Palaeomagnetism of the oldest Tertiary basalts in the Kangerdlugssuaq area of East Greenland

ANGELA M. FALLER

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Measurements have been made of the natural remanent magnetisation of Lower Tertiary basalts from Kangerdlugssuaq on the Blosseville Kyst of central East Greenland. The samples were taken from the base of a 9 km sequence of flows and are associated with fossiliferous marine sediments of uppermost Palaeocene age. The reversed polarity, mean stable remanence direction (D = 159°, I = –63°, α_{95} = 9°), and corresponding palaeomagnetic pole position (185° E, 63° N), are in close agreement with those found by previous workers who sampled higher parts of the basalt pile. The implications concerning the age of the opening of the North-east Atlantic and the geomagnetic polarity time scale are discussed.

Angela M. Faller, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, England. June 6th, 1975.

Tertiary flood basalts outcrop extensively in East Greenland between Kangerdlugssuaq and Scoresby Sund (fig. 1). It is generally accepted that these and the Faeroese lavas were produced during the initial rifting episode which immediately preceded the opening of the Northeast Atlantic. Brooks (1973) suggested that this vulcanicity occupied only a few million years, during which the whole of the East Greenland basalt pile was erupted. As palaeomagnetic results from these basalts are accumulated, together with palaeontological and radiometric age determinations, it becomes increasingly more meaningful to test this hypothesis and to improve the precision of the date of initial separation of the Greenland and European plates.

Palaeomagnetic results for the Tertiary basalts of the Scoresby Sund area have been reported by Tarling (1967), Watt & Watt (1971) and Hailwood et al. (1973). Fig. 1 shows all the localities in East Greenland which have been sampled. Tarling studied four successions of flows, at the top of the basalt in Kong Christian IX Land (Torvgletscher), Muslingehjørnet, Pyramiden, and at the head of Wiedemann Fjord. All were found to be reversely magnetised and to have mean directions of magnetisation which did not differ significantly and when combined gave D = 168°, I = – 62°, (α_{95} = 15°), corresponding to a pole position of 174°E, 63°N. Watt & Watt measured the magnetic polarity directly in the field and concluded that the basalts of Gåseland were predominantly reversely magnetised. Hailwood et al. sampled the north-east side of Sydbræ, where the lowest lavas outcrop immediately above the Pre-Cambrian basement. Their preliminary results suggested a mean inclination around – 60°, with no true polarity changes within a 600 m sequence of flows. They concluded, therefore, that this part of the pile was extruded during a reversed period of the geomagnetic field.

Although the stable samples of Tarling and of Hailwood et al. have reversed magnetisation, neither the time intervals represented by the different flow sequences nor their stratigraphic relationships are known. The four localities discussed by Tarling are separated by major faults, which precludes deduction of the total thickness of the basalts. This, however, is unlikely to exceed 3 km in the Scoresby Sund area, compared with over 9 km to the east of Kangerdlugssuaq, where the base is well exposed. It is probable, therefore, that Tarling and Hailwood et al. sampled the upper part of the total pile.

Clearly, before concluding that all the Tertiary basalts of East Greenland were erupted

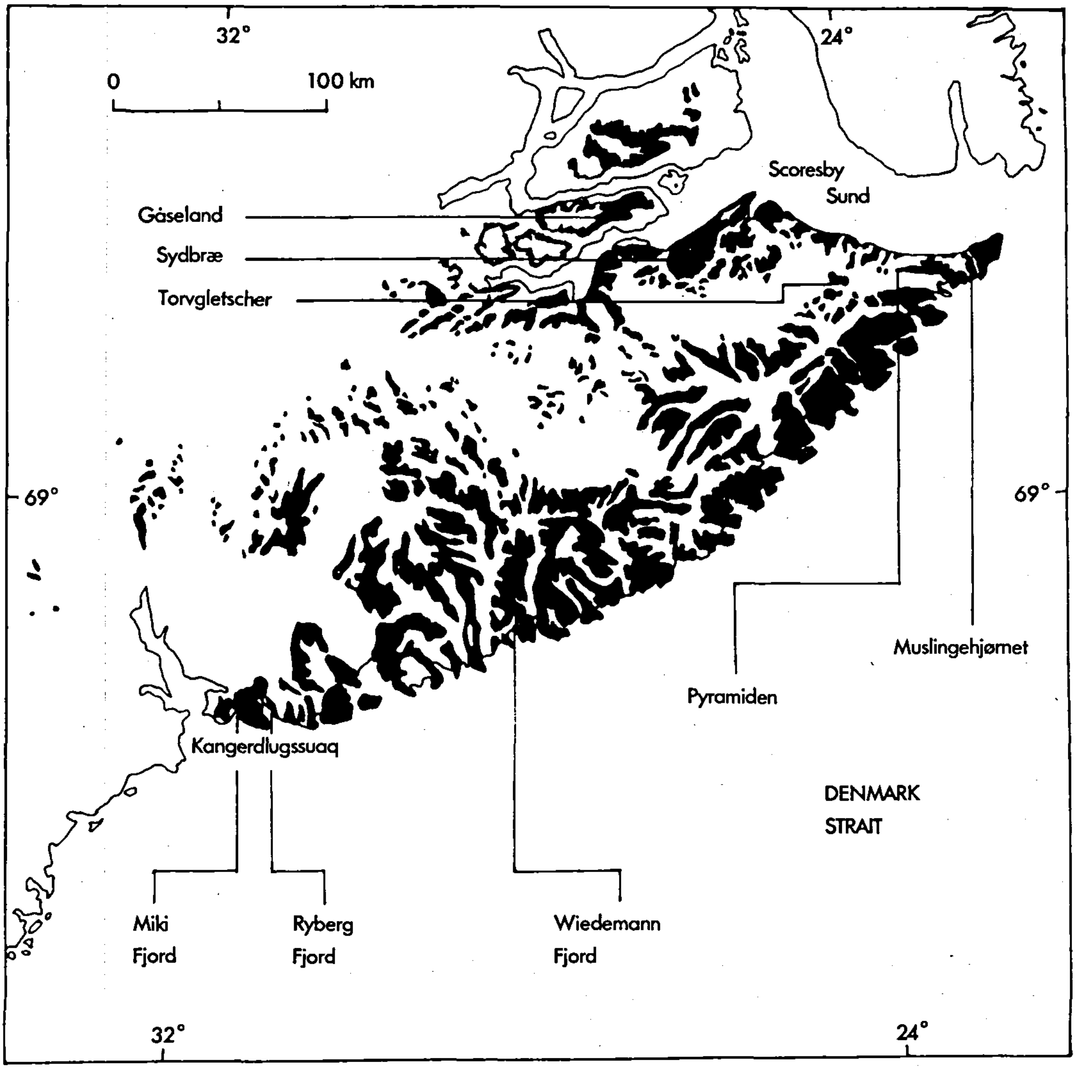

Fig. 1. Sketch map of East Greenland showing outcrop of Tertiary basalt (black) and localities sampled for palaeomagnetism for the present study and by previous workers (see text).

during the same geomagnetic reversal period, it would be desirable to make systematic palaeomagnetic measurements throughout the whole pile. This remains to be completed; but some results from samples known to be at the base of the thickest part of the pile in the Kangerdlugssuaq area are now available and are presented here.

Geology and Sampling

The area east of Kangerdlugssuaq (68°N, 31°W), where the base of the lava pile is adequately exposed was re-examined in 1974 by Soper et al. (in press). Here, late Cretaceous – early Tertiary marine sediments are overlain conformably by more than 9 km of tholeiitic basalts similar to those of the Scoresby Sund area. The lowest portion of the pile (the Vandfaldsdalen Formation) is submarine with pillow lavas, hyaloclastic breccias, slide breccias and bedded tuffs. A shale horizon ap-

TABLE 1. Details of sites sampled within the Vandfaldsdalen Formation

Site No.	*Sample Nos.*	*Locality*	*Description*	*Height above base*	*Dip*
1	1–3	5 km W of head of Ryberg Fjord	basalt flow 10 m thick	60 m	5° to 165°
2	4–6	N coast of Ryberg Fjord	basalt flow passing into autobreccia	200 m	10° to 155°
3	7–9	'Wager's locality', 2 km W of site 2	basalt flow 3 m thick	6 m	10° to 155°
4	10–12	2 km from coast of Miki Fjord in Vandfaldsdalen	20 m flow resting directly on non-volcanic sediments	0 m	10° to 165°
5	13–15	3 km S of site 4	15 m flow immediately below main breccia	320 m	10° to 165°

proximately 60 m above its base at Ryberg Fjord has yielded marine microfossils, dinoflagellates, which Professor C. Downie has dated as Lower Sparnacian (uppermost Palaeocene).

At Kap Brewster, the basalts are overlain unconformably by marine sediments of the Kap Dalton Formation, of Middle Eocene to early Oligocene age (Birkenmajer, 1972). The palaeontological evidence therefore suggests that the whole basalt sequence was developed in latest Palaeocene – earliest Eocene times. Radiometric age determinations do not at present improve the precision of this estimate. Beckinsale et al. (1973) obtained apparent ages from 45 to 60 Ma from the basalts and Hailwood et al (1973) a range from 47 to 52 Ma. The older values are close to those estimated radiometrically for plateau basalts elsewhere in the North Atlantic Tertiary Province.

Oriented hand samples were collected from five sites within the Vandfaldsdalen Formation in the Miki Fjord – Ryberg Fjord area by Dr. N. J. Soper (fig. 1). Details of these are presented in Table 1. Two cores were drilled from each oriented sample and the intensity and direction of the remanent magnetisation were measured on a Digico balanced fluxgate spinner magnetometer. Each core was then progressively cleaned by alternating field (a. f.) demagnetisation at peak fields of 5, 10, 20, 30, and 40 mT. The optimum peak field for each site was taken to be that which gave the greatest precision estimate for the site mean direction.

Results

The results are tabulated in Table 2. Fig. 2 shows the site mean directions after a.f. cleaning and correcting for dip. All cores from sites, 1, 3, 4 and 5 had NRMs of reversed polarity, and sites 3, 4 and 5 showed good

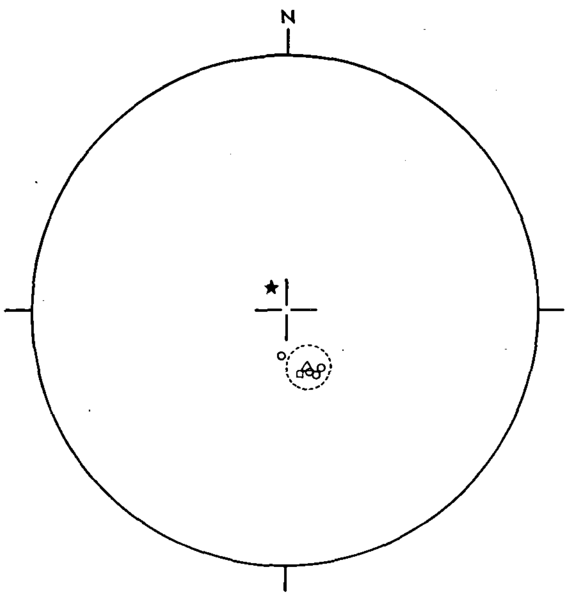

Fig. 2. Stereographic projection of site mean directions after a.f. cleaning and correction for tilt. Open symbols denote the upper hemisphere (reversed) and solid symbols the lower hemisphere (normal). The star indicates the present geomagnetic field, the circles refer to sites, the triangle and the circle of 95 % confidence to the overall mean direction for the Vandfaldsdalen Formation, and the square to the mean direction of Tarling (1967).

TABLE 2. Palaeomagnetic results from the Vandfaldsdalen Formation.

Site	TOTAL NRM									A. F. CLEANED									
	Intensity range (mA. m^{-1})	N	R	k	α_{95}	D in situ	I in situ	D dip corrected	I dip corrected	Optimum peak field (mT)	Intensity range (mA. m^{-1})	N	R	k	α_{95}	D in situ	I in situ	D dip corrected	I dip corrected
1	0.5– 5.4	6	4.23	2.8	48	267.2	–43.6	271.7	–42.3	30	0.7– 3.4	6	5.84	30.8	12.2	179.7	–64.0	182.9	–68.8
2	1400–2200	6	no agreement; polarity indeterminate							40	1100–1500	6	no agreement; polarity indeterminate						
3	7– 270	6	5.86	36.2	11.2	139.2	–50.3	134.7	–59.8	5	8– 220	6	5.89	45.5	10.0	149.9	–51.0	148.3	–60.9
4	500– 900	4	3.99	306	5.2	117.1	–17.5	114.2	–24.0	20	165– 350	4	4.00	1098	2.7	156.1	–49.0	153.6	–58.8
5	250– 730	6	5.97	161	5.2	162.7	–48.8	162.0	–58.7	40	215– 430	6	5.99	593	2.7	158.3	–50.7	156.3	–60.6
Mean of sites 1, 3, 4 & 5		4	3.11	3.3	59.5			152.9	–64.2			4	3.97	105	8.9			*158.5	*–62.8

* Corresponding palaeomagnetic pole position; 185.1 E, 63.4 N, dm = 15°, dp = 11°.

Key to palaeomagnetic symbols: N = number of samples; R = length of vector sum of N unit vectors; k = precision parameter; α_{95} = semi-angle of cone of 95 % confidence; D = declination measured clockwise from true north; I = inclination measured positively downwards from the horizontal; (dp, dm) = semi axes of oval of 95 % confidence about mean palaeomagnetic pole.

within-site grouping (k > 36). Site 1, which showed poorer grouping, was relatively weakly magnetised. The polarity of site 2 was indeterminate, to the extent of differences of sign between cores from the same sample, and the intensity was atypically high. A. f. cleaning at relatively low peak fields improved the within-site agreement appreciably for sites 1, 3, 4, and 5. Samples from 1, 3 and 4 lost unstable components of NRM during progressive demagnetisation, but all samples from site 5 showed great stability of direction and a regular decrease in intensity, suggesting a single component remanence with a wide range of coercivities. Since cleaning at site 2 did not lead to significant within-site agreement or even establish its polarity, and the basalts there were known to have been autobrecciated, it was not considered further.

Site means for 1, 3, 4 and 5 did not differ significantly after cleaning and were therefore combined. Although all the dips were gentle, correction for tilt improved the between-site precision. The mean direction was concluded to be D = 159°, I = – 63°, (α_{95} = 9°), which corresponds to a palaeomagnetic pole at 185°E, 63°N.

Discussion and Conclusions

Since sampling for palaeomagnetism was not the main objective of the expedition, the number of sites analysed is small. However the high stability of most of the samples, their reversed polarity, and their inferred biostratigraphic age together have important implications.

Although the sampling may not have been sufficiently extensive to eliminate completely the effects of secular geomagnetic field variations, the mean direction and hence the pole position deduced for the Vandfaldsdalen Formation agrees closely with the results of Tarling (1967) and Hailwood et al. (1973) further north (fig. 2). This suggests that all the basalts concerned were erupted during a period when there was little movement of the region with respect to the earth's magnetic axis. Also, since these oldest basalts are found to be reversely magnetised, as are those higher in the pile, with no known intermediate sections of normal polarity, there is more evidence than heretofore that the whole pile may have been erupted during a single reversed period of the geomagnetic field.

This reversed period is likely to immediately pre-date magnetic anomaly 24, the oldest recognised off the east coast of Greenland and off the Hatton Bank (Vogt & Avery, 1974). As Soper et al. (in press) have argued, if the maximum age of the oldest basalts is 58 Ma and all the basalts were erupted in a reversed period of length at least 2 Ma, anomaly 24 cannot be older than 56 Ma and may well be as much as 10 % younger. The implied revision of the geomagnetic polarity time scale of Heirtzler et al. (1968), who had placed anomaly 24 at 60 Ma, is in line with other current suggestions (Sclater et al., 1974; Molnar & Francheteau, 1975).

If the whole volume of East Greenland basalts was erupted during a single reversed period of 2–3 Ma, the estimated rate of effusion is about five times greater than that estimated for recent vulcanicity in Iceland, which is itself high by modern standards. The possibility that the East Greenland Tertiary vulcanicity could have occupied more than one reversed period must therefore be considered. For example, if the Vandfaldsdalen Formation was magnetised immediately prior to anomaly 25, basalts with normal polarity corresponding to anomaly 25 should occur higher in the pile and an even greater revision of the polarity time scale would be required.

The Kangerdlugssuaq area of East Greenland must therefore be regarded as the key to the problem because of the biostratigraphic age control which is not present elsewhere in the North Atlantic Tertiary Province. A complete palaeomagnetic investigation needs to be made throughout the 9 km basalt pile to verify or disprove the existence of a normally-magnetised part of the sequence.

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Dansk sammendrag

En række målinger af den naturlige remanente magnetisme er blevet udført på nedre tertiære basalter fra Kangerdlugssuaq (Blosseville Kyst, Østgrønland). Prøverne er fra basis af en 9 km mægtig lagserie af basalter, der overlejrer fossilførende marine sedimenter fra paleocæn. De opnåede værdier (D = 159°, I = –63°, α_{95} = 9°) og den hertil svarende beliggenhed af den palæomagnetiske pol (185°E, 63°N) er i god overensstemmelse med værdier opnået af andre forskere på grundlag af prøver indsamlet i yngre del af basaltserien. Resultaternes betydning for fastlæggelsen af tidspunktet for åbningen af nord-øst Atlanten og for den geomagnetiske tidsskala diskuteres.

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