Polarforschung 74 (1-3), 63 – 75, 2004 (erschienen 2006)

A Paleomagnetic, Geochemical and U-Pb Geochronological Comparison of the Thule (Greenland) and Devon Island (Canada) Dyke Swarms and Its Relevance to the Nares Strait Problem

by Steven W. Denyszyn[1], Henry C. Halls[1] and Don W. Davis[1]

Abstract: The Nares Strait controversy concerns the debate about whether or not a major sinistral transcurrent fault (the Wegener Fault) separates northern Greenland and Canada. To date no firm evidence has been found for the proposed 200 km sinistral offset, and to the contrary, geological correlations, mainly involving Paleozoic rocks across the Nares Strait, suggest that total left-lateral motion is no more than 70 km. The E–W trending Thule (Greenland) and Devon Island (Canada) dyke swarms lie on opposite sides of Baffin Bay and are offset sinistrally about 200 km, suggesting that if their correlation is established a convincing case for the Wegener Fault can be made. Paleomagnetic, geochemical and petrographic data allow, but do not yet establish, the correlation. Paleomagnetic results for Canadian sites (VGP = 6.9°N, 181.8 °E, A_{95} = 12.7°, N = 5) and Greenland sites (VGP = 11.5 °N, 178.3 °E, A_{95} = 13.8°, N = 4) are not significantly different at the 95 % confidence level. These levels are too large to resolve whether or not the Thule and Devon Island swarms have been offset. Geochemical data reveal a distinct and identical pattern in incompatible elements, while petrographically, the dykes are indistinguishable. U-Pb geochronological results for a Canadian dyke (720.2 ±2.0 Ma) and a Thule dyke (720.4 ±2.7 Ma) are identical within error and clearly identify the two sets of dykes as being parts of the same magmatic episode.

Zusammenfassung: Bei der Nares Strait-Kontroverse geht es um die Debatte, ob eine bedeutende Links-Seitenverschiebung (die Wegener-Störung) Nordgrönland von Kanada trennt. Bis heute sind keine zwingenden Belege für die postulierten 200 km Transportweite gefunden worden. Im Gegenteil: Geologische Korrelationen von paläozoischen Gesteinseinheiten auf beiden Seiten der Meeresstraße reduzieren die maximalen sinistralen Transportweiten zu nicht mehr als 70 km. Die E–W-streichenden Thule-Gangschwärme (in Grönland) und Devon-Gangschwärme (in Kanada) liegen auf beiden Seiten der Baffin Bay und erscheinen ca. 200 km sinistral versetzt. Falls die Korrelation dieser Gangschwärme gelingt, kann ein wichtiges Argument für die Existenz der Wegener-Störung geliefert werden. Paläomagnetische, geochemische und petrographische Daten erlauben eine Korrelation, wenn sie sie auch bisher noch nicht beweisen. Paläomagnetische Ergebnisse von kanadischen Gängen (VGP = 6,9°N, 181,8 °E, A_{95} = 12,7°, N = 5) und Vorkommen in Grönland (VGP= 11,5 °N, 178,3 °E, A_{95} = 13,8°, N = 4) sind im 95 % Konfidenzrahmen nicht hinreichend verschieden. Diese Daten sind jedoch nicht genau genug, um zu entscheiden, ob die Thule- und Devon-Gangschwärme versetzt sind. Geochemische Daten zeigen eine deutliche, identische Verteilung der inkompatiblen Elemente, während petrographische Daten gleichfalls keine Unterschiede zeigen. Geochronologische (U-Pb) Ergebnisse für einen kanadischen Gang sind innerhalb der Fehlergrenzen mit 720,2 ±2,0 Ma identisch mit 720,4 ±2,7 Ma für einen Thule-Gang. Die Ergebnisse machen deutlich, dass die beiden Gangprovinzen Teil desselben magmatischen Ereignisses sind.

INTRODUCTION

Controversy about the existence of a major sinistral fault lying between Greenland and Ellesmere Island (the "Nares Strait problem" of DAWES & KERR 1982a) originated with early reconstructions of the two landmasses by TAYLOR (1910) and WEGENER (1929) (Fig. 1, inset). TAYLOR (1910) proposed a sinistral fault with an offset of about 250 km to explain the generation of Tertiary mountain chains by land drifting away from polar regions; WEGENER (e.g., 1929) later incorporated these ideas into his theory of continental drift and the fault thereafter became known as the Wegener Fault. The problem arises because subsequently several geologists have compared the Paleozoic stratigraphy on either side of the Nares Strait and concluded that no more than 70 km of lateral movement is permissible (DAWES & KERR 1982b and references therein, HARRISON 2006). However, this conclusion has been questioned and alternative solutions more in harmony with plate tectonic expectations presented (e.g., MIALL 1983, JOHNSON & SRIVASTAVA 1982). In support of the plate tectonic model, geological and geophysical (particularly magnetic) studies suggest that oceanic crust underlies the Labrador Sea and that the opening of the Labrador Sea and Baffin Bay occurred between ~85 and 56 My ago (SRIVASTAVA et al. 1981, OAKEY 1994, CHALMERS & LAURSEN 1995), with Greenland moving in a NNE direction with respect to Canada.

The purpose of our investigation is to test for evidence of sinistral motion between Greenland and Canada by matching Proterozoic diabase dyke swarms across northern Baffin Bay. The idea of using dykes as markers that can be correlated to create reconstructions of past plate positions, such as that involving Greenland and Canada (PAYNE et al. 1965), is not new. But unlike previous work on the dykes (limited to a few geochemical and K-Ar age results), our study combines a number of analytical methods – paleomagnetism, petrography, geochemistry and U-Pb geochronology – to determine if a set of dykes in the Thule region of Greenland (DAWES 1991) can be correlated as an offset continuation of a dyke swarm with similar E–W trend, and vertical attitude (FRISCH 1984b, 1984c) in southeast Ellesmere Island and eastern Devon Island (Fig. 1). K-Ar dating on Thule dykes and sills and from Devon Island dykes yields ages in the range of 700 ±100 Ma (ESCHER & WATT 1976, DAWES & REX 1985, FRISCH 1988), too imprecise to be taken as definitive evidence for correlation. The Thule dyke swarm is at least 400 km long but is not seen in central Ellesmere Island (FRISCH 1984a, 1984b), a distance of less than 100 km to the west across Smith Sound. While the small amount of continuous outcrop in central Ellesmere (only 20 % of the area is free of ice cover) may not be representative of the whole, the density of the swarm is such that more dykes would be expected in Canada on strike with those in Greenland than are currently apparent (FRISCH 1984b, 1984c). If a

[1] Department of Geology, University of Toronto, 22 Russel Street, Toronto ON, M55 3B1, Canada;
<steve.denyszyn@utoronto.ca>

Manuscript received 07 October 2003, accepted 25 November 2005

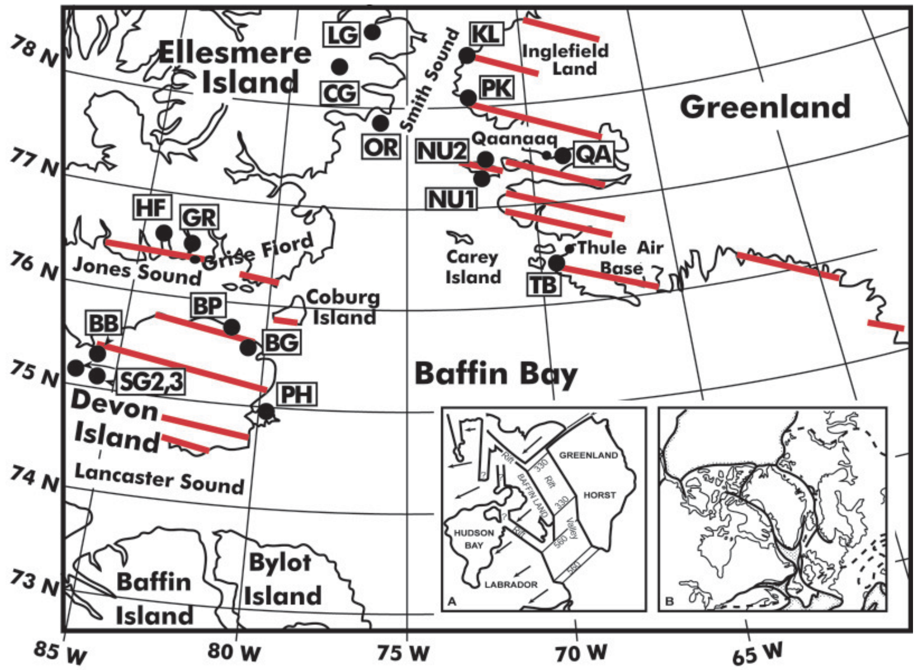

Fig. 1: Map showing the location of the Thule (Greenland) and Devon Island (Canada) dyke swarms and the locations of paleomagnetic sites. The dyke swarms are shown schematically by lines corresponding to relative dyke concentrations and overall trend (based on geological maps of the Greenland (Dawes 1991) and Canadian Geological surveys (Frisch 1984 a,b,c). Inset (A) = early continental reconstructions from Taylor (1910) and inset (B) Wegener (1915), showing the position of a major sinistral fault along Nares Strait to allow opening of Baffin Bay and the Labrador Sea (from de Paor et al. 1989).

single dyke swarm has been sinistrally offset the amount of displacement is about 200 km, the lateral distance required by plate tectonic reconstructions.

Evidence against significant offset in Precambrian rocks is that the Mesoproterozoic Thule Group in Greenland has almost perfect stratigraphic counterparts on Ellesmere Island to the west (Dawes et al. 1982), and seismic reflection data suggest that the Thule Basin continues under the Nares Strait to within 30 km of the Ellesmere coast (Neben et al. 2003). However, sedimentary sequences of the Borden Basin, northeast of Bylot Island, are also stratigraphically similar to the Thule Group and likewise contain basaltic flows and sills (Jackson & Iannelli 1981) and would become more proximal to the Thule Group after removing a sinistral displacement of ~200 km. Furthermore, the basement rocks, Archean gneisses of the Canadian Shield that underlie the Thule Group have a marked ENE to ESE structural trend similar to that on Devon Island but in contrast to the regional N-trend on Ellesmere Island on the opposite side of Smith Sound (cf. geological maps of Frisch 1984a, 1984b, 1984c and Dawes 1991). Aeromagnetic surveys have been able to trace one of the Thule dykes across Smith Sound to just offshore of Ellesmere Island, and conclude from interfingering anomalies that no fault exists (Oakey & Damaske 2006).

A large transcurrent fault in Precambrian rocks lying beneath northern Baffin Bay could be reconciled with the apparent continuity of Paleozoic sedimentary sequences across Nares Strait in several ways. The first is to disseminate the northern continuation of the fault as a series of fault strands located entirely within Ellesmere Island thus avoiding Nares Strait altogether (e.g., Wynne et al. 1983, Miall 1983, de Paor et al. 1989) or to place the fault within Ellesmere along the front of the Eurekan Orogen (e.g., Harrison 2006). Eurekan thrusting would have occurred in the final evolutionary stages of the Labrador Sea and early opening of the Atlantic (56-35 Ma) when Greenland assumed a more north-westerly trajectory culminating in a transpressive collision with the Ellesmere landmass (Srivastava et al. 1982, Oakey 1994, Piepjohn et al. 1998, Tessensohn & Piepjohn 1998).

In this paper we report paleomagnetic, petrographic, geochemical and U-Pb geochronological results from the Thule and Devon Island dyke sets and evaluate whether these data provide evidence for or against their being part of a single swarm.

METHODOLOGY AND DATA

Paleomagnetism

A total of 170 samples were collected, either as field-drilled cores or as blocks, from 15 E–W trending dykes, eight in Canada and seven in Greenland. Two Greenland sills were also sampled although these are not as yet proven to be part of the Thule magmatic event, as geochronological analysis, currently underway, is required to make this association. The samples were oriented by sun compass at all but four sites (PH, OR, SG2 and HF). About half the sites were obtained by HCH in 2001 on the Nares Strait Geocruise (TB, CA, GF, NU1, NU2, PK, KL and OR in Fig. 1) and the remaining half by HCH and SWD from 2002 to 2004 with logistic support from the Canadian Continental Shelf Project (BB, BG, SG2, SG3, HF, GR, LG, CG and QA in Fig. 1). All sites were located by a handheld Garmin Etrex or by onboard helicopter GPS system. Block samples were subsequently drilled in the laboratory, and all drill core sliced into cylindrical specimens 2.45 cm in both length and diameter. At least one specimen from each sample was subjected to detailed alternating field (AF) demagnetization, using a Schonstedt GSD-1 single-axis demagnetizer, in order to remove stray or present Earth field (PEF) components. Field increments averaged 0.5 mT up to maximum fields of 95 mT. After each demagnetization step, the direction and intensity of remanent magnetization were measured using a modified DIGICO spinner magnetometer with repeatability down to magnetization intensities of ~10^{-3} Am^{-1}. Measurement procedure included an averaging algorithm to reduce the dependence of results on the last sample axis to be demagnetized in the single axis demagnetizer. Thermal demagnetization was also used for selected specimens, using a Schonstedt TSD-1 thermal demagnetizer.

The paleomagnetic data were plotted on stereonets and vector diagrams and then analysed using Principal Component Analysis (Kirschvink 1980) that included a search routine to find all linear segments on vector diagrams, having three or more points, and that pass a minimum acceptance criteria given by a goodness of fit parameter, the Maximum Angle of Deviation (Kirschvink 1980), which was set at ≤10°.

The dykes are close to vertical with well-preserved chilled margins and in Greenland cut sub-horizontal Thule Group sediments and are overlain by flat-lying Paleozoic strata. Therefore tectonic activity that might remagnetize the rocks, or rotate magnetization directions, is likely to be minimal.

Magnetic susceptibility

Susceptibility *versus* temperature data were obtained from 23 specimens from the 15 dykes using a Sapphire Instruments susceptibility meter to determine the magnetic mineralogy of the samples. Measurements were also made on one specimen from each sample collected across the Kap Leiper Dyke (KL in Fig. 1) in order to model the linear total field anomaly discovered by an aeromagnetic survey of the Kane Basin (Damaske & Oakey 2006). The specimens were heated from 300 to 900 K and susceptibility measurements automatically recorded at 5-degree intervals.

Petrography and geochemistry

Thin sections were prepared from 25 samples, including at least one from each site shown in Figure 2. They were examined under a transmitted-light microscope using both plane-polarized and cross-polarized light.

Geochemical analyses were carried out on 27 samples collected within 30 cm of dyke chilled margins. Twenty-five were crushed, powdered and analyzed at the University of Toronto, using X-ray fluorescence on a Philips 2404 spectrometer for major and minor elements, and neutron activation analysis for trace and rare earth elements. Eight of these samples, plus two not previously measured, were sent to SGS Mineral Laboratories for major and minor element geochemistry using XRF, in part to provide an inter-laboratory check.

U-Pb geochronology

For U-Pb geochronological analyses at the University of Toronto's Jack Satterly Geochronology Laboratory (JSGL), 3- to 10-kg blocks were taken from the coarsest-grained parts of dykes, typically the centre. The samples were crushed using a jaw crusher and disc mill. Baddeleyites were separated using only the Wilfley water-shaking table, using a technique modified after Soderlund & Johansson (2002) that involved concentration of fine, heavy minerals on the table, separation of magnetic material using a hand-held magnet and picking baddeleyite from the residue. The sample was kept under liquid at all stages of the separation process. Only a few baddeleyite blades and fragments, most typically under 80 µm in length and weighing less than a microgram, were recovered from each sample. Dissolution, isotope dilution and sample loading methods were as described in Krogh (1973), using a ^{205}Pb-^{235}U spike and miniature bombs. No chemical separation procedures were required. The baddeleyite samples were then analyzed by a VG354 thermal ionization mass spectrometer using a Daly collector in pulse counting mode. The mass discrimination correction for this detector is constant at 0.07 %/AMU. Thermal mass discrimination corrections are 0.10 %/AMU. Dead time of the measuring system was about 20 nsec and was monitored using the SRM982 standard.

U-Pb ages were obtained from dykes at site CG on Ellesmere Island, and at site QA in Greenland (Fig.1). Both dykes have similar geochemical and paleomagnetic signatures to the other dykes shown in Figure 1. Further geochronological work is currently underway to determine the age of a dyke located more centrally with respect to the Devon Island swarm, as well as that of a Thule sill.

RESULTS

Paleomagnetism

Paleomagnetic results (Fig. 2) indicate a stable high coercivity (H_c), high unblocking temperature (t_{ub}) component of magnetization in both Thule and Devon Island dyke swarms that is revealed after removal of lower H_c and t_{ub} components by AF and thermal demagnetization. The directions of this component for each site are given in Table 1, along with their corresponding virtual geomagnetic poles (VGPs). The mean direction for the Devon Island swarm (D = 277 °, I = 6°, α_{95} = 20°, N = 5, VGP = 6.9 °N, 181.8 °E, A_{95} = 12.7°) is not significantly different at the 95 % confidence level from that for the Thule dykes (D = 293°, I = 13°, α_{95} = 25°, N = 4, VGP = 11.5 °N, 178.3 °E, A_{95} = 13.8°). These results are for five Canadian dykes (BB, PH, BG, BP and GR) and four dykes from Greenland (TB, NU2, QA and PK). One dyke from each geographic set (SG2 and NU1) has reversed polarity (Fig. 3) but in both cases the directions are not exactly antipodal and therefore have not been included in the "normal" polarity site means. The presence of opposing polarities suggests that the period of dyke injection on both Canada and Greenland spanned at least one reversal of the Earth's magnetic field. Sites LG, CG and KL which are remote from the main dyke concentrations have not been included in the means. Sites OR, HF and SG3 yielded scattered results, perhaps indicating the inadequacy at high latitudes of orienting samples with only a magnetic compass, and are not included in Table 1.

A baked-contact test (Everitt & Clegg 1962) was performed on dyke and host rock samples from site GR, where the host rock included anorthosite, an often-reliable retainer of stable remanence. Providing the remanence direction in the dyke and baked rocks is the same, and that the unbaked rocks contain a coherent but directionally distinct remanence, the test is considered positive in showing that the remanence is primary and formed at the time of original dyke cooling. A key aspect of the test is to obtain samples of partially baked host rocks that show a hybrid remanence and on which experiments can be

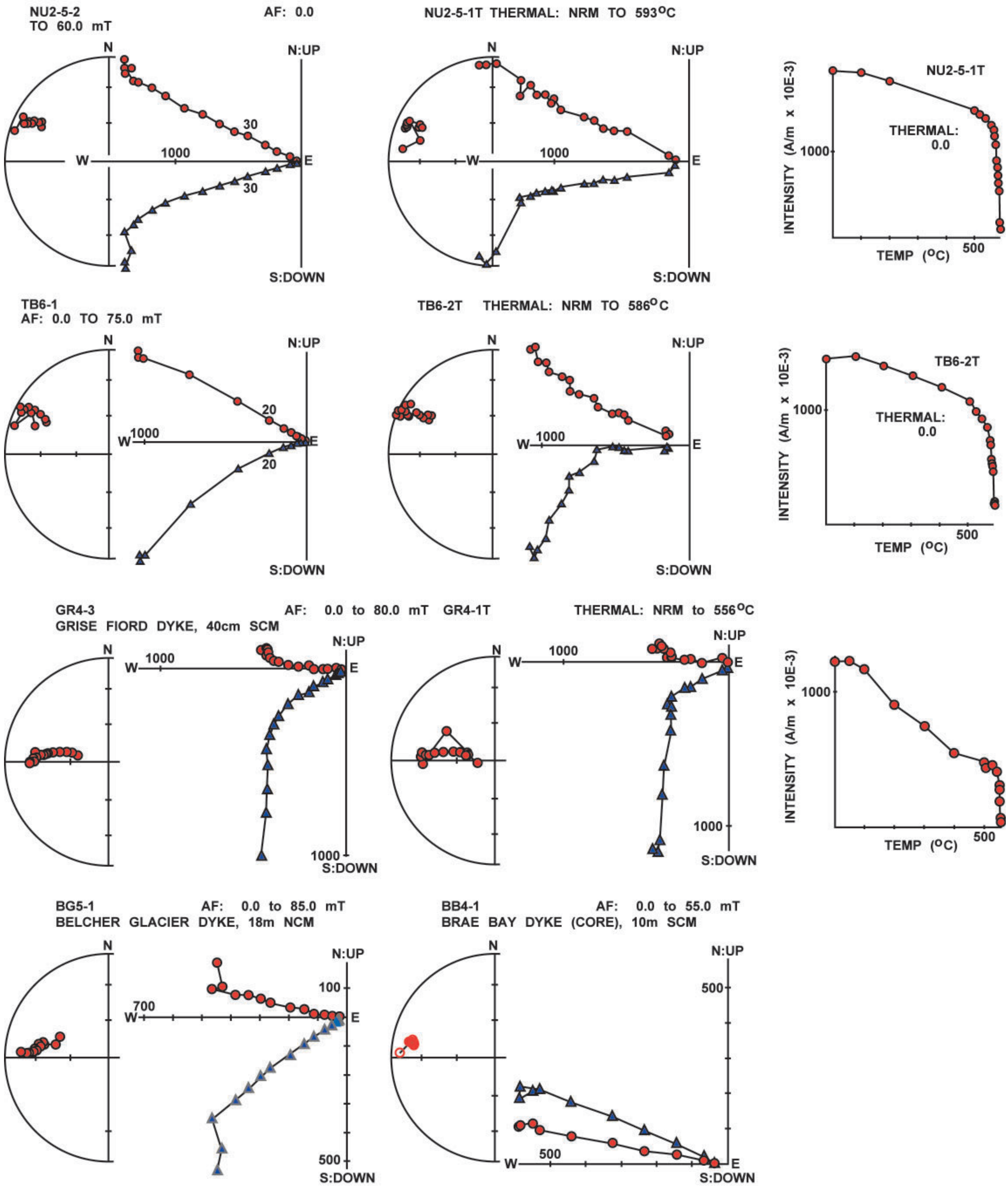

Fig. 2: Examples of demagnetization data from sites in Canada (GR, BG, BB) and Greenland (NU2 and TB) after AF and thermal demagnetization. AF data are presented as equal area stereoplots and as vector diagrams; thermal data include an additional intensity decay plot. On stereoplots solid/open symbols are downward-/upward-pointing magnetizations. On vector diagrams dots are projections of the tip of the magnetization vector on the horizontal plane (and directly give the declination), and triangles are projections on the W–E vertical plane. Linearity on both projections with decay towards the origin indicates destruction of magnetization with no or little change in direction, corresponding to the isolation of a single component, interpreted to be the primary one. Note the overall close agreement between AF and thermal results for specimens from the same sample.

Site	Lat. (N)	Long. (W)	W	N	D (°)	I (°)	k	α_{95} (°)	Plat (°N)	Plon (°E)	dp	dm
Greenland												
TB	76° 27.56'	69° 14.47'	30	9	296.5	26.4	37	8.6	19.6	178.0	5.04	9.31
NU2	77° 22.72'	71° 29.04'	20	8	288.9	16.1	107	5.4	12.3	181.9	2.86	5.56
PK	77° 56.31'	72° 12.51'	65	7	288.7	-18.5	132	5.3	-5.5	177.6	2.86	5.51
QA	77°29.1	68°51.9	33	6	298.8	26.1	106	6.5	19.5	175.7	3.80	7.03
NU1 (R)	77° 21.50'	71° 33.73'	40	8	108.8	37.7	59	7.3	16.6	355.6	5.07	8.60
KL (margin)	78° 41'	70° 40'	54	3	257.1	39.3	105	12.1	19.3	217.1	8.65	14.4
KL (interior)	78° 41'	70° 40'	54	8	283.0	10.9	74	6.5	7.9	187.6	3.33	6.58
Canada												
BB	75° 43.10'	82° 59.23'	20	4	282.2	22.4	790	3.3	-5.1	169.3	1.85	3.33
PH	75° 00.88'	79° 37.07'	30	5	282.1	12.6	8	28.3	9.3	180.9	8.72	17.2
GR	76° 25.92'	83° 01.28'	20	8	272.9	23.3	190	4.0	12.5	187.1	2.26	4.25
BP	75° 46.09'	81° 19.40'	34	9	279.2	-7.5	57	6.9	-1.4	178.8	3.14	6.24
BG	75° 35.71'	80° 11.72'	75	6	269.6	24.5	28	12.9	18.7	193.4	7.4	13.8
SG2 (R)	75° 37.20'	83° 22.22'	20	6	101.2	-26.4	103	6.6	-16.3	358.6	3.87	7.15
LG	78°43.60'	75°41.05'	50	7	243.1	13.7	91	6.4	1.3	212.3	3.23	6.43
CG	78°17.1	77°06.6	25	7	251.9	1.8	46	9.0	-2.7	210.8	4.50	9.00

Tab. 1: Summary of paleomagnetic results. W = intrusion width (m); N = number of samples; D = mean declination; I = mean inclination; k = Fisher precision parameter; α_{95} = radius of 95 % confidence circle about the mean; dp, dm = semi-axes of the oval of 95 % confidence about the pole. (R) denotes reversed-polarity dyke.

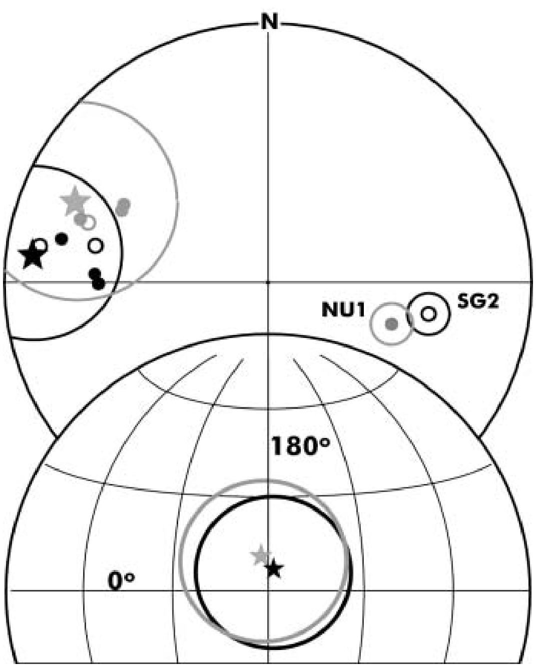

Fig. 3: Top: Summary of paleomagnetic results, with site mean directions (dots) and overall mean directions (stars) for each side (grey = Thule, black = Devon Island). Individual sample results for a single reversed-polarity dyke from each side. Solid/open symbols represent downward/upward inclinations. Bottom: Virtual geomagnetic pole positions for Thule (grey) and Devon Island (black) dykes. 95 % confidence circles about the mean pole positions are also shown.

carried out to demonstrate that the dyke remanence is younger than that in the host rock. Although the test was positive (Fig. 4) in terms of the change in paleomagnetic direction, no samples yielded a hybrid magnetization. The results of this test, combined with the presence of reversed magnetic polarity, suggest that the characteristic shallow inclination, westerly directed, magnetization is primary.

Magnetic susceptibility

Temperature *versus* susceptibility plots (Fig. 5) showed a sharp drop at about 580 °C for all samples, indicating Ti-poor magnetite as the carrier of the characteristic magnetization.

An aeromagnetic survey of the Kane Basin (Oakey & Damaske 2006) includes three lines that cross the Kap Leiper Dyke (site KL in Fig. 1), two of which are shown in Figure 6. For the line closest to the sampling site (line 2) the anomaly was removed from the regional by extrapolation of the background field by eye, and the resultant 2D anomaly fitted using Magix computer software. The susceptibility data and various parameters used in the model fitting are given in Table 2. The results (Fig. 7) show that a reasonable fit in amplitude between measured and calculated anomalies is obtained when remanent magnetization is ignored. When it is included, the theoretical anomaly becomes smaller but its shape becomes more like the observed one. The reason for the amplitude discrepancy is uncertain. The difference in the anomalies on lines 1 and 2 shows that the physical properties of the dyke vary along strike and therefore susceptibility measurements of a relatively small outcrop are unlikely to be representative of the larger volume of dyke that generates the anomaly. The important conclusion from this study is that the Kap Leiper Dyke produces a significant aeromagnetic anomaly that is traceable across Smith Sound (Oakey & Damaske 2004) and which therefore provides the most direct test for the existence of the Wegener Fault.

Petrography and geochemistry

Petrographic observations (Fig. 8) are of a uniform mineralogy in all of the specimens from east-west trending dykes. They tend to be plagioclase-pyroxene cumulates, which contain 50-60 % lath-shaped plagioclase; 25 % subhedral clinopyroxene,

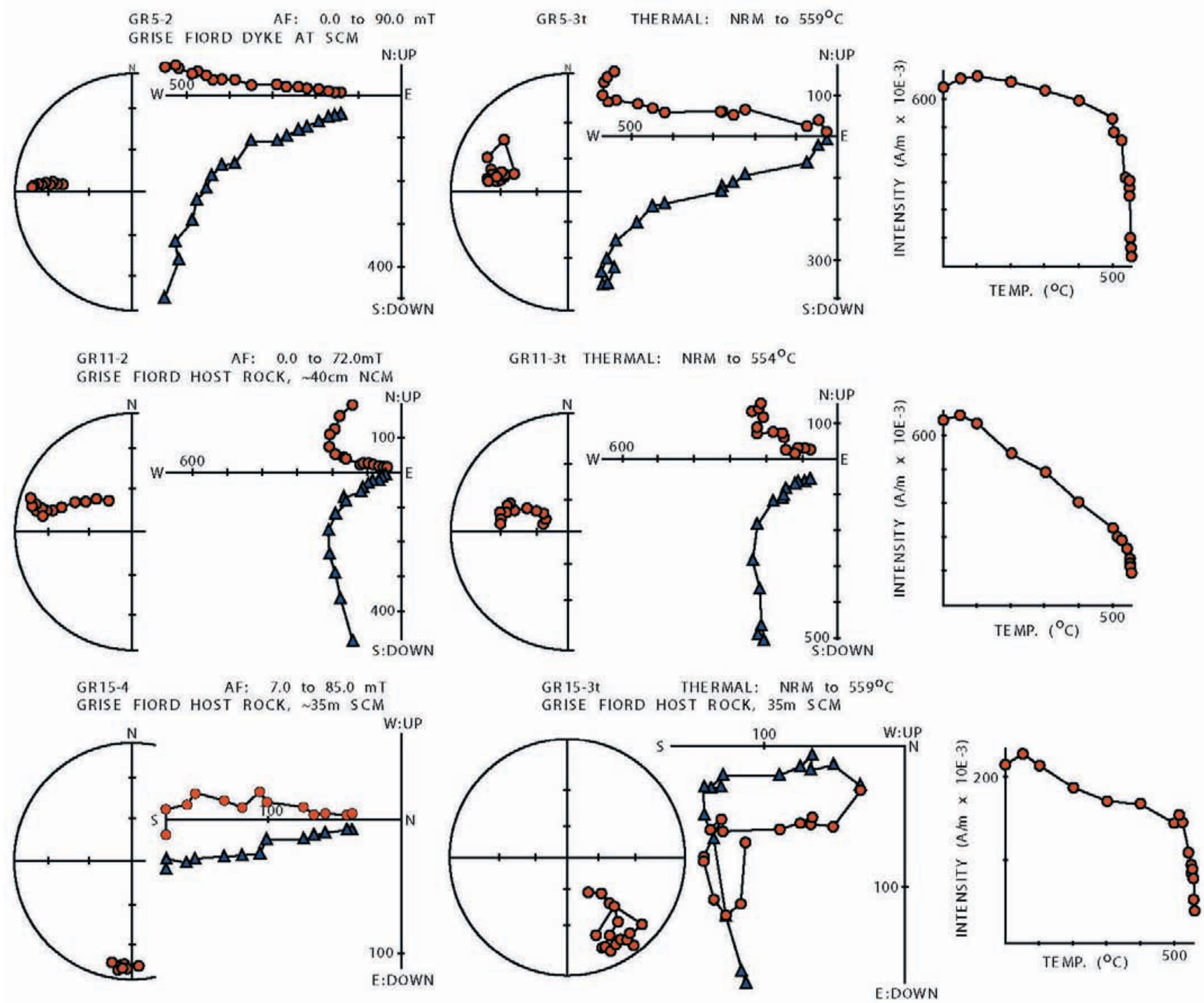

Fig. 4: Results of a paleomagnetic baked-contact test at site GR. Note similar magnetization directions for the dyke and proximal host rock using either AF or thermal demagnetization techniques, and the distinctly different direction of the magnetization in the more distal unbaked host rock. SCM/NCM is the southern/northern chilled margin. Other symbols as in Figure 2.

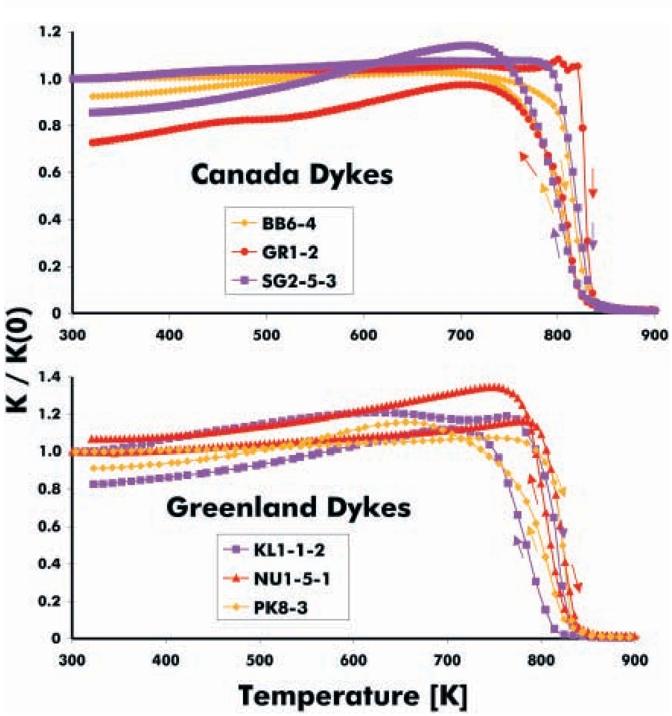

Fig. 5: Example plots of susceptibility (K) at temperature (T), normalized to room temperature susceptibility (K_0) *versus* T in degrees Kelvin, for representative dykes from the Thule and Devon Island swarms. Note the uniform drop in susceptibility at 850 K (580 °C), indicative of low-Ti magnetite as the carrier of the magnetization, and the lack of chemical/mineralogical change on the returning (cooling) part of the curves.

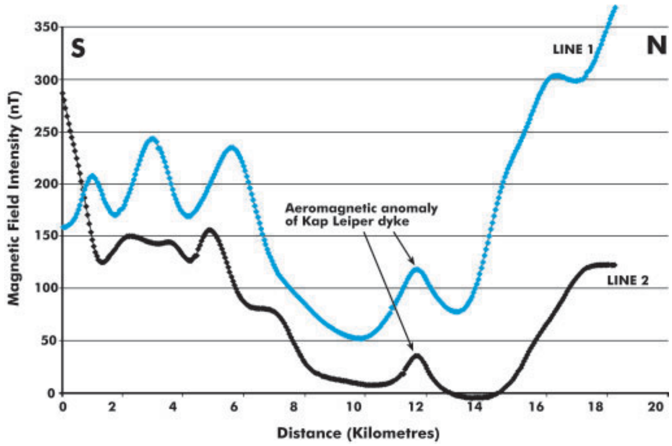

Fig. 6: Two aeromagnetic profiles showing total field anomalies (arrowed) caused by the Kap Leiper Dyke (courtesy G. Oakey and D. Damaske). Line 1 is 2 km to the west of Line 2 and is approximately 10 km west of site KL.

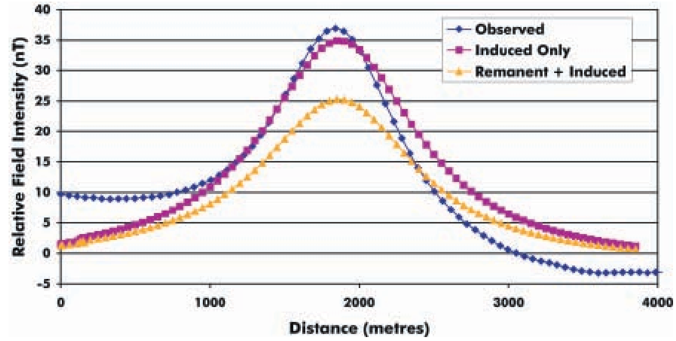

Fig. 7: Observed and calculated total magnetic field anomalies over the Kap Leiper Dyke. Modelled anomaly is Line 2 (see Fig. 6).

Dyke GPS Location: 78°41'N, 70°40'W; dyke thickness = 54 m; dip = 90°; trend: 105° from longitudinal joints and magnetic anomaly;
Field parameters using NOAA IGRF2000: Dec = -65°43'; Inc = +86°; F = 56324 nT.
Aeromagnetic flight line trend: 000°; Flight line elevation: 610 m;

NRM and susceptibility (K) data

Sample	Dec (°)	Inc (°)	J (10^{-6} emu/cc)	mean K (SI x 10^{-6})
KL 1	307	-32	1049	48397
2	273	-46	966	57421
3	290	-52	1088	50308
4	278	-43	1141	63468
5	277	-14	1124	37111
6	301	-22	757	41485
7	275	-45	945	41025
8	304	-54	651	45293
9	279	-40	683	52781
10*	262	+45	109	50616
11*	219	+7	314	36588

* Samples lie within 2 m of the southern chilled margin. They are either anomalous in direction or intensity compared to more interior samples and have been omitted from mean calculations of susceptibility K and NRM direction and intensity J. Other samples are from a traverse across the dyke and are more than 2 m from any margin.

Remanent magnetization
Mean NRM direction: Dec = 287°; Inc = -40°; k = 23; α_{95} = 11°; θ_{63} = 12 °; N = 9;
Mean NRM intensity J_R = 934 ±180 (st.dev.) 10^{-6} emu/cc = 0.934 A/m along a direction Dec = 287°; Inc = - 40°.
Conversion is 10^{-3} A/m = 10^{-6} emu/cc;
AF demagnetized remanence direction is: Dec = 283°; Inc = 11°; k = 74; α_{95} = 7°; k = precision parameter, α_{95} is the radius of the 95 % confidence circle about the mean: θ_{63} is the circular standard deviation, and N is the number of samples

Induced magnetization
Mean K = 48588 ±7960 (st. dev.) 10^{-6} SI; Field strength F_1 = 56324 10^{-9}; T = 44.82 A/m; Conversion is 10^{-4} T = $10^3/4\pi$ B A/m;
Induced magnetization intensity
$J_I = KF_I$ = 2.178 A/m. along a direction Dec = 294°, Inc = 86°.
Resultant Magnetization (sum of remanent and induced):
Dec = 288°, Inc = 61°, J = 1.8 A/m.

Tab. 2: Parameters used in magnetic modelling of Kap Leiper Dyke.

rarely as inverted pigeonite; 7-8 % orthopyroxene; 5-10 % subhedral biotite; and 7-10 % euhedral to subhedral opaques. Titanite is rare, and olivine is absent. Myrmekite and micrographic intergrowths occur commonly. Grain sizes of plagioclase and pyroxene from interior samples range from 0.5 to 1.5 mm.

Hydrous alteration occurs variably in most specimens, ranging from mild sericitization of plagioclase (e.g., NU2-7-1 in Fig. 8) to extensive sericitization and near-complete conversion of biotite and/or pyroxene to chlorite (e.g. BG7-6). Calcite has been observed in one specimen (PH1-1-1). Most samples contain pleochroic haloes, visible in amphibole, biotite and sometimes chlorite (Fig. 9). While the radioactive core is generally too small for petrographic identification, zircon or baddeleyite are suspected in the centre of larger haloes. The recognition of U-bearing minerals served as a guide to selecting which dykes were the best candidates for U-Pb age dating.

Geochemically, the Thule and Devon Island dykes are very similar. A Jensen diagram (Jensen 1976) indicates that they are of moderately tholeiitic composition, though near the alkaline field (Fig. 10). Incompatible trace element ratios show similar trends as well (Fig. 11). A more striking feature is the high TiO_2 content of the Thule and Devon Island swarms, typically about 4-5 wt%. This may have shifted data points toward the middle of the "tholeiitic" field on the Jensen plot when otherwise they would be classified as more alkaline (Fig. 12). Loss on ignition, which is often a measure of the degree of hydrous alteration, is generally low, between 1 and 2 wt%.

The anomalously high K, low Sr, and lower Fe content of the Kap Leiper Dyke (Figs. 10, 12) may be indicative of more extensive alteration and/or crustal contamination in this intrusion, though less-mobile trace element ratios (Fig. 14), considered less susceptible to alteration are also anomalous suggesting a magmatic origin. The dyke appears to have a unique composition compared to all the other E-W trending dykes in Figure 1, but it is most likely part of the Thule swarm as it has a similar trend and paleomagnetic direction (Tab. 1), and cuts Proterozoic Thule Group sedimentary rocks but not overlying Cambrian strata.

U-Pb geochronology

The uranium and lead isotopic results for each analysis (Tab. 3) were corrected for common lead contamination using the

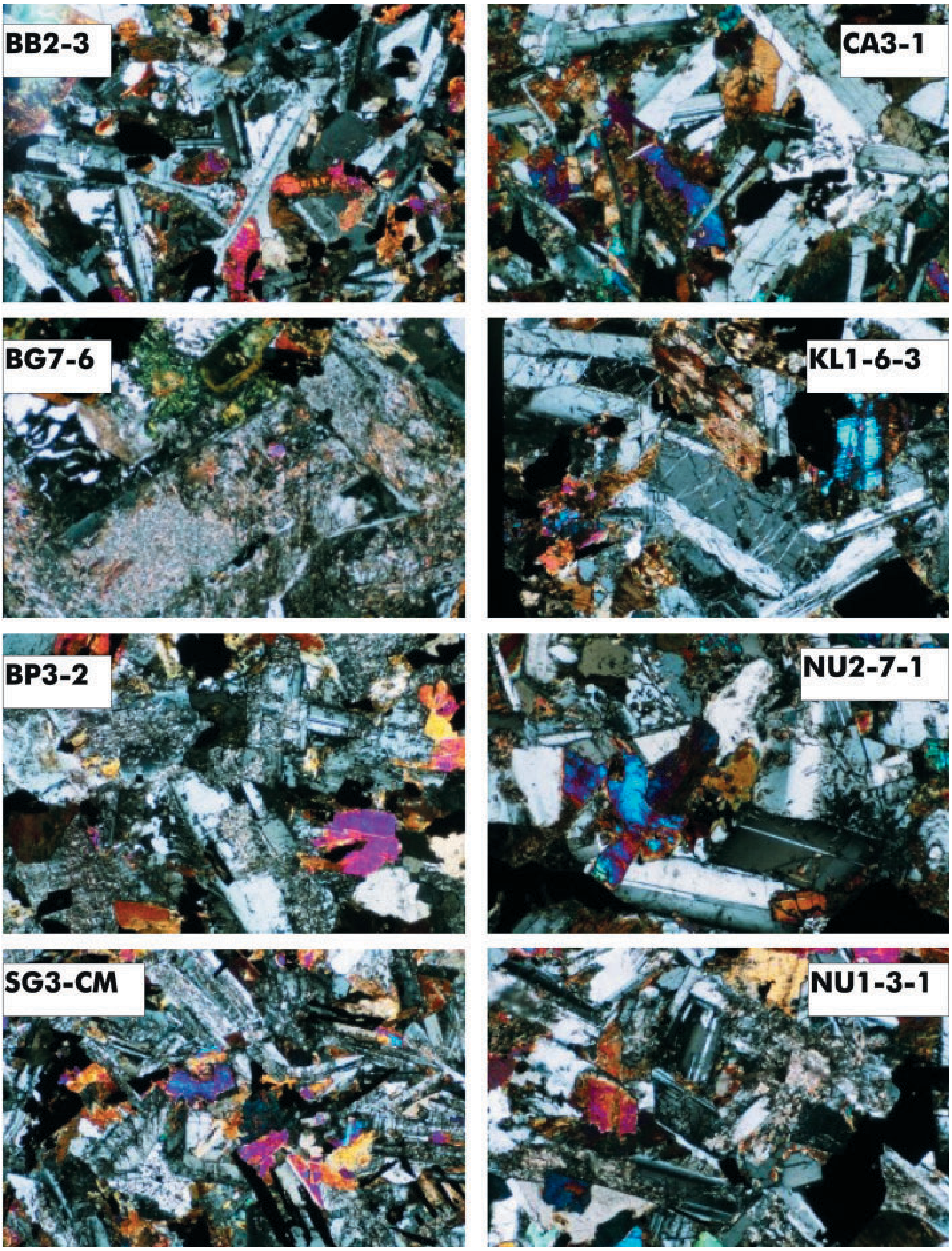

Fig. 8: Photomicrographs of dykes from Canada (left column) and Greenland (right column) under cross-polarized light, showing their similarity. Width of figures 2.5 mm.

isotopic composition of laboratory blank (see Tab. 3). Because of the small size of the fractions, which was necessary in order to analyze the best quality crystals, a significant proportion of the total Pb is common. This affects the measurement of ^{207}Pb much more than ^{206}Pb, causing the error ellipses to be much larger in the horizontal than the vertical direction on the Concordia plot (Fig. 13). Therefore, precise ages can only be calculated using the ^{238}U-^{206}Pb system. The use of one system makes the age results susceptible to secondary (low temperature) Pb loss. This is much less of a problem with baddeleyite than it is with zircon (Krogh et al. 1986) and there is no evidence for differential Pb loss within the errors of the ages on individual fractions. Averages of ^{206}Pb/^{238}U ages and fit parameters were calculated using the procedure of Davis (1982). U decay constants are from Jaffey et al. (1971) and all errors are reported as 2σ.

The Cadogan Glacier (CG) Dyke (Fig. 13) was dated using two single baddeleyite crystals. This sample suffered from having unusually high blanks, probably due to the difficulty in handling the tiny baddeleyite crystals. Nevertheless, a precise ^{206}Pb/^{238}U age of 720.2 ±2.0 Ma was obtained, although the low probability of fit indicates that the errors may be underestimated. The Qaanaaq (QA) Dyke (Fig. 13), the first Thule dyke to be precisely dated, yielded a ^{206}Pb/^{238}U age of 720.4 ±2.7 Ma from four fractions, consisting of from one to three baddeleyite crystals each. All data overlap the concordia curve.

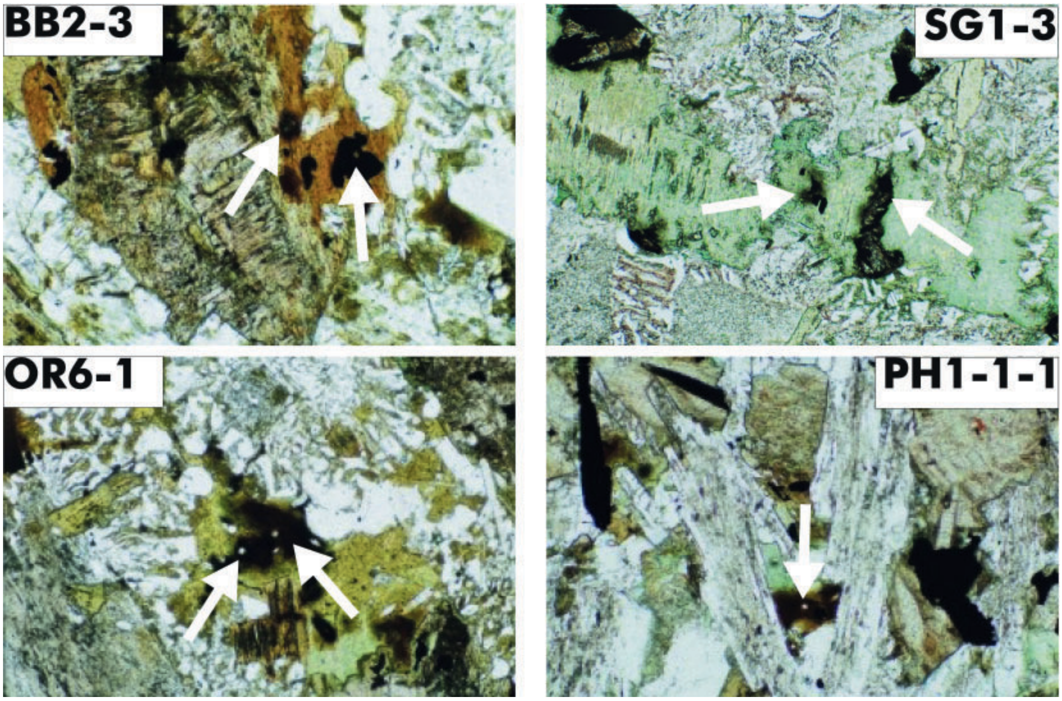

Fig. 9: Photomicrographs under plane light showing pleochroic haloes in amphibole, biotite or chlorite. These haloes may be caused by zircon and/or baddeleyite and therefore the samples containing them are candidates for U-Pb dating. Width of figures 1.5 mm.

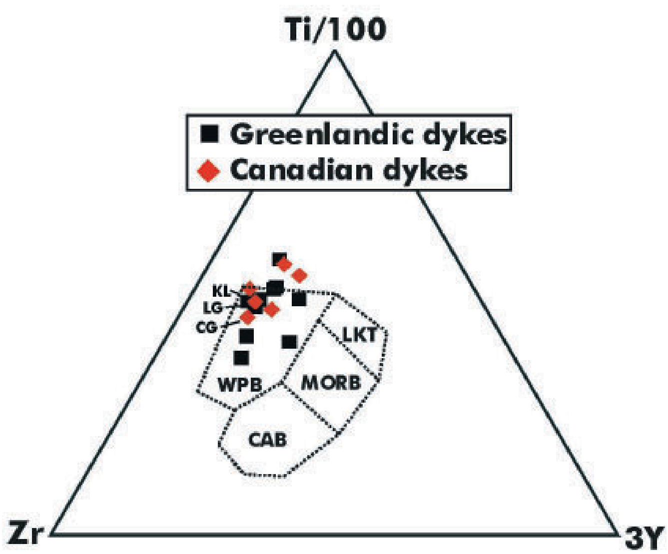

Fig. 10: Jensen diagram (JENSEN 1976) of Devon Island and Thule dyke swarm (diamonds and squares respectively). Data from samples located within 30 cm of dyke chilled margins. The most northern dykes (labeled LG, CG and KL) are indicated, as is BG, a low-Ti Canadian dyke.

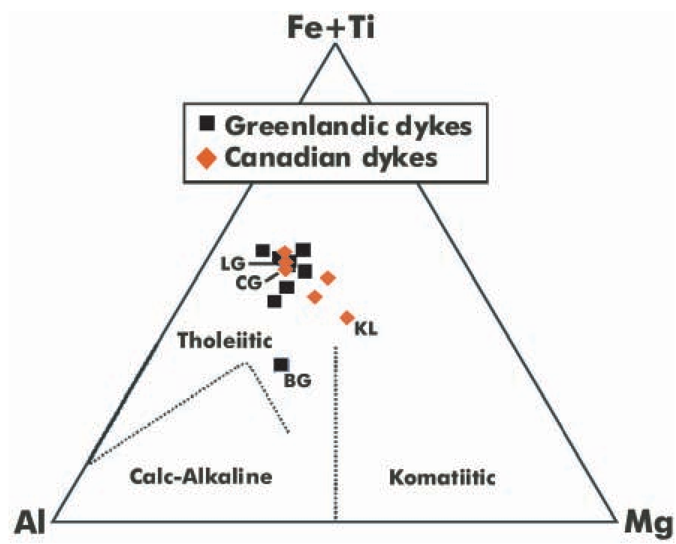

Fig. 11: Incompatible elements plot of Ti, Zr and Y (PEARCE & CANN 1973). WPB = within-plate basalt; LKT = low-K tholeiite; MORB = mid-ocean ridge basalt, CAB = continental alkali basalt. Note that the majority of analyses lie in the WPB field.

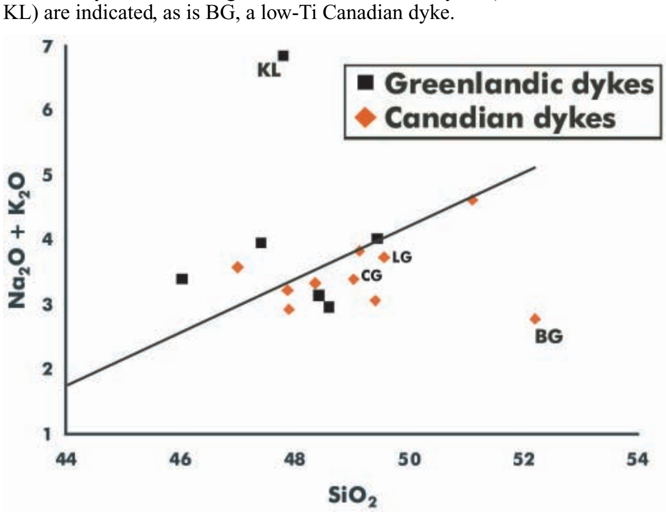

Fig. 12: Alkalis *versus* SiO_2 plot (division from HALD & TEGNER 2000) of dykes sampled, showing close grouping of dyke samples from both Canada and Greenland.

N	Description	weight (mg)	U ppm	Th/U	cPb (pg)	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$ age (Ma)	2σ	$^{207}Pb/^{235}U$ age (Ma)	2σ	disc. (%)	Error correl. coeff
	CG-7	***Cadogan Glacier diabase***												
1	1 fresh badd. frag.	0.0001	1903	0.001	4.8	313.8	0.1181	1.025	721	1.1	716.4	8.7	-2.9	0.8134
2	1 fresh badd. frag.	0.0001	1352	0.002	9.8	121.1	0.1172	1.019	714	2.5	713.6	24.8	-0.3	0.9538
	QA-2	***Qaanaaq diabase***												
1	2 brn. badd. frags.	0.0002	115	0.002	3.2	45.1	0.117	0.999	713.5	10.3	703.3	100.6	-6.8	0.9079
2	2 small badd. frags.	0.0001	249	0.073	1.3	154.4	0.118	1.025	719.7	2.5	716.7	18.9	-1.9	0.769
3	1 badd. needle, brn.	0.0001	315	0.2	1.2	217.4	0.1182	1.0349	720.2	2.2	721.4	13.1	0.6	0.6554
4	1 badd. in 2 brn. frags.	0.0001	79	0.276	1.6	127.5	0.119	1.1212	724.9	4.7	763.6	27.2	18.4	0.6412

Tab. 3: U-Pb isotopic data for baddeleyite from mafic dykes in Canada and Greenland. Note: Errors are given at 2σ. Sample locations are given in Table 1. badd. = baddeleyite; brn. = brown; frag. = fragment; Disc. = % discordance for the given age; cPb = total measured common Pb assuming the isotopic composition of laboratory blank: 206/204 = 18.221; 207/204 = 15.612; 208/204 = 39.360 (errors of 2 %). Th/U calculated from radiogenic $^{208}Pb/^{206}Pb$ ratio and $^{207}Pb/^{206}Pb$ age assuming concordance.

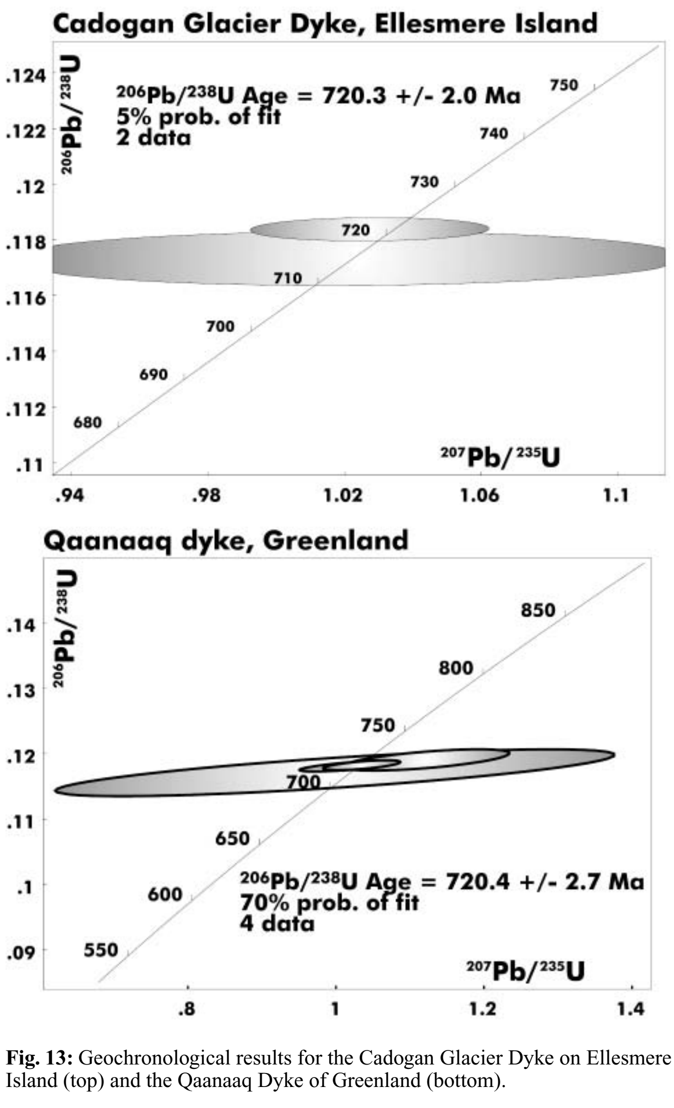

Fig. 13: Geochronological results for the Cadogan Glacier Dyke on Ellesmere Island (top) and the Qaanaaq Dyke of Greenland (bottom).

DISCUSSION

The paleomagnetic, geochemical, petrographic and geochronological results show little difference between the Thule and Devon Island dyke swarms, and therefore provide permissive evidence that they represent an offset segment of a single swarm at least 600 km long. However, the 95 % confidence ovals for the Devon Island and Thule pole positions are too large to resolve the question of whether the Canadian and Greenland dykes have been laterally offset.

The identical ages obtained from dykes CG and QA provide clear evidence that the Greenlandic and Canadian dykes are parts of the same swarm. In previous cases where different dykes of the same magnetic polarity are dated within a single swarm, U-Pb ages often differ by no more than 1 to 2 Ma. Examples include the giant 1.27 Ga Mackenzie swarm (LeCheminant & Heaman 1989); the 2.076 Ga Fort Frances swarm (Hamilton et al. 2002) and the 2.17 Ga Biscotasing swarm (Buchan et al. 1993, Halls & Davis 2004). We are presently hunting for physical and chemical variations across each swarm that can be correlated between Canada and Greenland, either a single dyke or group of dykes. Only the northern half of the Thule swarm has been sampled, so we are unable with the data now available to make a rigorous comparison.

Longitudinal geochemical changes for hundreds of kilometres along a dyke are negligible (e.g., Kalsbeek & Taylor 1986), and therefore a particular dyke of unusual or unique chemical composition (such as the Kap Leiper Dyke) may be traceable from Greenland into Canada (see next section).

A large radiating dyke swarm formed by Franklin dykes (U-Pb dated at 724 Ma; Heaman et al. 1992) radiates southeastwards from the western Arctic islands and gives similar paleomagnetic results (Fahrig et al. 1971, Fahrig & Schwarz 1973, Pehrsson & Buchan 1999) to those reported here for the Thule and Devon Island swarms. Their similarity in age and paleomagnetism, together with an overall strike that is compatible with the radiating pattern, suggests that the Thule and Devon Island swarms are part of the larger Franklin event, which would make it one of the largest dyke swarms in the world (at least 2700 km long).

Geochemical analyses on Franklin dykes from Victoria Island and the northern Northwest Territories (Jefferson et al. 1994) yield TiO_2 values typically <2 %. The higher TiO_2 values in the Thule and Devon Island dykes are an indication of their more fractionated nature and perhaps a result of the greater distance from the plume head that was the source of the Franklin swarm (Heaman et al. 1992). Alternatively, the high TiO_2 content reflects the geochemistry of the more immediately underlying mantle because unusually high TiO_2 is also a feature of Tertiary basalts from both western and eastern Greenland (Hald & Tegner 2000).

Does the Kap Leiper Dyke extend into Canada?

The 50 m-wide dyke at Kap Leiper was sampled as part of the Nares Strait Geocruise in 2001, and its aeromagnetic anomaly modelled (Fig. 6) in the following year. At that time it became clear that the dyke held great promise to resolve the Nares Strait debate if it could be followed aeromagnetically for the ~100 km across Davis Strait into Ellesmere island. With this in mind a follow-up survey was carried out (Oakey & Damaske 2006), specifically targeting dykes of the Thule swarm. The results showed that the dyke did indeed cross the channel and it was concluded that the Nares Strait controversy was effectively over (Oakey & Damaske 2006). However, on closer inspection of the aeromagnetic data the anomaly that can be truly ascribed to the dyke ends about 3 km off the Ellesmere shoreline and any westerly continuation is of a broader wavelength and similar to other anomalies to both the north and south. Furthermore, Thule Group sediments extend from the coast of Greenland under Kane Basin, but the region of subdued, longer wavelength anomalies that indicate the presence of the Thule sedimentary cover ends approximately along a north-south line that passes through the end of the Kap Leiper anomaly (Oakey & Damaske 2006). To search for any landward continuation of the Kap Leiper Dyke, we have carried out a helicopter reconnaissance of the Ellesmere shoreline, comprising Cocked Hat Island, along strike and to the west of the anomaly, and Pim Island, located immediately south of Cocked Hat Island. Despite nearly 100 % granite outcrop, no dyke was seen. For 50 km west of Cocked Hat Island, at least five broad tracts of continuous outcrop run for 5-10 km across the expected position of the dyke and yet no dyke has been mapped (Frisch 1984c). If the Kap Leiper Dyke continues into Canada, the Leffert Glacier Dyke (LG in Fig. 1) appears to be the only possible candidate. It runs along the north side of the Leffert Glacier and could represent a left-stepping segment of the KL dyke, with an offset of about 10 km. A comparison of chilled margin geochemistry and paleomagnetism of the LG and KL dykes is shown in Figure 14. Both dykes are of similar width, but the KL dyke differs geochemically from LG in having significantly different incompatible trace element (Nb, Zr, Y, Sr, Rb) ratios (Fig. 14). Since individual dykes can be traced for hundreds of kilometres with basically no change in the chemistry of their margins, the observed differences between KL and 14 LG are significant. One possibility that could account for the difference is crustal contamination and the different host rocks into which the dykes are injected – Thule sediments for KL and Archean granites for LG. Although KL contains more water, the variation in trace element ratios cannot be attributed to Thule contamination. The LG geochemistry (major-and minor-element) from chilled margins is identical to that of almost every other dyke from Ellesmere and Devon Islands (with a few exceptions), as well as those in Greenland (Fig. 10), which are intruded into Thule sediments. Therefore the difference between the KL and LG geochemistry appears to rule out their being from the same dyke. The LG and KL paleopoles are also clearly different at the 95 % confidence level (Fig. 14), but this difference may not constitute evidence against the correlation of KL and LG because the mean pole position for the Devon Island dykes is offset in the same sense as those from Greenland (Fig. 3), a difference that may reflect motion between Canada and Greenland. Our overall conclusion based on the geochemistry is that KL and LG are not sampling the same dyke. KL ends about 3 km off the Ellesmere shoreline where, based on the Judge Daly Promontory faults (Harrison 2006) the Wegener fault would be placed – i.e., along the western side of Davis Strait.

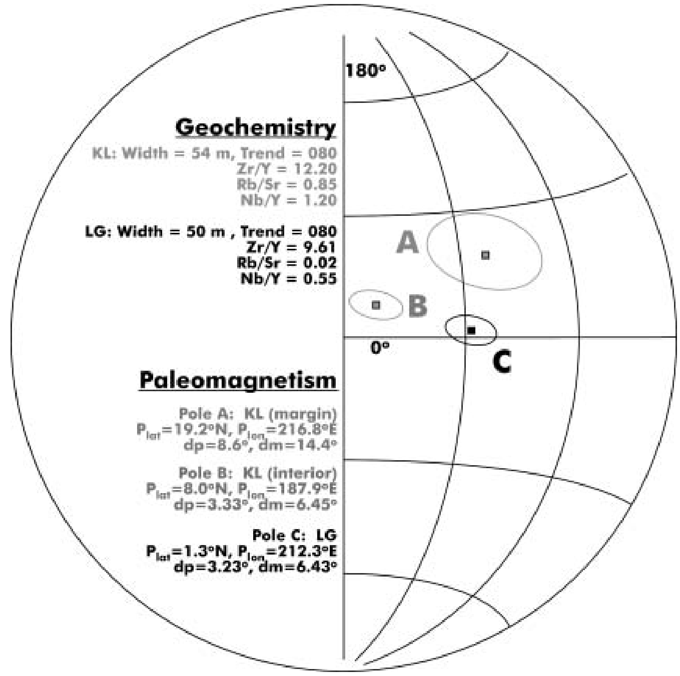

Fig. 14: Comparison of geochemical and paleomagnetic results for the Kap Leiper Dyke of Greenland and the Leffert Glacier Dyke of Ellesmere Island, the most likely candidate for the western extension of the Kap Leiper Dyke.

CONCLUSIONS

The data presented here provide clear evidence that the Thule and Devon Island dykes are both part of the Franklin dyke swarm with a U-Pb age of 720 ±3 Ma. Although the broad distribution of each dyke set makes it difficult to match them up precisely, their present exposure is consistent with a sinistral offset of about 200 km, as suggested by Taylor (1910) and Wegener (1915) at the turn of the 20th century. Further sampling is required to strengthen the paleomagnetic and geochemical correlations, as well as more extensive U-Pb dating, as the paleomagnetic data at the current 95 % confidence levels do not have sufficient resolution to support or deny the proposed sinistral offset of 200 km. The Kap Leiper dyke can be traced aeromagnetically from Greenland to offshore Ellesmere Island, but no onshore dykes can be correlated with it either paleomagnetically or geochemically, despite extensive outcrop, which leaves the question of an intervening fault running just off Ellesmere Island presently unresolved.

ACKNOWLEDGMENTS

Chris Harrison (Geological Survey of Canada, Calgary) first alerted HCH in 1999 to the possibility that the Thule and Devon Island dyke swarms could be sampled during the Nares Strait Geocruise, subsequently encouraged and arranged the participation of HCH in the cruise, and provided logistic support through the auspices of the GSC. Franz Tessensohn, German Geological Survey (BGR) Hanover, and Chief Scientist for the Nares Strait Geocruise, provided generous helicopter and financial support. Gordon Oakey (Atlantic Geoscience Centre, Dartmouth) and Detlef Damaske (BGR, Hanover) made available two aeromagnetic profiles across the Kap Leiper Dyke in Greenland. Jason Anderson (Erindale College, U. of Toronto) and Jimmy Nungaq (resident of Grise Fiord) offered reliable and proficient field assistance. Peter Dawes, Danish Geological Survey, Copenhagen, provided helpful references and field information about the Greenland dykes. The Canadian Polar Continental Shelf Project (PCSP) provided accommodation at their base in Resolute Bay, Nunavut, and also helicopter and Twin Otter support for the 2002-2004 field seasons. Helicopter pilots Harrison Macrae, (CCGC "Louis St. Laurent"), John Innis (PCSP) and Jerry Greening (PCSP) are particularly thanked for their expert judgment in potentially dangerous terrain. SWD acknowledges Mike Gorton, Department of Geology, University of Toronto for help in geochemical matters, everyone at the Jack Satterly Geochronology Laboratory at the University of Toronto for help and guidance in sample preparation and measurement, and the Northern Scientific Training Programme for financial support.

References

Buchan K.L., Mortensen J.K. & Card K.D. (1993): Northeast-trending Early Proterozoic dykes of southern Superior Province: Multiple episodes of emplacement recognized from integrated paleomagnetism and U-Pb geochronology.- Can. J. Earth Sci. 30: 1286-1296.

Chalmers J.A. & Laursen K.H. (1995): Labrador Sea: the extent of continental and oceanic crust and the timing of the onset of seafloor spreading.- Mar. Petrol. Geo. 12: 205-217.

Davis, D.W. (1982): Optimum linear regression and error estimation applied to U-Pb data.- Can. J. Earth Sci. 19: 2141-2149.

Dawes P.R. (1991): Geological compilation map of the Thule area, Greenland, scale 1: 500 000.- Geol. Surv. Greenland publ.

Dawes P.R., Frisch T. & Christie K.L. (1982): The Proterozoic Thule Basin of Greenland and Ellesmere Island: Importance to the Nares Strait debate.- In: P.R. Dawes & J.W. Kerr (eds), Nares Strait and the drift of Greenland: a conflict in plate tectonics, Meddel. om Grønland, Geosci. 8: 89-104

Dawes P.R. & J.W. Kerr (eds) (1982a): Nares Strait and the drift of Greenland: A conflict in plate tectonics.- Meddel. om Grønland, Geosci. 8: 369-386.

Dawes P.R. & Kerr J.W. (1982b): The case against major displacement along Nares Strait.- In: P.R. Dawes & J.W. Kerr (eds), Nares Strait and the drift of Greenland: a conflict in plate tectonics, Meddel. om Grønland, Geosci. 8: 369-386.

Dawes P.R. & Rex D.C. (1985): Proterozoic basaltic magmatic periods in northwest Greenland: Evidence from K-Ar ages.- Grønlands Geol. Unders. Rapp. pp. 130.

Denyszyn S.W. & Halls H.C. (2004): Paleomagnetic, geochemical and U-Pb geochronological correlation of Proterozoic dykes between Greenland and Canada, and its bearing on the Nares Strait Problem.- Amer. Geophys. Union, Spring Meeting May 2004, Montreal, Abstract GP33B-05.

De Paor D.G., Bradley D.C., Eisenstadt G. & Phillips S.M. (1989): The Arctic Eurekan Orogen: A most unusual fold-and-thrust belt.- Geol. Soc. Amer. Bull. 101: 952-967.

Escher A. & Watt W.S. (eds) (1976): Geology of Greenland.- Geol. Surv. Greenland, Copenhagen, 1-603.

Everitt, C.W.F. & Clegg, J.A. (1962): A field test of paleomagnetic stability.- Geophys. J. London 6: 312-319.

Fahrig W.F., Irving E. & Jackson G.D. (1971): Paleomagnetism of the Franklin diabases.- Can. J. Earth Sci. 8: 455-467.

Fahrig W.F. & Schwarz E.J. (1973): Additional paleomagnetic data on the Baffin diabase dykes and a revised Franklin pole.- Can. J. Earth Sci. 10: 576-581.

Frisch T. (1984a): Geology, Devon ice cap, District of Franklin, Northwest Territories.- Geol. Surv. Canada, map 1574A, scale 1: 250 000.

Frisch T. (1984b): Geology, Mackinson Inlet, District of Franklin, Northwest Territories.- Geol. Surv. Canada, map 1573A, scale 1: 250 000.

Frisch T. (1984c): Geology, Prince of Wales Mountains, District of Franklin, Northwest Territories.- Geol. Surv. Canada, map 1572A, scale 1:250 000.

Frisch T. (1988): Reconnaissance geology of the Precambrian shield of Ellesmere, Devon and Coburg Islands, Canadian Arctic Archipelago.- Geol. Surv. Canada Mem. 409: 1-102.

Hald N. & Tegner C. (2000): Composition and age of Tertiary sills and dykes, Jameson Land Basin, East Greenland: relation to regional flood volcanism.- Lithos 54: 207-233.

Halls H.C. & Davis D.W. (2004): Paleomagnetism and U-Pb geochronology of the 2170 Ma Biscotasing dyke swarm, Ontario, Canada: evidence for vertical-axis rotation across the Kapuskasing Zone.- Can. J. Earth Sci. 41: 255-269.

Hamilton M.A., Davis D.W., Buchan K.L. & Halls, H.C. (2002): Precise U-Pb dating of reversely magnetized Marathon diabase dykes and implications for emplacement of giant swarms along the southern margin of the Superior Province, Ontario.- Geol. Surv. Canada Current Res. 2002-F6: 1-8.

Harrison J.C. (2006): In search of the Wegener Fault: re-evaluation of strike-slip displacements along and bordering Nares Strait.- Polarforschung 74: 129-160.

Harrison J.C., Damaske D., Mayr U., Nowlan G.S. & Oakey G. (2003): Re-evaluation of Wegener Fault displacements.- Program with Abstracts, 4th Internat. Conf. Arctic Margins, 71-80.

Heaman L.M., LeCheminant A.N. & Rainbird R.H. (1992): Nature and timing of Franklin igneous events, Canada: implications for a Late Proterozoic mantle plume and the break-up of Laurentia.- Earth Planet. Sci. Letters 109: 117-131.

Higgins A.K. & Soper N.J. (1989): Short paper: Nares Strait was not a Cenozoic plate boundary.- J. Geol. Soc. London 146: 913-916.

Jackson G.D. & Iannelli T.R. (1981): Rift-related cyclic sedimentation in the Neohelikian Borden basin, northern Baffin Island.- In: F.H.A. Campbell (ed), Proterozoic Basins in Canada.- Geol. Surv. Canada Paper 81-10: 269-302.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C. & Essling, A.M. (1971): Precision measurements of half lives and specific activities of 235U and 238U.- Physics Rev. C4: 1889-1906.

Jefferson C.W., Hulbert L.J., Rainbird R.H., Hall G.E.M., Grégoire D.C. & Grinenko L.I. (1994): Mineral resource assessment of the Neoproterozoic Franklin igneous events of Arctic Canada: comparison with the Permo-Triassic Noril'sk-Talnakh Ni-Cu-PGE deposits of Russia.- Geol. Surv. Canada, Open File Rep. 2789, 1-48.

Jensen L.S. (1976): A new cation plot for classifying subalkalic volcanic rocks.- Ontario Geol. Surv. Miscell. Pap. 66: 1-22.

Johnson G.L. & Srivastava S.P. (1982): The case for major displacement along Nares Strait.- In: P.R. Dawes & J.W. Kerr (eds), Nares Strait and the drift of Greenland: A conflict in plate tectonics.- Meddel. om Grønland, Geosci. 8: 364-368.

Kalsbeek F. & Taylor P.N. (1986): Chemical and isotopic homogeneity of a 400 km long basic dyke in central West Greenland.- Contr. Mineral. Petrol. 93: 439-448.

Kirschvink J.L. (1980): The least-squares line and plane and the analysis of paleomagnetic data.- J. Royal Astron. Soc. 62: 699-718.

Krogh, T.E. (1973): A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations.- Geochim. Cosmochim. Acta 37: 485-494.

Krogh, T.E., Corfu, F., Davis, D.W., Dunning, G.R., Kamo, S.L., Greenough, J. & Nakamura, E. (1985): Precise U-Pb isotopic ages of diabase dykes and gabbros using trace baddeleyite.- In: H.C. Halls & W.H. Fahrig (eds), Mafic dyke swarms, Geol. Assoc. Canada Spec. Pap. 33: 147-152.

LeCheminant A.N. & Heaman L.M. (1989): Mackenzie igneous events, Canada: Middle Proterozoic hotspot magmatism associated with ocean opening.- Earth Planet. Sci. Letters 96: 38-48.

Miall A.D. (1983): The Nares Strait problem: A re-evaluation of the geological evidence in terms of a diffuse oblique-slip plate boundary between Greenland and the Canadian Arctic Islands.- Tectonophysics 100: 227-239.

Neben S., Brent T.A., Harrison, J.C., Tessensohn F. & Jackson H.R. (2003): New marine reflection seismic data in North Baffin Bay, Kennedy Channel and Hall Basin: subsurface constraints on structure and stratigraphy of the Nares Strait region.- 4th Internat. Conf. Arctic Margins,

Abstracts, 65-66.
Oakey G.N. & Damaske, D. (2006): Structural elements of the Kane Basin region of Nares Strait constrained by aeromagnetic data.- Polarforschung 74: 51-62.
Oakey G.N. & Damaske D. (2004): Tectonic elements of the Kane Basin region of Nares Strait constrained by aeromagnetic data.- 4th Internat. Conf. Arctic Margins, Abstracts, 67-68.
Oakey G.N. (1994): A structural fabric defined by topographic lineaments: correlation with Tertiary deformation of Ellesmere and Axel Heiberg Islands, Canadian Arctic.- J. Geophys. Res. 99: B10: 20311-20321.
Payne A.V., Baadsgaard H., Burwash R.A., Cumming G.L., Evans C.R. & Folinsbee R.E. (1965): A line of evidence supporting continental drift.- Internat. Union Geol. Sci. Upper Mantle Sympos., New Delhi, 83-93.
Pearce J.A. &, Cann J.R. (1973): Tectonic setting of basic volcanic rocks determine using trace element analyses.- Earth Planet. Sci. Letters 19: 290-300.
Pehrsson S.J. & Buchan K.L. (1999): Borden dykes of Baffin Island, Northwest Territories: A Franklin U-Pb baddeleyite age and a paleomagnetic reinterpretation.- Can. J. Earth Sci. 36: 65-73.
Piepjohn K., Tessensohn F., Harrison C. & Mayr U. (1998): Involvement of a Tertiary foreland basin in the Eurekan foldbelt deformation, NW coast of Kane Basin, Ellesmere Island, Canada.- Polarforschung 68: 101-110.
Stacey, J.D. & Kramers, J.D. (1975): Approximation of terrestrial lead isotope evolution by a two-stage model.- Earth Planet. Sci. Letters 26: 207-221.
Soderlund U. & Johansson, L. (2002): A simple way to extract baddeleyite (ZrO2).- Geochem. Geophys. Geosyst. 3: 10.1029/2001GC000212.
Srivastava S.P., Falconer R.K.H. & MacLean B. (1981): Labrador Sea, Davis Strait, Baffin Bay: geology and geophysics - a review.- In: J.W. Kerr & A.J. Fergusson (eds), Geology of the North Atlantic Borderlands. Can. Soc. Petrol. Geol. Memoir 7: 333-398.
Taylor F.B. (1910): Bearing of the Tertiary Mountain Belt on the origin of the Earth's plan.- Geol. Soc. Amer. Bull. 21: 179-226.
Tessensohn F. & Piepjohn K. (1998): Eocene compressive deformation in Arctic Canada, North Greenland and Svalbard and its plate tectonic causes.- Polarforschung 68: 121-124.
Wegener A. (1929): The origin of continents and oceans.- Transl. by John Biram from the 4th German edition, Dover, New York, 1-256.
Wynne P.J., Irving E. & Osadetz K. (1983): Paleomagnetism of the Esayoo Formation of north Ellesmere Island: Possible clue to the solution of the Nares Strait dilemma.- Tectonophysics 100: 241-256.