Basalts from the southeastern Greenland continental margin

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Rasmussen, M. H., Campsie, J., Dittmer, F. B. & Bailey, J. C.: Basalts from the southeastern Greenland continental margin. *Bull. geol. Soc. Denmark*, vol. 25, pp. 73–78, Copenhagen, December, 20th 1976. https://doi.org/10.37570/bgsd-1976-25-08

The petrography, chemistry and magnetic properties of igneous rocks, dominantly basaltic, dredged near Kap Walløe, have been studied to determine their provenance. With the exception of one basalt of possible local origin, all specimens were probably ice-rafted over 1000 km from the Lower Tertiary East Greenland igneous province.

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During cruise 711–71 of the USNS Lynch (1971), two dredge hauls – LD53 and LD54 – were recovered from 370 m and 550–730 m depth respectively at 60°28.7'N, 41°48.0'W on the upper continental slope about 55 km east of Kap Walløe, South East Greenland (see fig. 1). Dredge haul LD53 was similar to LD54 and the former yielded 120 kg of rocks; 64 wt. % were crystalline basement rocks, 25 % were basalts and 11 % were sediments. The geographical origin of the basalts of these dredge hauls is the topic of this paper.

On the nearby coast of South East Greenland, Precambrian basement is known from Kap Farvel to Kangerdlugssauq and no effusive basaltic rocks occur (Andrews, Bridgewater, Gormsen, Gulson, Keto & Watterson 1973). The East Greenland Tertiary igneous formations distributed along the coast from Kap Gustav Holm to Shannon Island contain huge volumes of basalt and related rock types (Brooks 1973; Noe-Nygaard 1973).

The shelf in the vicinity of Kap Walløe is considered to be a continuation of the Precambrian shield found on shore (Johnson, Sommerhoff & Egloff 1975). The in situ presence of basalts on the shelf might be expected on the basis of the magnetic anomalies recorded by Vogt (1970) and basaltic debris in the sea-floor sediments (Sommerhoff 1973; Atlasov & Dibner 1964). However, no distinct short wavelength, high amplitude magnetic anomaly pattern characteristic of basalt formations was observed at the dredge locality.

Results

The angularity of all 79 dredged basalt samples varied from angular to rounded with a predominance of angular samples (46 %). Thirty-one of the basaltic samples were selected for study. Anorthite determinations on plagioclases were made via the U-stage. The major elements and Rb, Sr and Cu were determined via X-ray fluorescence analysis; Ba, Co, Cr, Ni and V by optical spectrometry.

Of the 31 analysed samples, 15 form a group of porphyritic and aphyric basalts and are mainly olivine-tholeiitic in composition according to Yoder & Tilley's (1962) normative classification (table 1). The concentration ratios of trace elements in this ol-tholeiite group have been calculated as a function of the average of the trace element values of the samples with the 4 highest differentiation indices (FeO*/MgO) over the average value of the 4 lowest. For Ba and Cu the ratio is 1.2 indicating a slight increase with increasing index, while that of Ni (0.8) and in particular that of Cr (0.5) decrease as might be expected. Rb (0.8) shows a relatively large scatter probably reflecting the relatively high mobility of this large ion in altered rocks. The ratios of Co,

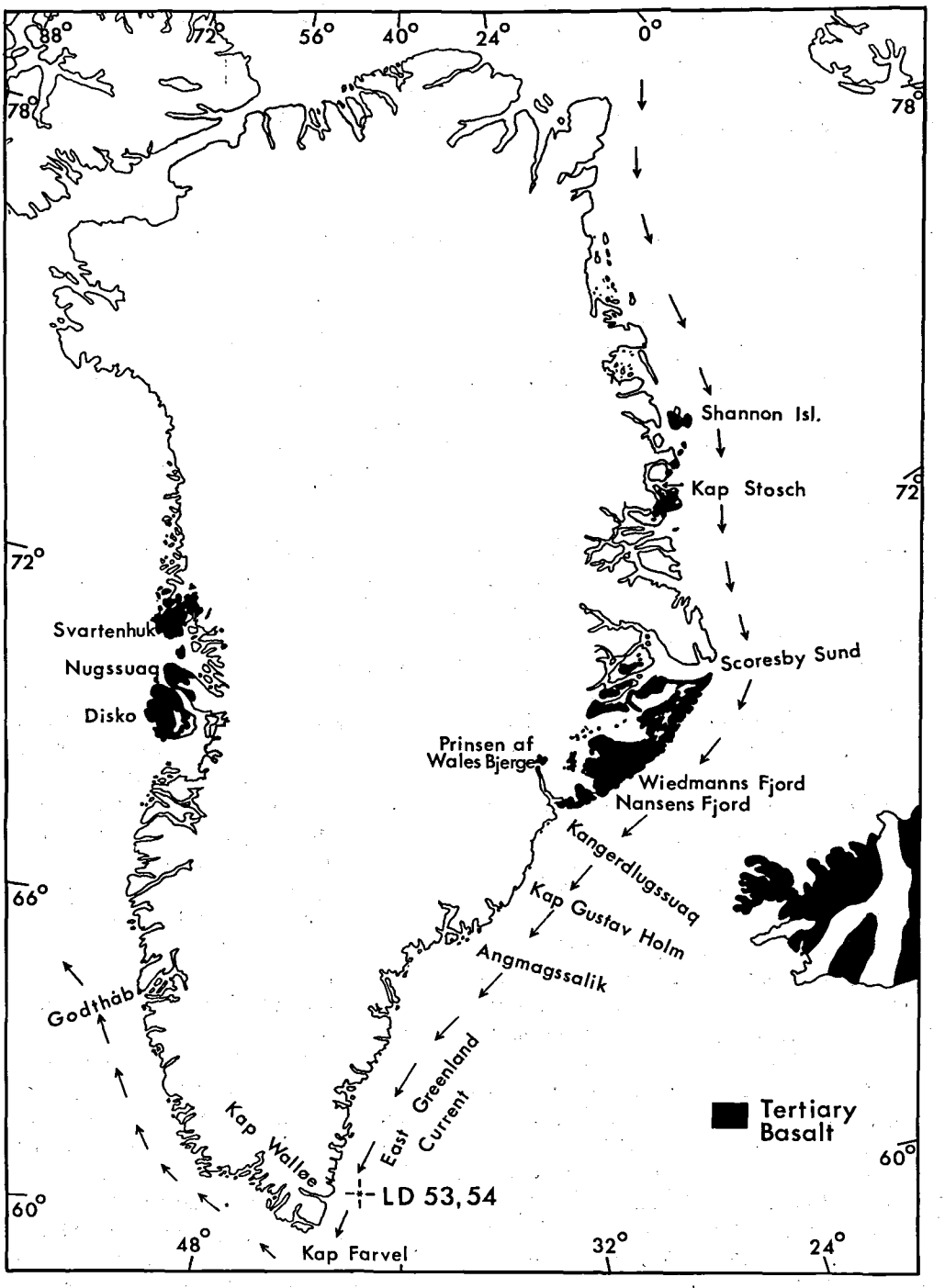

Fig. 1. Map of Greenland showing Tertiary basalt distribution on land after Brooks (1973), the East Greenland Current after Koch (1945) and position of Lynch 711–71 dredge hauls LD53–54.

V and Sr are all around 1.0. The regularity of the distribution of these trace elements lends support to the view that these 15 olivine-tholeiites may be comagmatic.

The ol–tholeiite group has plagioclase phenocrysts or glomerocrysts, 1–6 mm across with An_{77-82}, which make up 4–15 % of the rock. Clinopyroxene microphenocrysts sometimes occur up to 1 vol. %. Serpentinised pseudomorphs after olivine, less than 1 mm across, are always found and amount to 0.5–2 vol. %. The doleritic to intergranular fine-grained groundmass of the porphyritic basalts is similar to that of the aphyric basalts and is composed of plagioclase with An_{55-66}, clinopyroxene, ore and serpentinised remnants.

For 7 samples of the ol-tholeiite group Königsberger's ratio Q, the natural remanent magnetisation (NRM) over the induced magnetisation as a function of the susceptibility K times the earth's magnetic field F (0.5 Ø), has been determined using a portable spinner magnetometer and a susceptibilitymeter. With one exception all samples have Q values equal to or less than 2.

A group of 13 heterogeneous samples, including altered porphyritic and aphyric basalts, fresh dolerites, a pyroclastic basalt, a metabasalt and a rhyodacite, might individually in terms of petrography, major or trace element chemistry be related to the ol-tholeiite group but have for reasons of brevity been omitted from the present discussion. Three individual sample descriptions that may be correlated with published data from Greenland can be given.

Sample OSG 515 is a porphyritic basalt with chloritised plagioclase phenocrysts (13 vol. %) up to 10 mm long and with An_{46}. The intergranular groundmass is fine to medium-grained and composed of rather chloritised plagioclase of An_{33}, fresh clinopyroxene, fresh olivine, ilmenite and magnetite, minor green-brown biotite and apatite. The rock is normatively an alkali-rich olivine tholeiite with extremely high Ba and very high Rb and Sr values (table 1).

Sample OSG 535 is a fresh olivine porphyritic andesine (An_{32}) basalt with semi-crystalline groundmass where plagioclase and pyroxene are barely distinguishable, massive and skeletal ore and glass. The prismatic olivine microphenocrysts (25 vol. %) have Fo_{75} ($2V_x$ = 84°) and are up to 2 mm long. The rock is normatively an olivine-rich tholeiite with enrichment of Rb, Sr, Cr and Ni (table 1).

Sample OSG 536 is a fresh olivine porphyritic lava with a fine-grained groundmass composed of thin elongate clinopyroxene, ore and minor perovskite and interstitial, reversely pleochroic, golden-brown phlogopite plus unidentified material. The microphenocrysts of euhedral olivine (31 vol. %) are up to 2 mm long, have Fo_{92} ($2V_z$ = 88.5°) and show cleavage parallel to the c-axis. The rock is normatively an olivine nephelinite with trace element enrichments similar to sample OSG 535 (table 1).

Discussion

If the LD53–54 basalts were of in situ origin one should observe a distinct short wavelength high amplitude magnetic anomaly pattern at the dredge locality. No such pattern was seen on the Lynch 711–71 magnetic profile.

If the studied basalts were of local origin, i.e. from the nearby continental shelf and from there carried across to the dredge locality in the bottom of an ice-mass (Sommerhoff 1973), they should have become more rounded (Holmes 1960). Against this stands the fact that 46 % of the basalt samples were angular.

If not of local or in situ origin the basalts would then have to be ice-transported via the East Greenland Current (Koch 1945) from a distant source area, e.g. the Tertiary East Greenland basalt province.

Sample OSG 536 can be pin-pointed to the Kangerdlugssuaq Fjord region, where an almost identical rock type, an olivine nephelinite, Sample MM 20385A, has been described (Brooks & Rucklidge 1974), see table 1. Sample OSG 535 may originate in the Prinsen af Wales Bjerge in the backland of the Kangerdlugssuaq Fjord. From this locality Anwar (1955) has described a similar olivine-phyric oligoclase-andesine basalt, sample 2215 (see table 1).

The ol-tholeiite group distinguished in the LD53–54 materials is comparable to tholeiites

Table 1: Major and trace element analyses of dredged rocks from Kap Walløe continental slope and East Greenland

	1	2	3	4	5	6	7	8	9	10
SiO_2	49.46 ± 0.64	50.42	47.33	47.37	47.72	46.73	45.57	43.26	38.09	39.92
Al_2O_3	14.32 ± 0.55	14.76	13.38	13.19	13.33	15.70	7.56	5.88	4.72	4.48
Fe_2O_3	4.29 ± 1.26	4.84	4.89	4.82	5.53	2.85	2.88	3.66	5.63	4.89
FeO	8.50 ± 1.05	8.15	8.62	8.54	8.18	9.90	8.56	11.66	10.21	11.12
MnO	0.18 ± 0.01	0.21	0.18	0.21	0.20	0.17	0.16	0.22	0.18	0.20
MgO	7.06 ± 0.34	5.37	6.31	6.55	6.31	4.68	17.30	17.86	19.24	18.09
CaO	10.84 ± 0.38	10.96	11.79	11.40	10.74	7.27	7.46	8.96	9.91	10.96
Na_2O	2.65 ± 0.28	2.44	2.35	2.48	2.03	3.44	2.03	1.73	2.11	2.43
K_2O	0.28 ± 0.07	0.27	0.26	0.26	0.25	1.91	1.24	1.16	2.00	1.19
TiO_2	2.20 ± 0.22	2.33	2.64	2.48	2.38	2.79	3.91	3.55	4.99	4.10
P_2O_5	0.22 ± 0.06	0.25	0.30	0.25	0.26	1.32	0.37	0.64	0.85	0.58
H_2O^+			2.15	1.92	2.61	2.94	2.32	1.41	1.69	1.86
Sum	100.00	100.00	99.20	99.47	99.54	99.70	99.36	99.99	99.62	98.82
FeO*/MgO	1.77 ± 0.16	2.43	2.08	1.98	2.11	2.66	0.64	0.84	0.80	0.86
C. I. P. W weight norm+										
q		2.6			1.3					
or	1.6 ± 0.4	1.6	1.6	1.5	1.5	11.3	7.3	6.8		
ab	22.0 ± 2.4	20.7	20.5	21.5	17.7	29.1	17.2	12.0		
an	25.6 ± 2.5	28.5	26.0	24.7	27.4	21.8	7.9	4.8		
di	20.9 ± 1.1	20.1	22.5	26.1	21.4	4.7	21.3	28.3	16.7	32.3
hy	15.7 ± 5.4	18.5	19.5	12.8	22.4	5.0	6.2			
ol	4.6 ± 4.3		1.3	5.2		14.2	26.9	31.4	41.0	29.1
mt	2.2 ± 0.0	2.2	2.6	2.5	2.6	2.2	2.2	5.3		5.3
il	4.1 ± 0.4	4.4	5.2	4.8	4.7	5.3	7.4	6.7	9.5	7.8
ap	0.5 ± 0.1	0.6	0.7	0.6	4.7	3.1	0.9	1.5	2.0	1.3
ne								1.4	7.0	8.9
lc									9.3	5.5
ac									4.3	3.7
Trace elements in p. p. m.										
Rb	3.2 ± 2.0	6	2.7	2.5	2.1	43	17	–	38	32
Ba	53 ± 13	113	54	49	101	1200	225	–	470	270
Sr	216 ± 18	230	272	253	335	921	790	–	1020	762
Cr	168 ± 61	–	175	160	109	35	750	–	615	800
Ni	104 ± 12	79	95	93	48	25	650	–	735	585
V	342 ± 24	–	330	342	343	175	179	–	265	315
Co	48 ± 3	–	45	47	48	38	65	–	95	92
Cu	225 ± 39	197	211	207	155	56	142	–	305	200

Col. 1: Mean ± standard deviation of 15 tholeiites from Kap Walløe cont. slope, recalculated waterfree.
Col. 2: Mean of 13 Kap Stosch tholeiites (Noe-Nygaard & Pedersen 1974).
Col. 3: Mean of 9 Scoresby Sund tholeiites (Brooks et al. in prep.).
Col. 4: Mean of 6 Wiedemanns Fjord tholeiites (Brooks et al. in prep.).
Col. 5: Mean of 8 Nansens Fjord tholeiites (Brooks et al. in prep.).
Col. 6: Alkali-rich olivine tholeiite, sample OSG 515 from 535 from Kap Walløe cont. slope.
Col. 7: Olivine porphyritic andesine basalt, sample OSG 535 from Kap Walløe cont. slope.
Col. 8: Olivine-phyric oligoclase-andesine basalt, sample 2215 from Prinsen af Wales Bjerge (Anwar 1955).
Col. 9: Olivine nephelinite, sample OSG 536 from Kap Walløe cont. slope.
Col. 10: Olivine nephelinite, sample MM 20385A from Kangerdlugssuaq Fjord (Brooks & Rucklidge 1974).
$FeO^* = FeO + 0.9 \times Fe_2O_3$.
+ Adjustments made before C. I. P. W. weight norm calculation: Col.s 1, 2, 6, 7, 9, $Fe_2O_3 = 1.50\,\%$; col.s 3–5, $Fe_2O_3/FeO = 0.15$; col.s 8, 10, none.

from both the southern (Fawcett, Brooks & Rucklidge 1973; Brooks, Nielsen & Petersen in prep.) and the northern basalt plateau (Noe-Nygaard & Pedersen 1974). However, Kap Stosch tholeiites generally have higher differentiation indices and are quartz normative. Comparing mean trace element values in the ol-tholeiite group, there is close agreement with Scoresby Sund and Wiedemanns Fjord means (see table 1). With Nansens Fjord tholeiites the match is only partial, since Ba and Ni differ by a factor of 2. A comparison with Kap Stosch tholeiites shows that Sr, Cu and Ni are similar, while Ba and Rb differ by a factor of 2.

Taking the magnetic Q values into account

it is observed that LD53–54 ol-tholeiites have Q values similar to subaerial tholeiite flows from the southern basalt plateau (cf. Tarling 1967), and distinctly lower than values from submarine lavas (Carmichael 1970).

On the basis of the above mentioned parameters, it is preferred to correlate the ol-tholeiite group with the Scoresby Sund and Wiedemanns Fjord region. The group of 13 heterogeneous samples, individually related to the ol-tholeiite group to a greater or lesser extent, might possibly also stem from this region.

Sample OSG 515, which is separable from the ol-tholeiite group due to its alkali enrichment and extremely high Ba and Sr contents, is geochemically similar to Gardar dykes described by Bridgewater & Harry (1968) from the west coast of Greenland. Gardar dykes are known to occur in the Kap Walløe vicinity (Andrews et al. 1973) suggesting that sample OSG 515 might be of local origin.

Conclusion

Among the studied rocks there are no samples of clearly in situ origin. With the exception of one sample of possible local origin, all the rocks are believed to have a distant source. Two olivine porphyritic rocks can be referred to the Kangerdlugssuaq Fjord backland with a high degree of certainty. Fifteen moderately differentiated ol-tholeiites of varying textural appearance can rather safely be correlated with the Scoresby Sund and Wiedemanns Fjord region. The remaining 13 samples may possibly also stem from this region. In general the source area of the dredged basaltic erratics seems to have been the southern basalt plateau which is cut by highly productive glaciers.

Acknowledgements. The authors thank the following individuals for assistance in this work. Jørgen Thuesen calculated the C.I.P.W. norms. Ib Sørensen and Haldis Bollingberg performed analyses of major and trace elements. Erik T. Larsen constructed the portable spinner magnetometer. C. Kent Brooks made unpublished data available for comparison. G. Leonard Johnson and the US Naval Oceanographic Office supplied ship's facilities for collection of the dredge materials. Julius Egloff, Jr. and Dennis Twomey assisted in the dredge operation and collection of magnetic data.

Dansk sammendrag

31 udvalgte vulkanske bjergartsprøver, hovedsagelig basaltiske, optaget med bundskrab fra den sydøstlige grønlandske kontinental skråning i nærheden af Kap Walløe, er blevet undersøgt petrografisk, kemisk og magnetisk med henblik på at bestemme deres oprindelsessted.

Med undtagelse af én basalt prøve af formodet lokal oprindelse antages alle prøver at være transporterede af is fra den Tertiære østgrønlandske basalt provins. 2 olivin porfyriske bjergarter kan med stor sandsynlighed henføres til Kangerdlugssuaq Fjordens bagland. En gruppe på 15 moderat differentierede og ret ensartede olivin tholeiitiske basalter kan med rimelig sikkerhed korreleres med basalter fra Scoresby Sund og Wiedemanns Fjord området. Andre 13 prøver, som er beslægtede med den forannævnte gruppe i større eller mindre grad, stammer muligvis også fra samme område.

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