$^{40}Ar–^{39}Ar$ dating of alkali basaltic dykes along the south-west coast of Greenland: Cretaceous and Tertiary igneous activity along the eastern margin of the Labrador Sea

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A 380 km long coast-parallel alkali basalt dyke swarm cutting the Precambrian basement in south-western Greenland has generally been regarded as one of the earliest manifestations of rifting during continental stretching prior to break-up in the Labrador Sea. Therefore, the age of this swarm has been used in models for the evolution of the Labrador Sea, although it has been uncertain due to earlier discrepant K–Ar dates. Two dykes from this swarm situated 200 km apart have now been dated by the $^{40}Ar–^{39}Ar$ step-heating method. Separated biotites yield plateau ages of 133.3 ± 0.7 Ma and 138.6 ± 0.7 Ma, respectively. One of the dykes has excess argon. Plagioclase separates confirm the biotite ages but yield less precise results. The age 133–138 Ma is earliest Cretaceous, Berriasian to Valanginian, and the dyke swarm is near-coeval with the oldest igneous rocks (the Alexis Formation) on the Labrador shelf.

A small swarm of alkali basalt dykes in the Sukkertoppen (Maniitsoq) region of southern West Greenland was also dated. Two separated kaersutites from one sample yield an average plateau age of 55.2 ± 1.2 Ma. This is the Paleocene–Eocene boundary. The swarm represents the only known rocks of that age within several hundred kilometres and may be related to changes in the stress regime during reorganisation of plate movements at 55 Ma when break-up between Greenland and Europe took place.

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The Labrador Sea between Labrador (Canada) and south-western Greenland (Fig. 1) has a long history of slow extension and basin formation leading up to continental rupture and the start of ocean-floor spreading (e.g. Balkwill *et al.* 1990). The time of the start of extension and the time of continental rupture are important parameters for models of the extension process and the extension rate (e.g. Chian *et al.* 1995a, b; Chalmers *et al.* 1997), and for the interpretation of the geology and hydrocarbon potential in the offshore areas (Chalmers *et al.* 1993; 1995a). However, neither of these times are well constrained. The start of ocean-floor spreading is placed between magnetic anomalies 33 and 27 and cannot at present be more precisely defined owing to the anomalous character of the crust in question (Roest & Srivastava 1989; Chian & Louden 1994; Chalmers & Laursen 1995; Chian *et al.* 1995a, b; Srivastava & Roest 1995; Chalmers 1997).

Ages varying from 160 Ma to 130 Ma have been used to define the onset of rifting between Labrador and Greenland (160 Ma: Chian & Louden 1994; Chian *et al.* 1995b; 130–135 Ma: Keen *et al.* 1994; Chian *et al.* 1995a; Chalmers 1997). Well stratigraphy in the Labrador Sea basins indicates that rifting started there in the early Cretaceous at around 130 Ma. Other evidence comes from the dating of dykes in West Greenland. Watt (1969) described an extensive, coast-parallel swarm of dykes along the south-west coast of Greenland. Their extent, dip directions, and coast-parallel behaviour suggest that they were emplaced during a

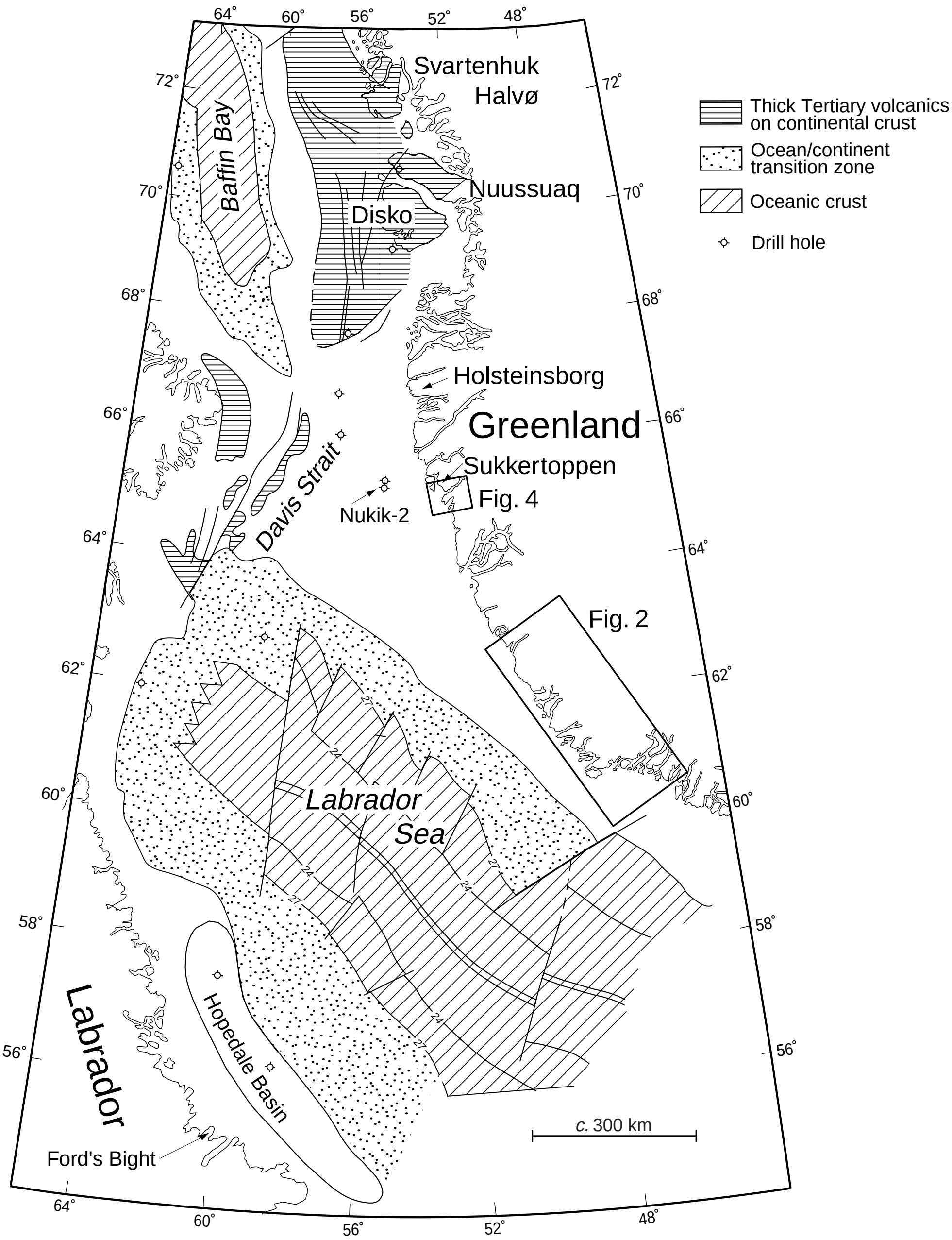

Fig. 1. Map of the Labrador Sea and surrounding areas, after Whittaker (1995). Details of the two dated dyke swarms are given in Figs 2 and 4.

major regional rifting event. This is the earliest known indication of a regional rifting event on the Greenland side of the Labrador Sea. Watt (1969) reported a whole-rock K–Ar age of 138 Ma for one basalt dyke but also noted that a lamprophyre dyke cutting a basalt dyke gave a K–Ar biotite age of 162 Ma – hence the two different ages for the start of extension used by different authors as noted above. The age discrepancy may be caused either by excess argon in the 'old' sample or by loss of argon from the 'young' sample; the K–Ar dating method does not allow distinction between these two possibilities.

Other Mesozoic igneous rocks in western Greenland are mafic alkaline and undersaturated rocks such as kimberlites and lamprophyres which form small dyke swarms occurring intermittently from Ivittuut in the south to Sukkertoppen (Maniitsoq) in the north (Figs 1, 2; Larsen & Rex 1992). These rocks have ages up to 200 Ma and do not appear to be related to any regional tectonic events. In contrast, later Tertiary igneous activity related to continental break-up gave rise to the voluminous tholeiitic flood lavas farther north in the Disko – Svartenhuk Halvø region (e.g. Clarke & Pedersen 1976). A small swarm of alkali basaltic dykes of hitherto unknown age occurs in the Sukkertoppen area some 300 km north of the major coast-parallel dyke swarm and 500 km south of the onshore Tertiary igneous rocks (Fig. 1).

The objective of this work is to constrain better the onset of continental extension in the Labrador Sea by new dating of the coast-parallel dyke swarm with the ^{40}Ar–^{39}Ar step-heating method. The results show that the older K–Ar age of 162 Ma is in error. The Sukkertoppen dyke swarm was included in the present dating project, and a Tertiary age is reported.

Analytical procedures

The ^{40}Ar–^{39}Ar analyses were carried out at the University of Leeds, UK, and the analytical procedures followed those outlined in Rex *et al.* (1993). Standard hornblendes Fy12a, MMHb1 and Hb3gr and biotite LP-6 were used for J calibrations. In addition, Tinto biotite (409 Ma), a Leeds laboratory standard, was also used. All irradiations were carried out at the Ford reactor, Ann Arbor, Michigan, USA. Two irradiations (Runs 1426, 1428 and 1534, 1536, Table 2) were of duration 50 hours in position L67. Runs 1896 and 1897 (Table 3) were of duration 48 hours in position H75. Correction factors used for runs 1426 and 1428 were (40/39)K = 0.031, (37/39)Ca = 1280 and (36/39)Ca = 0.26. The remaining runs used correction factors (40/39)K = 0.031, (37/39)Ca = 1000 and (36/39)Ca = 0.24. Errors are quoted at the one sigma level. Correlation plot data were processed using the program 'Isoplot' (Ludwig 1990).

South-West Greenland coast-parallel dyke swarm

The dykes in this swarm occur in a broad, up to 30 km wide strip that stretches along the coast for about 380 km from Sydprøven in the south to Frederikshåb Isblink in the north (Fig. 2; Watt 1969; Nielsen 1987). The dykes strike parallel to the coast and follow the direction of the coast also in the south where it abruptly changes direction. Because of the parallel alignment of the dykes, cross-cutting relations are very rarely observed. The dykes are on average 10 m thick, with dips usually near vertical except in the south-westernmost part of the swarm, on the Nunarsuit peninsula, where the dips become shallower towards the coast, to *c.* 30° seawards. The rocks are doleritic with subophitic to intergranular textures. They consist of plagioclase, brown augite, Fe-Ti-oxides, olivine, minor amounts of brown primary biotite, accessory apatite, and sometimes some green secondary biotite. Many rocks are relatively unaltered, with preserved fresh olivine, but all have somewhat clouded plagioclase. Chemical analyses of the two dated rocks are given in Table 1. According to the IUGS chemical classification system (Le Maitre 1989) one sample is an alkali basalt and the other is a basalt.

Two samples were chosen for Ar–Ar dating: GGU 45293 from the southern part of the swarm and GGU

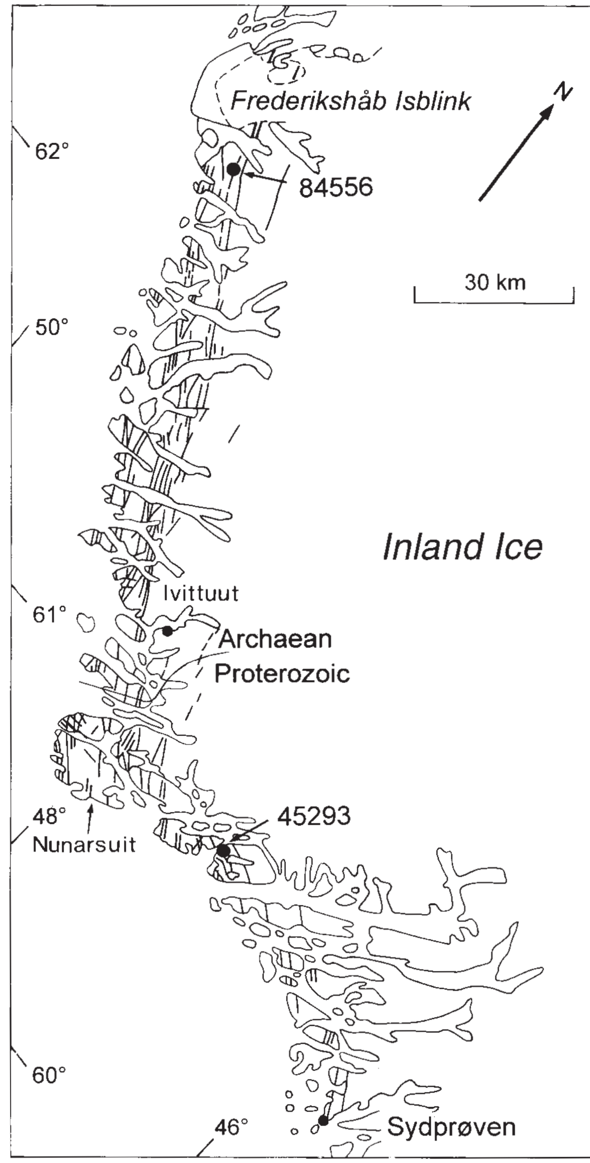

Fig. 2. The South-West Greenland coast-parallel dyke swarm. The locations of the two dated samples GGU 45293 and GGU 84556 are indicated.

Table 1. Chemical analyses of alkali basaltic dykes from south-western Greenland

GGU no.	45293	84556	265424	265880
SiO_2	44.79	45.71	45.67	44.78
TiO_2	3.99	2.75	1.95	1.31
Al_2O_3	14.30	15.04	16.24	14.00
Fe_2O_3	4.02	5.14	1.71	2.42
FeO	10.47	7.32	7.18	6.45
MnO	0.23	0.21	0.12	0.16
MgO	4.93	6.29	4.61	9.97
CaO	9.20	10.81	6.83	11.00
Na_2O	3.50	2.65	3.59	1.96
K_2O	1.37	0.87	2.19	2.48
P_2O_5	1.45	0.70	0.53	0.62
Vol	1.46	2.10	8.92	4.30
	99.71	99.59	99.54	99.44
Rb	29	15	57	78
Ba	856	1038	1194	1790
Pb	7	6	8	6
Sr	949	634	1016	1090
La	46	25	91	125
Ce	95	54	156	211
Nd	49	29	53	69
Y	30	23	21	20
Th	4	4	10	14
Zr	137	82	237	146
Nb	45	23	71	141
Zn	141	115	87	76
Cu	41	55	37	74
Co	36	47	31	49
Ni	12	86	34	204
Sc	19	22	16	20
V	240	322	140	177
Cr	6	129	38	636
Ga	31	28	19	16

Major elements (in wt%): GEUS' Rock Geochemical Laboratory, mainly XRF analyses; FeO by titration and Na_2O by AAS.
Vol: Loss on ignition corrected for iron oxidation during ignition.
Trace elements (in ppm): J.C. Bailey, Geological Institute, University of Copenhagen, XRF analyses.
Samples GGU 45293 and 84556 from the South-West Greenland coast-parallel dyke swarm. Locations in Fig. 2.
Samples GGU 265424 and 265880 from the Sukkertoppen dyke swarm. Locations in Fig. 4.

84556 from the northern part (locations in Fig. 2). Plagioclase and biotite were separated from each sample and dated independently. The results are given in Table 2 and shown in Fig. 3. The biotites from both samples give well defined plateau ages of 133.3 ± 0.7 Ma and 138.6 ± 0.7 Ma respectively, and isochron ages on correlation diagrams (intercept ages) of 133.2 ± 0.8 Ma and 136 ± 4 Ma respectively (errors quoted at 1σ level). The isochron ages are within 1σ of each other, and the average age is 135 Ma. The two plagioclase separates show much less well-defined age plateaus. Selected steps representing in all 39.0% and 26.5% released argon give 122.7 ± 0.8 Ma and 140.9 ± 0.8 Ma, respectively, with isochron ages on correlation diagrams of 127 ± 12 Ma and 134 ± 12 Ma. The plagioclase data thus support the biotite ages but have considerably larger uncertainties.

In the correlation diagrams the minerals from the southern sample (45293) show $^{40}Ar/^{36}Ar$ intercepts within errors of the atmospheric value (295.5). In contrast, both biotite and plagioclase from the northern sample (84556) have $^{40}Ar/^{36}Ar$ intercepts considerably higher than the atmospheric value, indicating that excess argon is present in this sample. The two samples are petrographically quite similar although 84556 is more altered than 45293. The most obvious difference between them is that the southern dyke is intruded into Proterozoic basement of age around 1800 Ma whereas the northern dyke is intruded into Archaean basement of age around 2800 Ma (Kalsbeek *et al.* 1990). An apparent dependence of the argon spectra on the nature of the side wall was also found by Reid & Rex (1994) in the Mehlberg dyke in southern Africa. The part of this dyke that cuts high-K granitoids contains excess argon, whereas the part of the dyke that cuts massive K-poor quartzites does not. Regional variations in excess argon in basement rocks have been found across the Grenville Front in Ontario and are ascribed to interaction of mineral blocking trajectories with the ambient pressure of argon (Smith *et al.* 1994). A similar explanation may apply to igneous rocks intruded into basement of different ages and lithology.

Sukkertoppen dyke swarm

The dykes in this swarm were found during prospecting work by Kryolitselskabet Øresund A/S and were described in a company report by Juhava (1974). The dykes occur in a *c.* 20 km by 40 km area east of the town Sukkertoppen (Maniitsoq) (Fig. 4). It is possible

Table 2. Results of stepwise degassing of separated biotite and plagioclase from the South-West Greenland coast-parallel dyke swarm

Step	T °C	$^{39}Ar_K$	$^{37}Ar_{Ca}$	$^{38}Ar_{Cl}$	Ca/K	$^{40}Ar^*/^{39}Ar_K$	% $^{40}Ar_{Atm}$	Age, Ma	Error, Ma	%^{39}Ar
GGU 45293 biotite Run no. 1428, J = 0.01017 ± 0.5%										
1	600	5.3	0.91	0.97	0.34	2.622	48.2	47.5	7.4	1.5
2	680	4.7	0.33	0.36	0.14	7.444	58.2	131.7	1.1	1.3
3	720	17.9	0.27	0.83	0.03	7.521	12.7	133.0	0.6	4.9
4	750	23.4	0.20	0.89	0.02	7.485	6.9	132.4	0.4	6.4
5	785	34.4	0.23	1.21	0.01	7.490	3.4	132.4	0.3	9.4
6	835	49.9	0.30	1.82	0.01	7.523	1.7	133.0	0.5	13.7
7	940	71.1	0.45	2.87	0.01	7.584	1.7	134.1	0.3	19.5
8	1075	151.4	1.22	4.22	0.02	7.554	2.4	133.5	0.3	41.6
9	1250	5.8	2.05	0.15	0.71	30.55	4.3	488.2	1.4	1.6
Plateau age = 133.3 ± 0.7 Ma (steps 2–8); intercept age = 133.2 ± 0.8 Ma.										
$^{40}Ar^*/^{39}Ar_K$ = 7.834 ± 0.2; Wt% K = 8.5; $^{40}Ar^*$ = 477 × 10^{-7} cm^3g^{-1}.										
GGU 84556 biotite Run no. 1534, J = 0.01041 ± 0.5%										
1	630	2.0	0.91	0.42	0.92	59.39	7.6	868.4	1.9	0.8
2	705	2.4	0.20	0.35	0.16	11.65	49.6	206.5	3.1	0.9
3	750	5.8	0.24	0.70	0.08	9.541	14.8	170.8	0.7	2.3
4	790	9.2	0.23	0.83	0.05	8.781	9.2	157.8	1.4	3.6
5	840	15.9	0.29	1.22	0.04	8.254	5.3	148.7	0.4	6.3
6	945	42.5	0.55	2.89	0.03	8.131	2.7	146.6	0.6	16.8
7	1040	63.4	0.55	3.51	0.02	7.708	2.3	139.2	0.3	25.1
8	1110	87.3	1.01	3.20	0.02	7.634	1.3	138.0	0.2	34.5
9	1340	24.4	5.55	0.78	0.45	7.691	3.3	139.0	0.4	9.6
Plateau age = 138.6 ± 0.7 Ma (steps 7–9); intercept age = 136 ± 4 Ma.										
$^{40}Ar^*/^{39}Ar_K$ = 8.309 ± 0.14; Wt% K = 5.6; $^{40}Ar^*$ = 341 × 10^{-7} cm^3g^{-1}.										
GGU 45293 plagioclase Run no. 1426, J = 0.01056 ± 0.5%										
1	600	3.2	8.5	0.19	5.29	7.828	77.9	143.3	19.0	2.6
2	720	8.0	13.5	0.09	3.36	6.792	56.7	125.0	1.1	6.5
3	805	8.7	14.0	0.06	3.19	7.437	17.0	136.4	0.6	7.1
4	905	7.8	6.6	0.06	1.68	6.710	23.6	123.5	1.2	6.4
5	985	13.1	4.9	0.14	0.75	6.547	27.3	120.6	0.6	10.7
6	1070	26.8	9.4	0.44	0.70	6.707	27.1	123.5	0.3	21.9
7	1130	37.7	14.5	0.77	0.76	7.104	25.7	130.5	0.3	30.8
8	1200	12.5	14.8	0.49	2.36	7.847	35.4	143.6	0.5	10.2
9	1325	4.8	12.4	0.24	5.15	8.012	41.6	146.5	1.0	3.9
Total gas age = 129.8 ± 0.6 Ma; intercept age = 127 ± 12 Ma.										
$^{40}Ar^*/^{39}Ar_K$ = 7.066 ± 0.4; Wt% K = 2.4; $^{40}Ar^*$ = 124 × 10^{-7} cm^3g^{-1}.										
GGU 84556 plagioclase Run no. 1536, J = 0.01041 ± 0.5%										
1	600	1.7	5.4	0.07	6.17	16.74	43.7	289.8	3.3	2.3
2	780	9.0	18.7	0.12	4.16	8.186	23.9	147.5	0.5	11.7
3	910	12.5	20.8	0.16	3.30	7.813	4.5	141.1	0.6	16.4
4	1015	9.1	6.0	0.13	1.31	7.789	6.7	140.6	0.9	11.9
5	1070	8.5	4.9	0.14	1.15	8.044	9.1	145.1	1.0	11.1
6	1105	11.2	4.4	0.20	0.78	8.211	10.0	148.0	0.6	14.6
7	1145	17.0	7.6	0.33	0.89	8.923	10.8	160.2	0.4	22.3
8	1330	7.5	17.2	0.31	4.59	15.04	11.4	262.4	1.0	9.8
Total gas age = 163.2 ± 0.3 Ma; intercept age = 134 ± 12 Ma.										
$^{40}Ar^*/^{39}Ar_K$ = 9.094 ± 0.2; Wt% K = 1.8; $^{40}Ar^*$ = 119 × 10^{-7} cm^3g^{-1}.										

Columns 3–5 are volumes (× 10^{-9} cm^3). $^{40}Ar^*$ = radiogenic ^{40}Ar, gas volumes corrected to S.T.P.
Errors are quoted at the 1σ level.

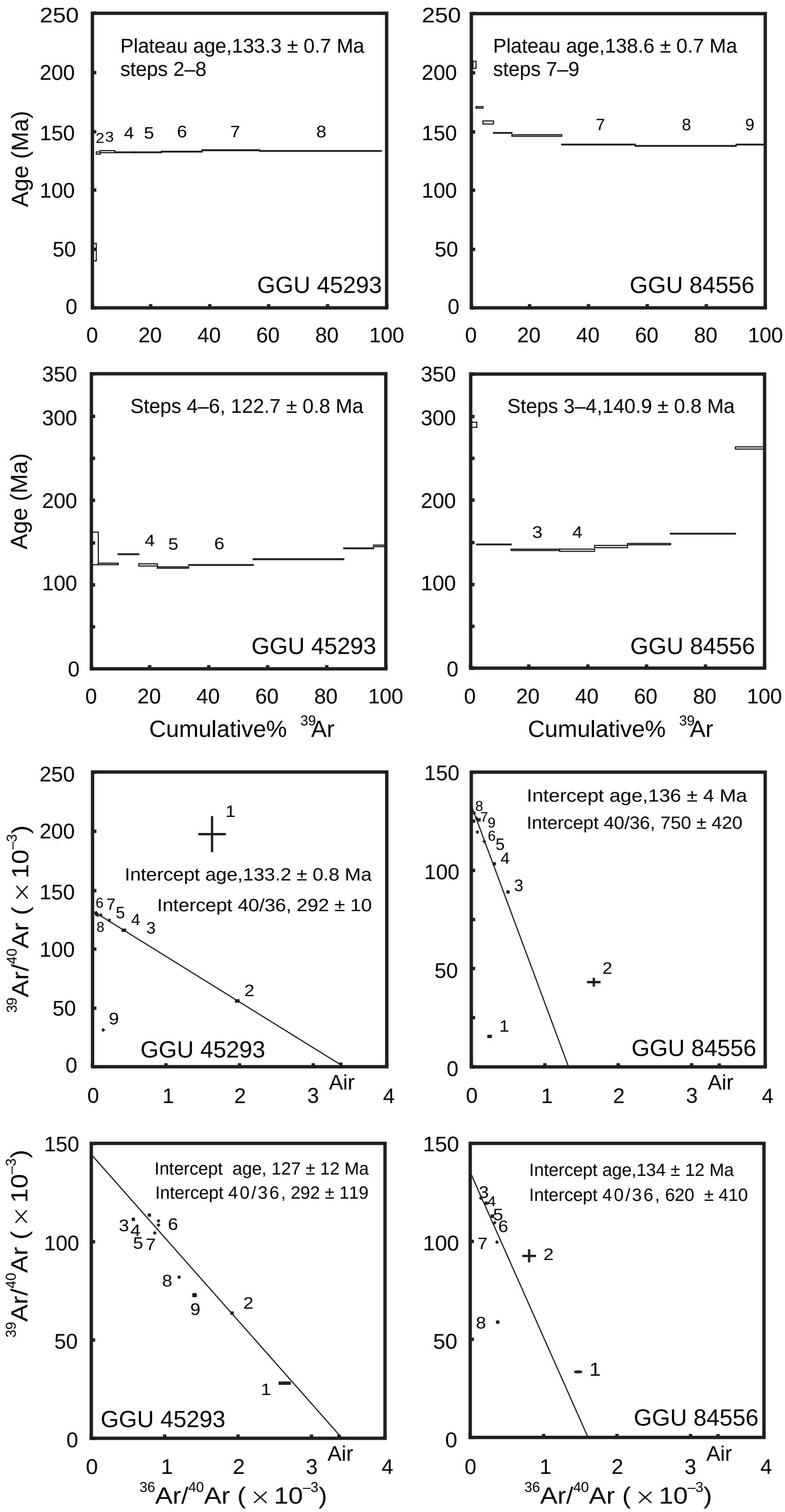

Fig. 3. Age spectra and correlation diagrams for separated biotite and plagioclase from two samples from the coast-parallel dyke swarm in south-western Greenland. The quoted uncertainties are 1σ.

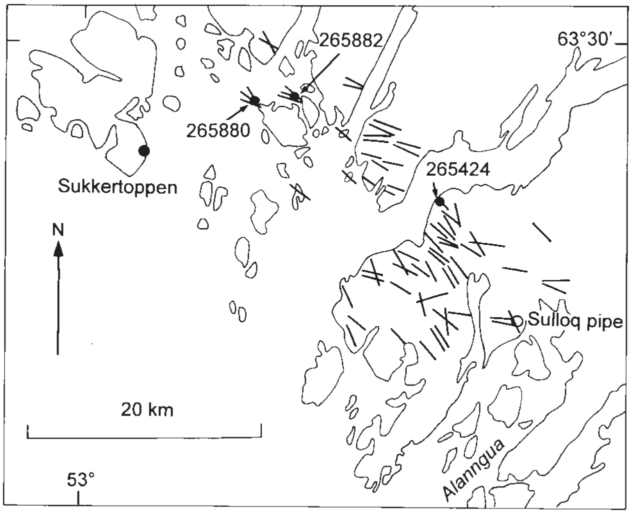

Fig. 4. The Sukkertoppen dyke swarm, after Juhava (1974). The dykes are shown schematically by strike lines with exaggerated lengths. In the field, each dyke can only be followed over a short distance. The locations of the dated (GGU 265882) and analysed (GGU 265424 and 265880) samples are indicated.

that they continue farther to the north; this area was not investigated. The dykes strike mostly NW, approximately parallel to the coast in the area, but the strikes vary between N and W. Dips are steep. The dykes are usually 0.2–2 m thick, with variable thickness along strike and frequent *en echelon* displacements. They have brownish pitted weathering surfaces. Many dykes have a zonal structure with contact-parallel variations in grain size and mineral distribution. At Alanngua fjord one dyke shows a diatreme-like, 45 m by 65 m enlargement named the Sulloq pipe (Fig. 4). This is rich in gneiss inclusions, but no mantle inclusions have been found.

The dykes are porphyritic and are described by Juhava (1974) as lamprophyres because of the ubiquitous mafic phenocrysts. However, many samples also have plagioclase phenocrysts. Chemically, they are potassic trachybasalts and basalts (Le Maitre 1989). The appropriate lamprophyre name would be camptonite (Rock 1991). Two analyses are presented in Table 1.

Table 3. Results of stepwise degassing of separated amphibole from the Sukkertoppen dyke swarm

Step	*T* °C	$^{39}Ar_K$	$^{37}Ar_{Ca}$	$^{38}Ar_{Cl}$	Ca/K	$^{40}Ar^*/^{39}Ar_K$	% $^{40}Ar_{Atm}$	Age, Ma	Error, Ma	%^{39}Ar
GGU 265882 kaersutite		Run no. 1896, J = 0.00257 ± 0.5%								
1	725	0.07	0.17	0.01	4.90	8.08	98.4	37.1	73.3	0.8
2	975	0.12	0.24	0.02	4.10	24.79	54.4	111.4	17.1	1.3
3	1040	2.40	9.18	0.83	7.61	11.70	16.7	53.4	0.8	27.2
4	1065	2.69	10.54	0.90	7.80	12.32	5.6	56.2	1.0	30.4
5	1085	1.42	5.69	0.45	7.98	12.85	3.9	58.6	2.5	16.0
6	1115	0.28	1.20	0.09	8.50	14.80	14.3	67.3	3.9	3.2
7	1210	0.89	4.59	0.29	10.30	13.41	12.2	61.1	1.4	10.0
8	1340	0.98	5.24	0.31	10.65	25.94	18.0	116.4	2.9	11.1
Plateau age = 55.7 ± 0.8 Ma (steps 3–5).										
$^{40}Ar^*/^{39}Ar_K$ = 14.06 ± 1.4; Wt% K = 0.9; $^{40}Ar^*$ = 24.1 × 10^{-7} cm^3g^{-1}.										
GGU 265882 kaersutite		Run no. 1897, J = 0.00258 ± 0.5%								
1	735	0.07	0.16	0.01	4.26	42.74	91.9	188.7	39.5	0.7
2	825	0.04	0.04	0.00	2.09	66.61	22.9	286.1	35.3	0.4
3	945	0.05	0.09	0.01	3.41	16.59	75.6	75.6	18.6	0.5
4	980	0.05	0.12	0.01	5.41	29.80	58.2	133.6	44.5	0.4
5	1025	0.66	2.50	0.24	7.52	11.55	33.1	53.0	4.0	6.4
6	1075	5.24	20.39	1.78	7.74	11.73	10.4	53.8	0.5	50.8
7	1145	2.86	11.63	0.93	8.09	12.39	5.0	56.8	0.6	27.7
8	1330	1.35	7.58	0.43	11.18	23.49	10.6	106.1	1.5	13.1
Plateau age = 54.7 ± 0.5 Ma (steps 5–7).										
$^{40}Ar^*/^{39}Ar_K$ = 13.96 ± 1.0; Wt% K = 1.0; $^{40}Ar^*$ = 24.7 × 10^{-7} cm^3g^{-1}.										

Columns 3–5 are volumes (× 10^{-9} cm^3). $^{40}Ar^*$ = radiogenic ^{40}Ar, gas volumes corrected to S.T.P.
Errors are quoted at the 1σ level.

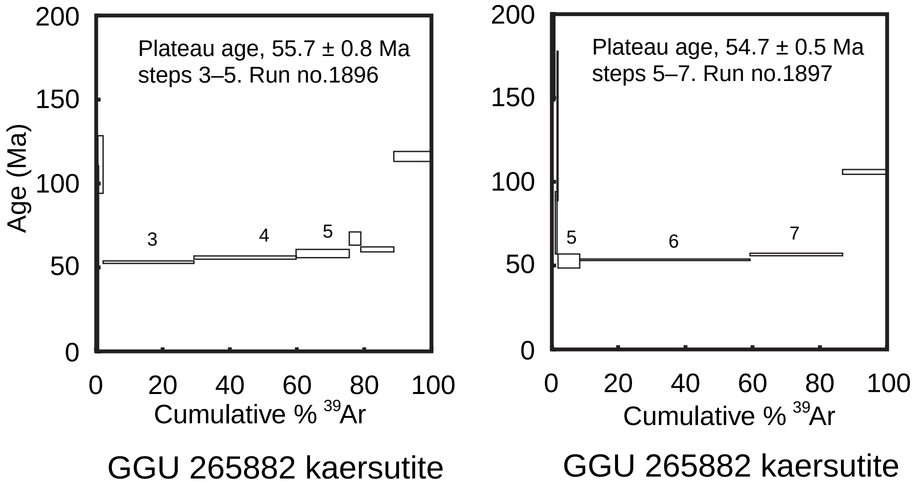

Fig. 5. Age spectra for two kaersutite separates from one sample from the Sukkertoppen dyke swarm.

The mafic phenocrysts are augite, kaersutite and olivine in varying proportions. The groundmass has panidiomorphic-granular to intersertal texture and consists of augite, plagioclase, kaersutite, Fe-Ti-oxides, brown mica, apatite, and a nearly isotropic matrix of zeolite(?). The rock may contain ocelli filled with carbonate or zeolite or both. The dated sample (GGU 265882) contains up to 1 cm kaersutite megacrysts which were separated for dating.

Two samples were originally selected for separation and dating of kaersutite (no samples had sufficient amounts of mica). Kaersutite from sample GGU 265880 was run in duplicate with disappointing results. The very low potassium content resulted in poor spectra and uncertain correlation plot isochron ages (53 ± 15 and 70 ± 12 Ma). The first analysis of sample GGU 265882 was spoilt by operational difficulties resulting in one step with age 54.7 ± 1.8 Ma from 75% of the gas and a correlation plot isochron age of 56 ± 10 Ma. A new separate was subsequently analysed in duplicate, and the results are shown in Table 3 and Fig. 5. The mean of two plateau ages is 55.2 ± 1.2 Ma. The correlation plots produced very poor isochrons (not shown). In both runs the last heating step produced excess argon. How this argon is hosted in apparently homogeneous megacrysts is not clear; the side wall is of Archaean age and there may be a side wall effect as described above for the coast-parallel dyke swarm.

Discussion

The development of the Labrador Sea during the Mesozoic and Tertiary is known from reflection and refraction seismic surveys, magnetic profiling, and exploratory wells drilled on the shelves of both West Greenland and eastern Canada. Data from the Canadian side have been reviewed by Balkwill *et al.* (1990) and Keen *et al.* (1990) and the igneous rocks by Pe-Piper *et al.* (1990). Data from the Greenland side have been summarised by Chalmers *et al.* (1993, 1995a). In the following, the absolute ages given for chronostratigraphic units are from Gradstein *et al.* (1994).

Start of extension in the Labrador Sea area

The oldest rocks known from the Labrador–Greenland basins are the volcanic rocks of the Alexis Formation drilled in wells in the Hopedale Basin on the Labrador shelf (Fig. 1). Rocks from the Alexis Formation have yielded whole-rock K–Ar ages in the interval 139–104 Ma, i.e. Early Cretaceous (Umpleby 1979). They are reported to be alkali basalts (Balkwill *et al.* 1990; Williamson *et al.* 1995), but no analyses are published. Possible coeval onshore igneous rocks are lamprophyre–carbonatite dykes at Ford's Bight on the coast of central Labrador (King & McMillan 1975), K–Ar dated at 145 and 129 Ma (Umpleby 1979). The Alexis Formation is overlain by the sedimentary Bjarni Formation, and the oldest age assigned to this is Barremian (127–121 Ma) based on spores and pollen (Umpleby 1979).

On the Greenland shelf, the oldest sequences have not been drilled. Chalmers *et al.* (1993) tentatively correlated the oldest sequence (Kitsissut sequence) with the lower Bjarni Formation on the Labrador shelf. It is not known whether the Kitsissut sequence includes igneous rocks or whether igneous intrusive rocks of similar age are present in the offshore areas. Chalmers *et al.* (1993) suggested that the main phase of rifting is represented by the overlying Appat sequence which is correlated with the upper Bjarni Formation of Albian age (112–99 Ma).

Onshore West Greenland, Mesozoic igneous rocks form two age groups (Larsen & Rex 1992). One broad group at 220–166 Ma comprises small dyke swarms of kimberlite, carbonatite, and ultramafic and alkaline lamprophyre. These rocks show no obvious tectonic relations to regional rifting events. A younger group at 141–119 Ma includes the coast-parallel dyke swarm considered here and also comprises ultramafic and alkaline lamprophyre dykes north of Frederikshåb Isblink (Hansen & Larsen 1974). These lamprophyre dykes occur at the northernmost extent of the regional coastal dyke swarm and may be related to it; the age interval is right but is too broad to allow any firm conclusions on the relationship.

The South-West Greenland coast-parallel dyke swarm dated in this work is generally regarded as one of the earliest manifestations of rifting in the Labrador Sea region (Watt 1969; Balkwill *et al.* 1990; Pe-Piper *et al.* 1990; Chalmers *et al.* 1993; Chian & Louden 1994, Chian *et al.* 1995b). The dyke swarm is situated adjacent to that part of the Labrador Sea where sea-floor spreading subsequently took place, whereas the swarm is not present farther north adjacent to the broad and tectonically complicated continental shelf areas of the northern Labrador Sea and the Davis Strait (Fig. 1; e.g. Chalmers *et al.* 1995a). The two dated samples are situated 200 km apart (Fig. 2). Although the biotite *plateau* ages of 133.3 ± 0.7 Ma and 138.6 ± 0.7 Ma suggest that the southern sample (45293) may be slightly younger than the northern sample (84556), the biotite *isochron* ages of 133 ± 0.8 Ma and 136 ± 4 Ma are within the analytical uncertainty of each other. This supports the notion that the coast-parallel dyke swarm was emplaced along its entire length within a short time span as a consequence of a regional stretching event. Our data indicate that this event is of earliest Cretaceous age, Berriasian to Valanginian, and that the earlier age determination of 162 Ma (Watt 1969) is in error. The dyke swarm is nearly coeval with the alkali basalts of the Alexis Formation on the Labrador shelf, perhaps slightly older. More precise dating of the Alexis Formation is necessary to determine if these igneous rocks situated on conjugate rift margins were produced in the same event.

Tertiary rocks

Tertiary igneous rocks are widespread and voluminous in the Labrador Sea – Davis Strait region. Biostratigraphic and radiometric (mostly K–Ar) ages of drilled and onshore exposed rocks are dominantly Paleocene, ranging back into the late Cretaceous (Balkwill *et al.* 1990; Pe-Piper *et al.* 1990; Larsen *et al.* 1992; Storey *et al.* 1998). The start of normal velocity ocean floor spreading in the Labrador Sea took place in the Paleocene, around geomagnetic chrons C27–C28 (61–63 Ma, Berggren *et al.* 1995) (Chalmers 1991; Chian & Louden 1994; Chalmers & Laursen 1995) and was accompanied by a burst in volcanic activity, where large amounts of tholeiitic picrites and basalts were erupted onto the continental margins of West Greenland and Labrador (Clarke & Pedersen 1976; Chalmers *et al.* 1995b; Storey *et al.* 1998). This period of volcanic activity ended at about 59 Ma (Storey *et al.* 1998). Eocene volcanic activity in West Greenland at around 52 Ma is also reported by Storey *et al.* (1998), and intrusion of sills and dykes took place between the two volcanic episodes.

The age of 55.2 ± 1.2 Ma obtained in this work for the alkali basalt dyke swarm in the Sukkertoppen area is unusual in West Greenland, the only other known examples being some dykes and sills on Disko and Nuussuaq *c.* 400 km north of Sukkertoppen (Storey *et al.* 1998). South of Disko Bugt (69°N) the Sukkertoppen dyke swarm represents the only known occurrence of onshore Tertiary rocks. Offshore, 100 km due west of Sukkertoppen, the Nukik-2 well (Fig. 1) terminated in tholeiitic dolerites of Paleocene age according to biostratigraphy (Rolle 1985) and K–Ar dating (68–62 Ma; Hald & Larsen 1987) and thus apparently unrelated to the onshore dyke swarm. The Sukkertoppen dykes have no obvious relations to other features either onshore or offshore, although the arcuate trend of the swarm (Fig. 4) is reminiscent of the arcuate fault pattern seen offshore between Sukkertoppen (Maniitsoq) and Holsteinsborg (Sisimiut) (Fig. 1; Chalmers *et al.* 1995a). However, 55 Ma (magnetochron C24r) is the time at which sea-floor formation started along the East Greenland margin (Talwani & Eldholm 1977), accompanied by reorganisation of the plate movements on a regional scale. Even though the Sukkertoppen dyke swarm is far removed from the sites of construction of new ocean floor (min. 500 km), it is possible that stresses related to the plate reorganisation and the opening in the east could have produced tension in the west, leading to reactivation of old faults and small degrees of melting and production of the alkaline dyke swarm.

Conclusions

^{40}Ar–^{39}Ar ages for two samples situated 200 km apart in the 380 km long coast-parallel dyke swarm in South-West Greenland indicate that the swarm was emplaced within a short time interval in the earliest Cretaceous, 133–138 Ma (Berriasian to Valanginian). An age of 162 Ma reported by Watt (1969) is thus in error. The coast-parallel dyke swarm comprises the oldest known rocks (igneous or other) that can be related to regional rifting in the Labrador Sea region. Possibly coeval igneous rocks on the Labrador side are the offshore basalts of the Alexis Formation, known from drill holes.

An ^{40}Ar–^{39}Ar age for kaersutite from one sample from a small swarm of alkali basalt dykes in the Sukkertoppen region indicates an Early Tertiary age, around the Paleocene–Eocene boundary at 55 Ma. These rocks are the only known Tertiary igneous rocks onshore in West Greenland south of Disko Bugt, although older (Paleocene) tholeiitic basalts occur offshore adjacent to the Sukkertoppen region. The activity at 55 Ma may be caused by tension due to changes in the stress regime during reorganisation of plate movements and the onset of sea-floor spreading along the East Greenland margin.

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