis								
Fe_2O_3	5.40	5.24	3.79	5.57	5.31	4.94	4.36	5.76
FeO	43.51	43.38	43.03	43.21	42.81	43.57	44.18	43.37
Total	102.44	100.80	98.90	101.09	98.99	100.92	101.51	100.98
Rhomb	94.47	94.83	95.82	94.47	94.86	94.94	95.77	94.28

Sample no. EG 7183

Spinel phase

	1	2	3	4	5	6	7	8
SiO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	26.37	27.16	26.09	26.97	25.33	25.82	26.56	26.15
Al_2O_3	1.25	1.71	1.38	1.41	1.32	1.31	1.48	1.30
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	66.57	63.80	66.30	65.69	67.45	67.58	66.24	66.51
MnO	1.46	1.23	1.45	1.40	1.42	1.41	1.49	1.53
MgO	0.25	0.29	0.23	0.33	0.26	0.14	0.26	0.28
ZnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	95.01	94.19	95.45	95.79	95.78	96.27	96.04	95.77
Recalculated Analysis, Ilmenite Basis								
Fe_2O_3	32.49	29.55	32.37	31.41	33.78	33.38	32.04	32.65
FeO	37.30	37.19	37.14	37.39	37.01	37.51	37.38	37.10
Total	99.13	97.12	98.66	98.91	99.12	99.57	99.21	99.00
Recalculated Analysis, Ulvospinel Basis								
Fe_2O_3	14.94	11.47	15.01	13.47	16.93	16.19	14.36	15.24
FeO	53.11	53.47	52.78	53.55	52.20	52.99	53.30	52.78
Total	97.39	95.33	96.94	97.13	97.45	97.87	97.46	97.28
Usp	75.70	79.30	75.20	77.45	72.70	73.85	76.07	75.14

Rhombohedral phase

	9	10	11	12	13
SiO_2	0.00	0.00	0.00	0.00	0.00
TiO_2	51.16	50.39	50.48	50.26	51.04
Al_2O_3	0.22	0.20	0.29	0.25	0.13
Cr_2O_3	0.00	0.00	0.00	0.00	0.00
FeO	46.85	48.23	48.47	47.63	47.69
MnO	0.44	0.49	0.44	0.45	0.46
MgO	1.49	0.93	0.85	1.40	0.78
ZnO	0.00	0.00	0.00	0.00	0.00
Sum	100.16	100.23	100.52	99.99	100.11
Recalculated Analysis, Rhombohedral Basis					
Fe_2O_3	4.21	5.46	5.36	5.78	3.95
FeO	43.06	43.31	43.64	42.42	44.14
Total	100.58	100.77	101.06	100.57	100.50
Rhomb	95.74	94.57	94.55	94.20	96.08

Færdig fra trykkeriet den 9. oktober 1973

PLATES

Plate I

Aerial photograph, looking approximately west, of the eastern section of the field area showing the relatively prominent dips found in the coastal areas. The headland just off to the right of the picture is Kap Brewster. Photograph reproduced by permission of the Geodætisk Institut, Copenhagen (A20/72).

PLATE I

Plate II

Aerial photograph, looking approximately west from a position near the upper reaches of Stenos Gletscher. The almost horizontal, undisturbed attitude of the flows is well seen as is the uniform level of the upper surface of the lava plateau, which is believed to be its original top. Photograph reproduced by permission of the Geodætisk Institut, Copenhagen (A20/72).

PLATE II