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Continuity of Basement Structures and Dyke Swarms in the Kane Basin Region of Central Nares Strait Constrained by Aeromagnetic Data.

by Gordon N. Oakey[1] and Detlef Damaske[2]

Abstract: Aeromagnetic data were collected over southern Kane Basin and adjacent coastal land areas during two field programs, the Nares Strait Expeditions 2001 and a base-camp operation in 2003, to link basement structures between Greenland and Ellesmere Island and identify possible offsets resulting from tectonic motions during the Eurekan Orogeny. The total field magnetic data are dominated by high-frequency anomalies associated with the crystalline basement rocks of the Archean Platform beneath thin Proterozoic sedimentary cover. On Ellesmere Island, discontinuities of the magnetic anomalies reveal structural elements within the complex distribution of Archean basement rocks. The wavelength of the magnetic anomalies increases beneath Kane Basin and Princess Marie Bay resulting from an increased source depth, a combined effect of water depth and cover of non-magnetic rocks. Several dykes have been identified from the magnetic data, extending seaward from the Greenland coast. Field relationships of one exposure at Kap Leiper indicate these dikes are early Proterozoic, significantly older than the recent tectonic activity. The magnetic data map the offshore extension of the Kap Leiper Dyke from the exposure onshore Greenland to the coastline of Ellesmere Island. The continuity of this feature refutes the possibility of extending the Wegener Fault through central Kane Basin. If the western end of the mapped Kap Leiper Dyke represents a faulted bounded termination, then it can be argued that the Wegener Fault lies just off the Ellesmere Island coast. However, if the Wegener Fault represents an Eocene compressive boundary, then a compressive zone (equivalent to Judge Daly Promontory) would be expected. This is not consistent with the presence of undeformed Proterozoic and Paleozoic sedimentary sequences on Bache Peninsula. Conversely, if the Wegener Fault represents a simple Paleocene strike-slip boundary, then offsets of other structures should be observed. The magnetic data also identify offshore extensions of basement structures from Ellesmere Island further east than the position of the dyke termination and no clearly defined N–S oriented fault boundary is observed. The inability to define a simple Wegener Fault boundary and the possible continuity of basement structures across southern Kane Basin suggest that the Archean block of southeastern Ellesmere Island may be part of the rigid Greenland Plate.

Zusammenfassung: Über dem südlichen Kane Basin und den angrenzenden Landgebieten wurden in zwei Kampagnen aeromagenetische Daten gewonnen. Die erste Kampagne erfolgte vom Schiff aus während der Nares Strait Expedition 2001, die zweite von einer festen Basis aus im Jahr 2003. Ziel war es, Strukturen im Grundgebirge von Grönland und Ellesmere Island zu verknüpfen und nach einem möglichen Versatz durch tektonische Bewegungen entlang der Wegener-Störung zu suchen. Das magnetische Totalfeld ist gekennzeichnet durch überwiegend hoch-frequente Anomalien, verursacht durch die unter einer dünnen Überdeckung von Proterozoischen Sedimenten anstehenden Kristallingesteinen des Archaikums. Unterbrechungen der magnetischen Anomalien über Ellesmere Island zeichnen Strukturelemente des komplexen archaischen kristallinen Basements nach. Die Wellenlänge der magnetischen Anomalien nimmt unter dem Kane Basin und der Princess Mary Bay zu, was auf die größere Tiefe der magnetischen Quellen hinweist, verursacht durch die Kombination von größerer Wassertiefe und Überdeckung durch nicht magnetische Gesteine.
Mehrere magmatische Gänge können, ausgehend von der grönländischen Küste, anhand der magnetischen Signatur identifiziert werden. Anhand der Lagerungsverhältnisse in einem Aufschluss bei Kap Leiper kann auf ein proterozoisches Alter dieser Gänge geschlossen werden, also sehr viel älter als die junge Tektonik in der Region. Der Kap-Leiper-Gang kann in den aeromagnetischen Daten von Grönland bis an die Küste von Ellesmere Island verfolgt werden. Das schließt die Fortsetzung der Wegener Störung von Norden durch das zentrale Kane Basin aus. Wenn das westliche Ende des aeromagnetisch kartierten Kap-Leiper-Gangs durch eine Störung gekappt ist, dann könnte man den Verlauf der Wegener-Störung direkt an der Küste postulieren. Wenn jedoch die Wegener-Störung eine eozäne kompressive Grenze darstellt, dann könnte man in Analogie zur Judge Daly Promontary eine kompressive Zone erwarten. Dagegen sprechen Vorkommen von undeformierten proterozoischen und paläozoischen Sedimenten auf der Bache Halbinsel. Wenn die Wegener-Störung dagegen eine einfache paläozäne Blattverschiebung darstellt, dann sollten Versätze anderer Strukturen zu finden sein.
Die magnetischen Daten zeigen außerdem die Fortsetzung der Basementstrukturen von Ellesmere Island unter Wasser, und zwar weiter nach Osten als das Ende der Gangsignatur. Eine klare N–S orientierte Störung kann nicht beobachtet werden. Das Fehlen einer einfachen Wegener-Störungsgrenze und die Fortsetzung der Basementstrukturen nach Osten durch das südliche Kane Basin machen es wahrscheinlich, dass der archaische Block von SE Ellesmere Island einen Teil der rigiden grönländischen Platte darstellt.

INTRODUCTION

During the tectonic development of the North Atlantic and the Arctic oceanic basins, Greenland moved as an independent plate relative to both the North American plate and Eurasian plate during the Paleogene (BULLARD et al. 1965, PITTMAN & TALWANI 1972, SRIVASTAVA & TAPSCOTT 1986) and resulted in a complex intraplate tectonic history in the Nares Strait region between north Greenland and Ellesmere Island. A discrete strike-slip plate boundary within Nares Strait – the Wegener Fault – has been discussed since the concept of continental drift was first proposed (WEGENER 1915) (Fig. 1). Plate kinematic models (e.g. SRIVASTAVA 1978, SRIVASTAVA & TAPSCOTT 1986) attributed at least 300 km of NE-oriented sinistral strike-slip faulting along the Wegener Fault. These models, however, led to two significant contradictions with the observed onshore geology: 1) the correlation of onshore geological units across Nares Strait suggests that only a few tens of kilometres of lateral motion are possible, and 2) the orientation of a strike-slip Wegener Fault plate boundary does not adequately explain the compressional deformation associated with the early Cenozoic Eurekan Orogeny of the Canadian-Greenland Arctic (DAWES & KERR 1982).

ROEST & SRIVASTAVA (1989) presented a revised kinematic model that identified two distinct episodes of plate motion in the Nares Strait area: approximately 200 km of NE-oriented Paleocene motion, followed by 200 km of NW-oriented Eocene plate convergence. This two-phase kinematic model is compatible with the regional tectonic framework (MIALL 1991) and adequately restricts the orogenic convergence to the Eocene (TESSENSOHN & PIEPJOHN 1998). A different kinematic model presented by OAKEY & CHALMERS (2001) define a more

[1] Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada.
[2] Bundesanstalt für Geowissenschaften und Rohstoffe, Postfach 51 01 53, 30361 Hannover, Germany.

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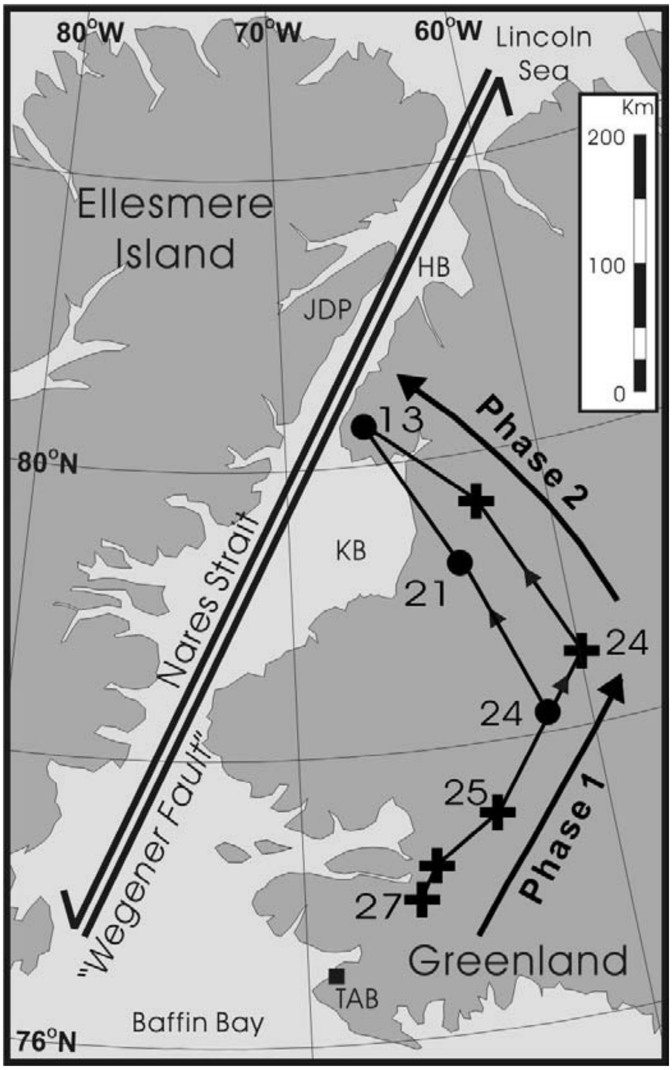

Fig. 1: Location of the Wegener Fault within Nares Strait between North Greenland and Ellesmere Island. Flow line paths for the Paleocene (Phase 1) and Eocene (Phase 2) motion of the Greenland Plate are shown with numbered positions of individual magnetochron intervals are from Roest & Srivastava's (1989) = (+) and Oakey & Chalmers' (2001) models. The location of the Thule Airbase (TAB) is also shown. Kane Basin = KB; Hall Basin = HB; Judge Daly Promontory = JDP.

northward plate convergence direction indicating a component of oblique thrusting during the Eocene.

Geological investigations onshore Judge Daly Promontory (JDP) have identified strike-slip faults and basin systems that were later overprinted by compression (Mayr & de Vries 1982, Piepjohn et al. 2000). These structures were interpreted to be the onshore equivalent of the major Wegener Fault. Further south, aeromagnetic data over Kane Basin (Fig. 2), collected in 1981 and 1982 (Hood et al. 1985) defined Precambrian rocks beneath Kane Basin, deepening to the north, with basement structures extending seaward from Bache Peninsula exhibiting about 25 km of sinistral offset, suggesting the continuity of the Wegener Fault along the entire length of the Nares Strait. However, onshore geology in the Kane Basin region does not have the structural overprinting and physical offsets expected from the Eurekan Orogeny (Peel & Christie 1982), and the geometry of the tectonic evolution across Nares Strait has been an ongoing debate.

As part of the joint BGR-GSC Nares Strait Expedition 2001, new aeromagnetic data were collected to improve the understanding of onshore–offshore continuity of geological structures and identify Eurekan structures. Results from the Hall Basin area of Judge Daly Promontory identified an offshore extension of the Eurekan Frontal Thrust northward into the Lincoln Sea (Damaske & Oakey 2006). Preliminary results offshore Inglefield Land identified seaward extension of Paleoproterozoic dikes, which were not "imaged" from previous mapping. This resulted in a second mapping program in 2003 to identify the lateral extent of the dikes and, should offsets occur, quantify the amount of offset along the Wegener Fault.

PHYSIOGRAPHY OF KANE BASIN

The coastal morphologies of Greenland and Ellesmere Island in the Kane Basin area are vastly different (Fig. 3). The ice-free area of Inglefield Land has generally low relief and elevations rarely exceed 600 m. Many small lakes are linked by a complex system of river channels. Although the Greenland coastline is relatively uncomplicated, shallow rocky shoals and small islands are common. At the mouths of many of the river systems are broad outwash plains. Near-vertical cliffs along the northern coast of Inglefield Land are generally less than 600 m. In contrast, Ellesmere Island has an extremely complex coastline, dominated by deeply incised fjords and elongated peninsulas. Much of the Prince of Wales Mountains are ice-covered and elevations often exceed 1200 m. Numerous valley glaciers extend from the interior ice-cover to reach the coast. The maximum elevation within the survey area was over Thorvald Peninsula with a height of 1880 m. North of Hayes Fiord, topography is significantly lower, with elevations over Knud Peninsula generally below 900 m and over Bache Peninsula generally below 600 m. On the northern coast of Princess Marie Bay, elevations are generally below 900 m. All of these low-land areas are ice-free.

The bathymetry within Kane Basin is fairly flat, with depths ranging between 200-300 m. A deeper channel (>300 m) runs parallel to the Inglefield coastline and links with another channel extending from Buchanan Bay (depths >400 m) at the northern end of Smith Sound. Within Smith Sound, bathymetric depths exceed 500 m. This channel system is characteristic of deeply scoured glacial channels.

GEOLOGY OF KANE BASIN

The geology of the Kane Basin and surrounding land areas is broadly divided into an Archean to Paleoproterozoic crystalline basement with overlying sedimentary sequences of Mesoproterozoic Thule Supergroup and Cambrian to Devonian sequences of the Arctic Platform (Fig. 4). Onshore exposure of Cretaceous rocks on Ellesmere Island are part of the Franklin-Pierce Basin.

Within the Kane Basin, seismic coverage is limited, and the geometry and lithology of the sedimentary sequences are poorly constrained. A new geological map of the Nares Strait (Harrison et al. in press) shows a broad offshore exposure of Archean and Paleoproterozoic crystalline basement rocks with

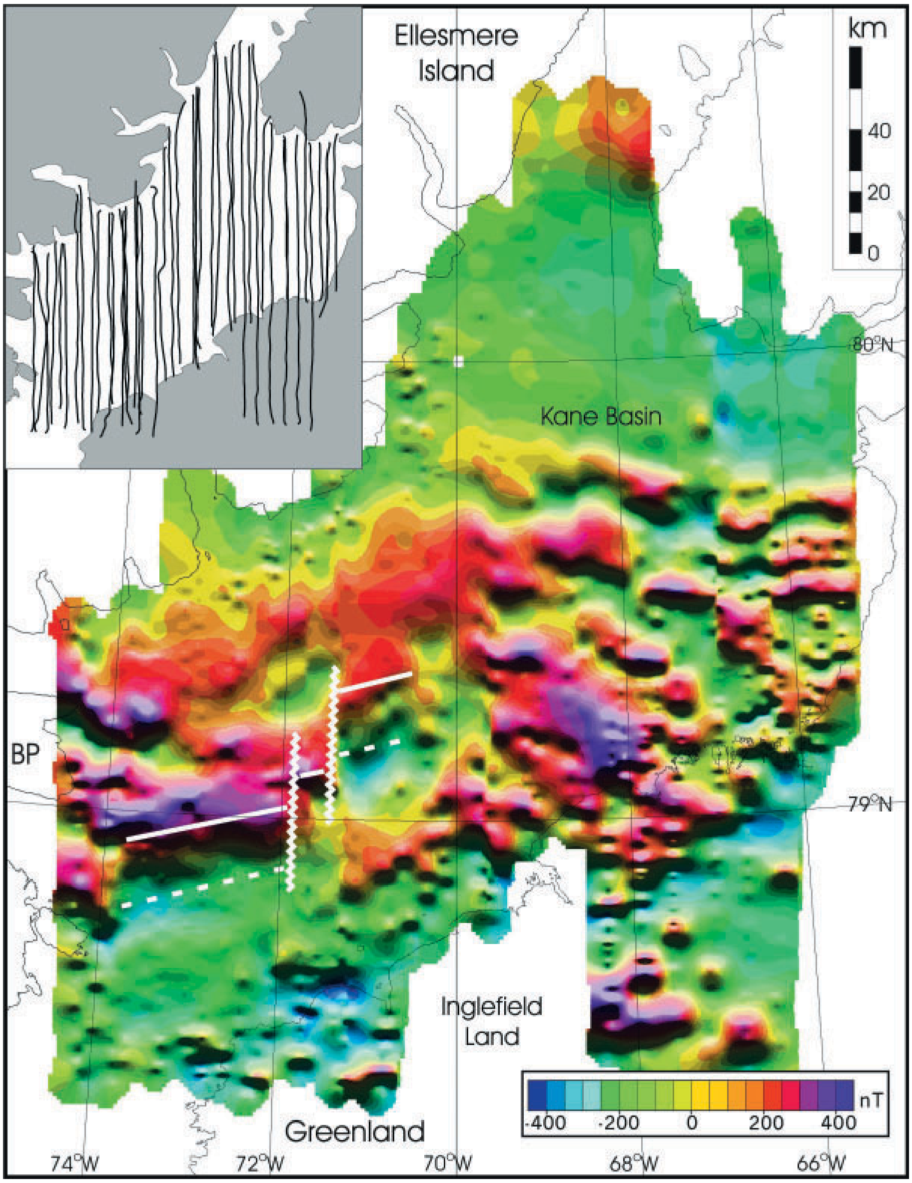

Fig. 2: Aeromagnetic data acquired in 1981 and 1982 between Inglefield Land and Ellesmere Island over Kane Basin (Hood et al. 1985) with the interpreted offshore continuation of basement structures from Bache Peninsula (BP) (solid and dashed white lines) and the structural offsets (jagged white lines) defining the supposed 25 km of offsets along the Wegener Fault. The insert shows the location of the flight lines.

a narrow belt of the Neoproterozoic sequences of the Arctic Platform. However, the possibility of patches of Mesoproterozoic Thule Supergroup rocks cannot be discounted. The eastern limit of the Cretaceous-Paleogene strata within the Franklin-Pierce Basin is not depicted as a structurally controlled boundary, however new interpretations of seismic data suggest that shallow-angle reverse thrust faults control the basin geometry (Jackson et al. 2006).

On Greenland, high-grade basic, intermediate and granitic rocks with migmatized gneisses dominate the lithology of the Paleoproterozoic Etah meta-igneous complex of Inglefield Land (Dawes 1988). Highly metamorphosed meta-sedimentary rocks of the Etah supra-crustal sequence include narrow marble-rich belts. Flat-lying sedimetary rocks of the Mesoproterozoic Thule Supergroup and overlying Neoproterozoic sequences of the Arctic Platform dominate cliff exposures on northern Inglefield Land.

On Ellesmere Island, extreme ice coverage limits the ability to provide continuous mapping of geology. Within the Prince of Wales Ice Field, ultramafic granites and high-grade gneisses are exposed in a limited number of cirques, equivalent to the Etah meta-igneous complex of Inglefield Land. In the Knud Peninsula area meta-sediments dominate coastal exposures, equivalent to Etah supra-crustal sequence, including narrow marble-rich belts (Frisch 1984). On Knud Peninsula and southern Bache Peninsula are exposures of flat-lying undeformed rocks of the Thule Group. Flat-lying Neoproterozoic sequences of the Arctic Platform are exposed on Bache Peninsula, however, north of Princess Marie Bay these rocks are faulted and folded.

Of particular interest for this study are the Proterozoic dyke intrusives mapped on both Greenland and Ellesmere Island, specifically, the petrologically unique Kap Leiper Dyke which is the most northern dolerite intrusion in North-West Greenland (Dawes et al. 1982). Dated at 627 ±25 Ma, this dyke cuts sediments of the Rensaller Bay Formation, the lower unit of the Thule Supergroup. The offshore continuity of the Kap Leiper Dyke provides a critical marker for identifying the extent of the crystalline basement and possible overprinted tectonic activity.

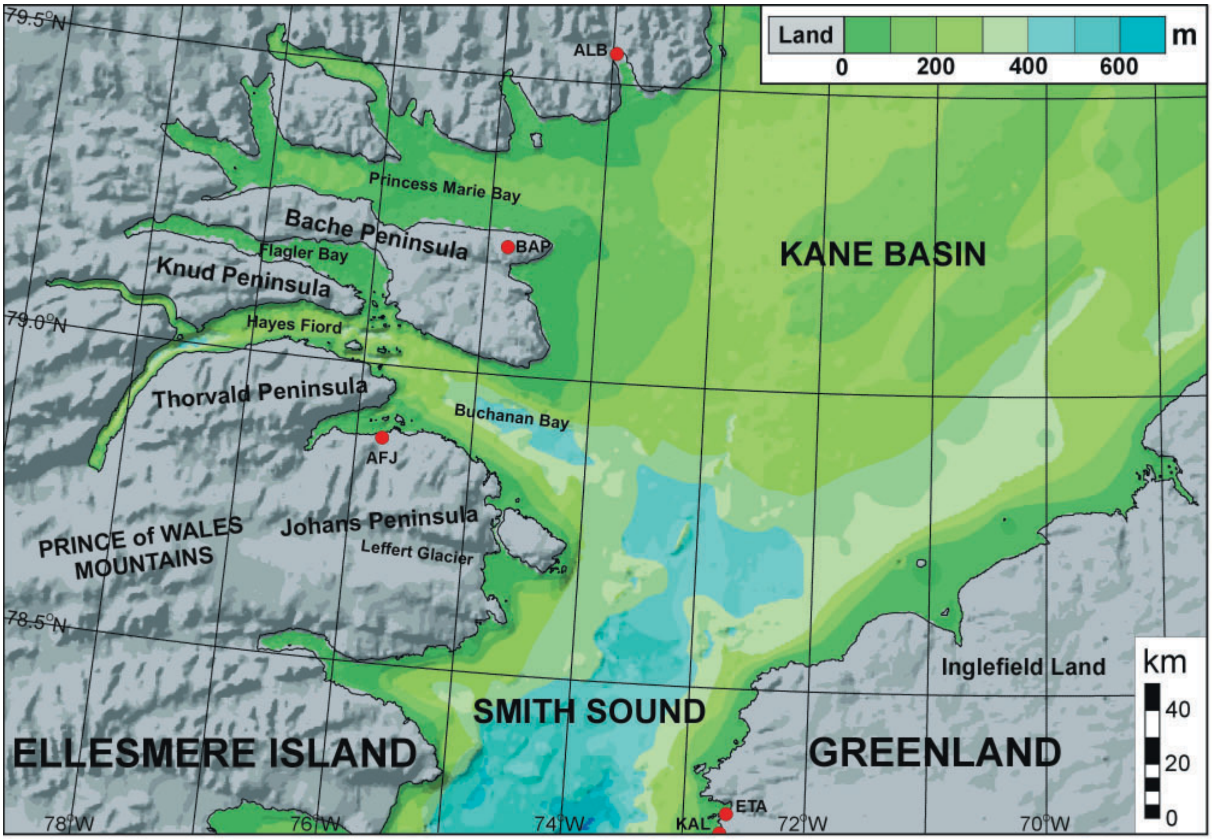

Fig. 3: Physiography of Kane Basin showing major geographical locations. Locations of the magnetic base stations for the 2001 and 2003 field programs are also shown: Kap Alexander = KAL; Etah = ETA; Alexandra Fiord = AFJ; Bache Peninsula = BAP; Allman Bay = ALB.

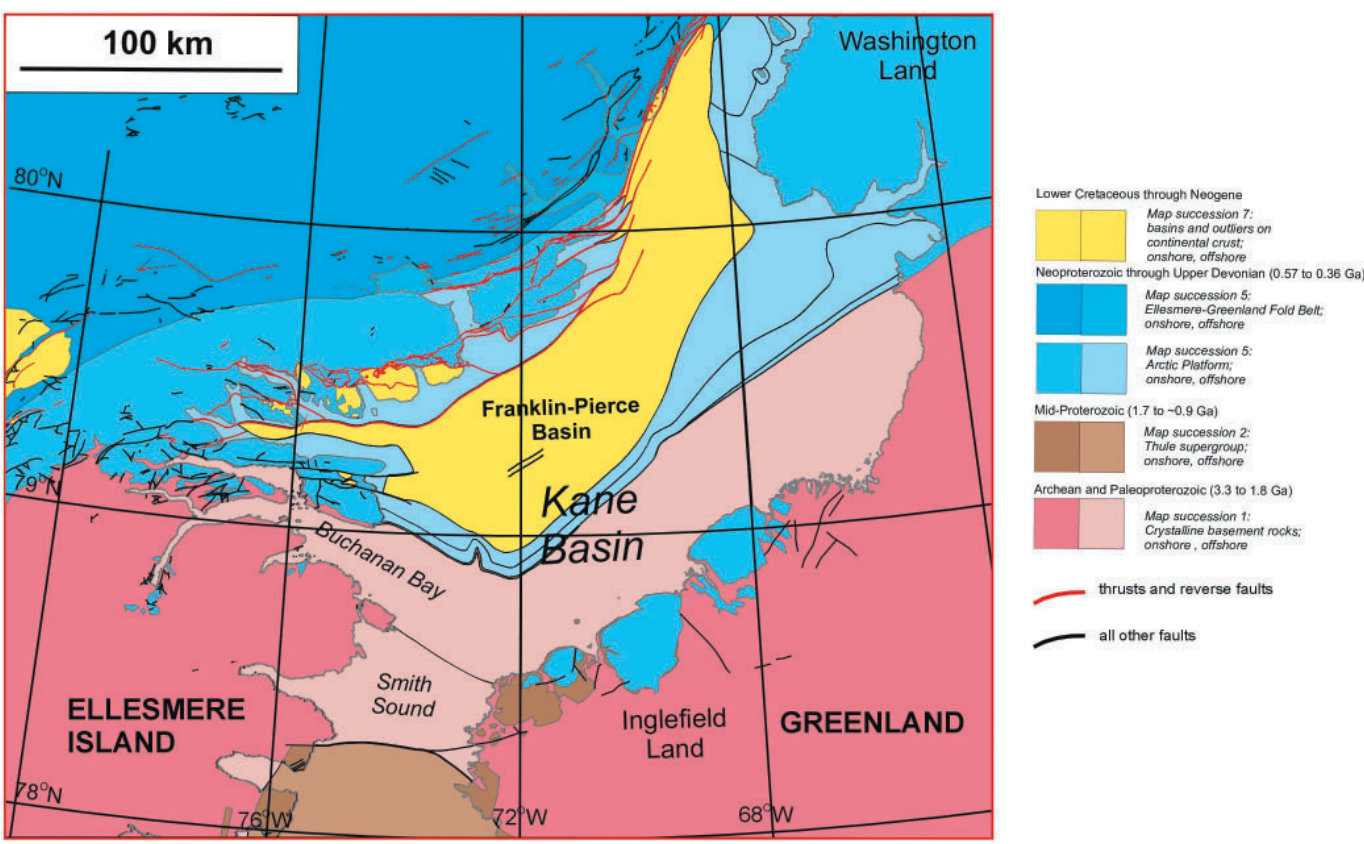

Fig. 4: Geology of Kane Basin. Map successions are based on the descriptions of Harrison et al. (in press) showing the offshore Cretaceous-Paleogene Franklin-Pierce Basin overlying the Arctic Platform and thin Thule Supergroup strata.

THE SURVEY

Program activities

The aeromagnetic surveying of Kane Basin began as part of the joint Canadian-German (GSC/BGR) cruise Nares Strait 2001, operated from the Canadian Coast Guard (CCGC) icebreaker "Louis S. St-Laurent". During this surveying program, the area of western Kane Basin was mapped to provide a marine extension to aeromagnetic data collected by the Geological Survey of Greenland (now GEUS) over Inglefield Land (Stemp & Thorniing 1995). A second survey during 2003 completed the coverage across Kane Basin and linked the mapping to onshore Ellesmere Island. The 2003 program was based at Alexandra Fiord on Ellesmere Island as part GSC's Northern Resource Development Program. Logistical support for the 2003 field season was provided by the Canadian Polar Shelf Project (PCSP).

Survey design and data acquisition

The physiography of the survey area must be incorporated into the survey design. Ideally, survey lines should be flown as low as possible, especially over water where magnetic source depths are deeper. However, extreme changes in flight elevations are difficult, and because of high coastal cliffs, a compromise must be made between the flight elevation over water and onshore.

Based on the survey parameters used by Hood et al. (1985), survey design for this area was defined at 2 km N–S line spacing at an elevation of 2000 ft (610 m) with E–W tie-lines at 10 km (i.e., at a ratio of 1:5, standard for reconnaissance surveys (Damaske et al. 2005). This minimized the requirement to change flight elevations for onshore areas. For areas of higher elevation, a targeted terrain clearance of 1000 ft (305 m) was planned to minimize variability of source depths, simplify tie-line acquisition, and provide appropriate safety for flying over rugged ice-covered terrain. Coordinates of the way-points were calculated using a Lambert Conformal projection with a central meridian of 70 °W and standard parallels of 76°45' N and 79°15' N.

Surveying for both field seasons was from helicopter platforms, during the 2001 with a CCG twin-engined helicopter (type Bo 105), and 2003 with a single-engine helicopter (type Bell 106 - Jet Ranger) contracted by PCSP from Universal Helicopters, Newfoundland. A Cesium-magnetometer was towed in bird configuration from a 25 m cable below the helicopter. Flight-line navigation was done using the helicopter's (Global Positioning Satellite) GPS-system. Altitude was controlled by both barometric and radar altimeter on the CCG helicopter and barometric altimeter on the PCSP helicopter. Survey positioning was recorded from a separate GPS-antenna fed directly to the data acquisition system. For the 2003 survey, a GPS base station was set up at Alexandra Fiord to apply post-processing differential navigation corrections and improve the navigational positional accuracy.

A critical design component of the survey was the time of the day that flights occurred. Based on a permanent magnetometer base station at the Thule airbase on Greenland, it was determined that the optimal times to survey were between 00:00 and 08:00 UT when the amplitude of the diurnal variations was a minimum.

A total of 11,806 km of surveying was completed over Kane Basin (3573 km in 2001, and 8333 km in 2003) during the two field seasons covering an area of approximately 20,000 km^2 (Fig. 5).

Base stations

Geomagnetic activity was monitored for both field seasons at multiple locations to provide adequate reference for spatial and temporal variability of the magnetic field. In 2001, base stations were set up on Bache Peninsula (BAP), on Kap Alexander (KAL) and close to the deserted Inuit village of Etah

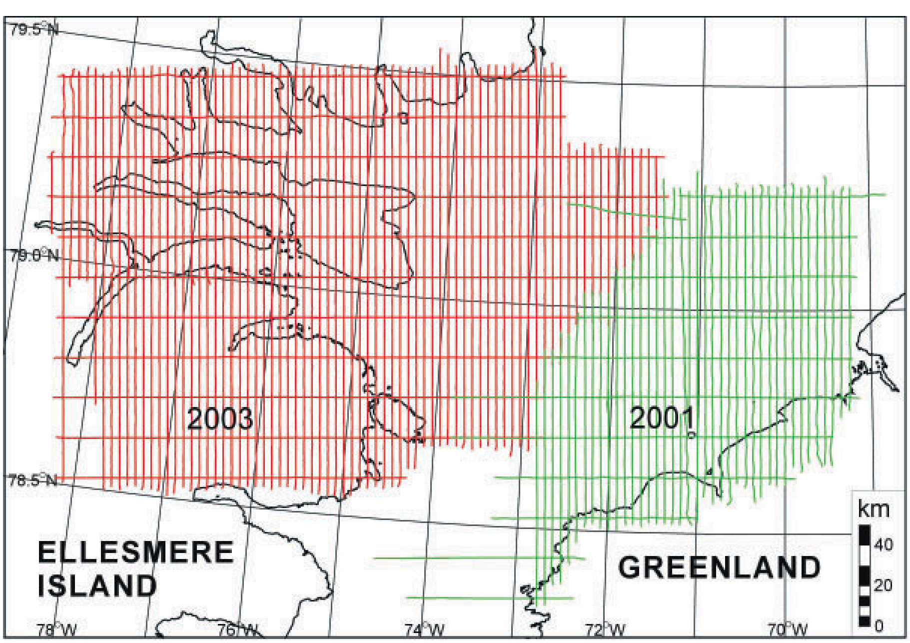

Fig. 5: Survey geometry of the 2001 and 2003 aeromagnetic surveys. A 2 km survey line spacing was designed on a Lambert conformal base (central meridian: 70 °W; standard parallells: 76°45' N and 79°15' N). Tie lines are spaced at 10 km.

(ETA) and in 2003, base stations were set up at the operational base at Alexandra Fiord (AFJ) and in Allman Bay (ALB) (see Fig. 3).

During the 2001 field program diurnal activity during survey time rarely exceeded 100 nT with daily maximum deviation rarely over 200 nT (Fig. 6). In contrast, during the 2003 field program diurnal activity during survey time often exceeded 200 nT and a maximum deviation observed May 30 exceeded 800 nT (Fig. 7, Julian day 150). A comparison of all base station data from the two field seasons showed minimal spatial and temporal variability of the magnetic field, and only the data from the BAP station were applied to the 2001 survey and AFJ station for the 2003 survey. The total magnetic field was recorded at one-minute intervals. Data were smoothed with a 30-minute low-pass filter to exclude short-period variations, thus avoiding introduction of "artificial" anomalies in the more distant parts of the survey area. The filtered base-station data were then interpolated to 1-second intervals and subsequently subtracted from the survey's total magnetic field values.

Data processing and map production

The internal (main-field) component in the recorded data was removed by calculating for each survey point using the IGRF (International Geomagnetic Reference Field) model 2000 of IAGA (International Association of Geomagnetism and Aeronomy, Division V, Working Group 8, 2000) and subtracting it from the magnetic field values. The central date for each survey was used for each survey block, 22 August 2001, and 31 May 2003.

After base station correction and IGRF removal, some discrepancies between the magnetic field values at the intersections of profile- and tie-lines remained. The calculated deviations were minimized using an iterative leveling approach (DAMASKE et al. 2005). In this way not only the higher frequency parts of the diurnal variation were accounted for, but also discrepancies due to differences in elevation or from any other effect were reduced.

The difference in the overlapping "seam" between the two survey blocks was calculated and a simple DC-correction of 42.0 nT was applied to link the surveys together. The overlapping survey line segments from the 2001 survey were trimmed back to minimize gridding artifacts. The final grid was produced from the levelled data incorporating only the survey lines using a cell size of 400 m and interpolated with a minimum curvature algorithm (SMITH & WESSEL 1985). The total field map is shown in Figure 8 with an illumination angle from the north, preferentially defining EW-oriented structures.

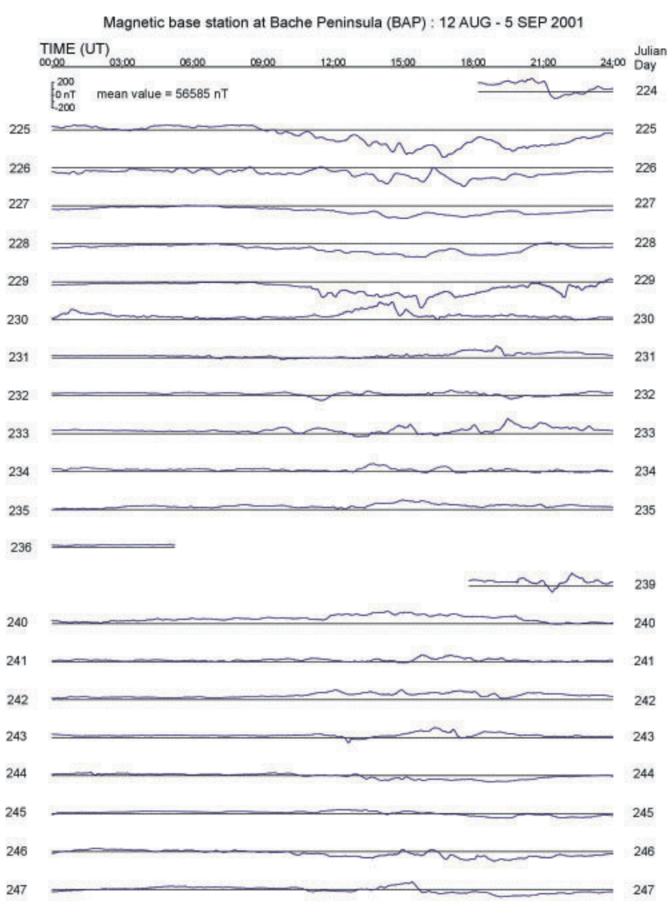

Fig. 6: Diurnal variations used for 2001 survey from Bache Peninsula (BAP). Survey flights were operated between 00:00 UT (Universal Time) and 08:00 UT to minimize the effect of the diurnal variation.

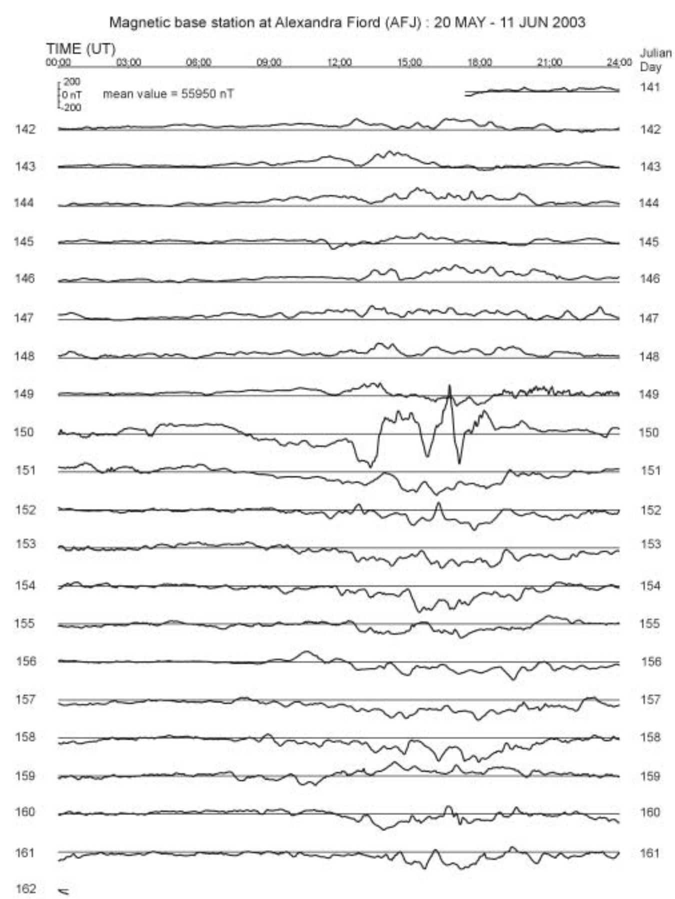

Fig. 7: Diurnal variations used for 2003 survey from Alexandra Fiord (AFJ). Survey flights were operated between 00:00 UT (Universal Time) and 08:00 UT to minimize the effect of the diurnal variation.

DISCUSSION OF ANOMALIES

Interpretation of total field anomaly

The total magnetic field map shows a complex pattern of high amplitude, high frequency anomalies over Ellesmere Island and coastal Inglefield Land (Fig. 8). Longer wavelength anomalies over Kane Basin correspond to an increased source depth, a combined effect of water depth and cover of non-magnetic rocks. Discontinuities of the magnetic anomalies reveal structural elements within the complex distribution of Archean basement rocks. The interpretation of the total field map is shown in Figure 9.

On Ellesmere Island, positive magnetic anomalies are generally elongated, oriented SW-NE, however, direct correlation with basement rocks is problematic and anomalies often cut across exposures of non-magnetic metasediments. This suggests that in most locations the metasedimetary rocks are relatively thin and must be underlain by ultramafic basement rocks. At least three of these magnetic lineations (M1, M2, and M3) can be directly correlated with outcrops of marble,

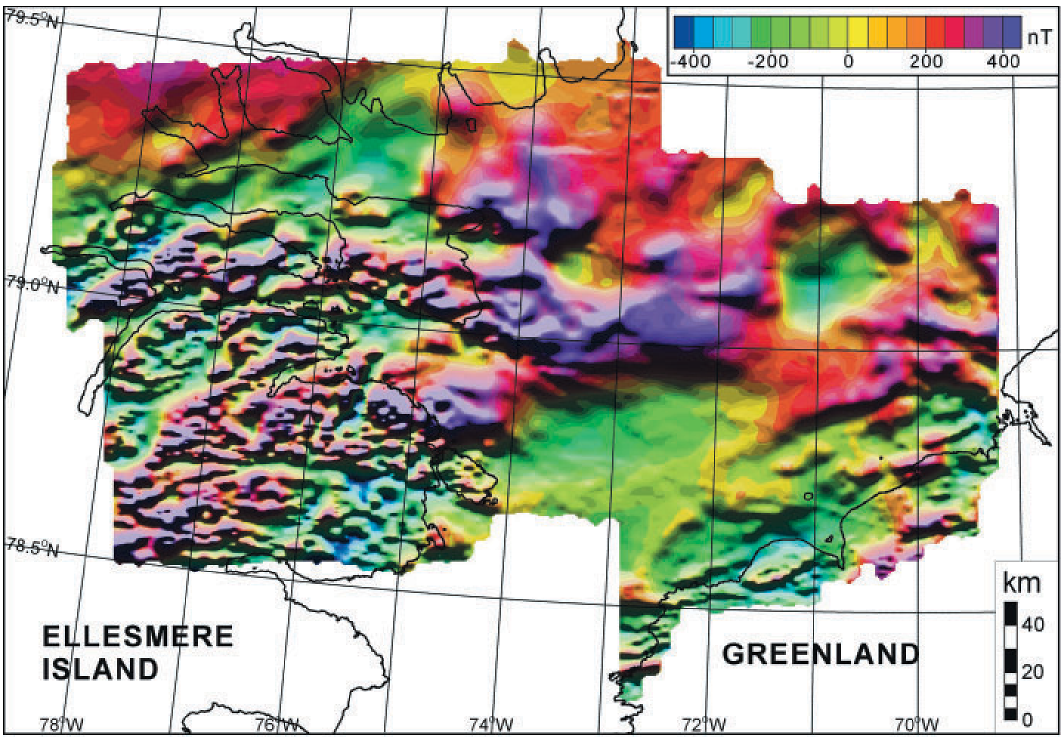

Fig. 8: Shadow illuminated total field anomaly map of the new survey data. Sun illumination angle is from the north. Generally, complex patterns of high amplitude - high frequency anomalies are observed onshore and near-shore; longer wavelengths within Kane Basin.

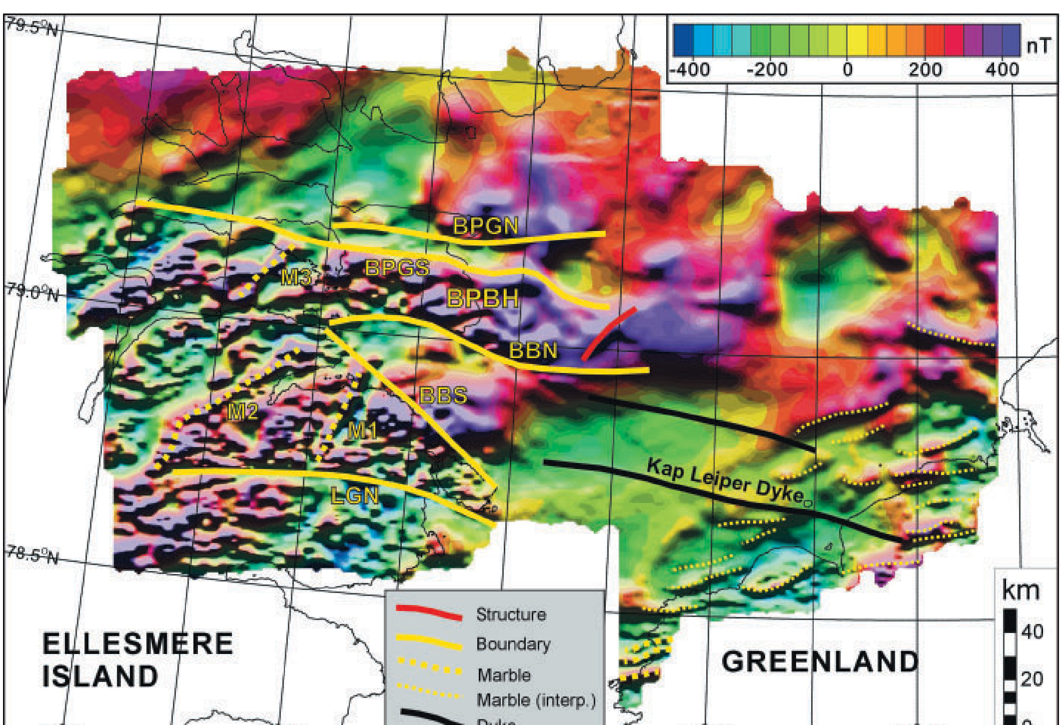

Fig. 9: Shadow illuminated total field anomaly map with interpretive overlay. Shown are the correlations with onshore marble belts (M1, M2, M3); Kap Leiper Dyke; BPGN = Bache Peninsula graben north; BPGS = Bache Peninsula graben south; BPBH = Bache Peninsula basement high; BBN = Buchanan Bay northern shore; BBS = Buchanan Bay southern shore; LGN = Leffert Glacier northern edge.

possibly a result of associated mineralization of copper, nickel and zinc (Frisch 1984).

Although many of these magnetic lineations extend across large fjords (such as Hayes Fiord and Flagler Bay), there are four notable discontinuities each associated with significant physiographic features. In each case, there is an abrupt change in the frequency content, however there do not appear to be any significant horizontal offsets across the boundaries.

Boundary 1
is defined along the northern edge of Leffert Glacier (LGN) where the linear magnetic anomalies to the north are abruptly truncated by an elongated E–W-oriented magnetic low. This boundary corresponds to a significant topographic offset with high (>4000 ft) near-vertical cliffs. Also closely associated with this boundary is the E–W oriented Leffert Glacier dike (Frisch 1984). Although the orientation of this dike is consistent with the Kap Leiper Dyke, it is petrographically different (Denyszyn & Halls 2006).

Boundary 2 and Boundary 3
are located along the southern shore of Buchanan Bay (BBS) and the northern shore (BBN). Within Buchanan Bay, high amplitude anomalies indicate the continuity of Archean basement rocks across the bay. The reduced frequency content of these anomalies partially reflect the increased bathymetric depth, however the abrupt edges and the significant attenuation must also be the result of increased depth to magnetic source with overlying non-magnetic rocks. Although these non-magnetic rocks are likely Proterozoic meta-sedimentary rocks, there is no direct evidence for their age. The eastern edge of the high amplitude anomalies within the Buchanan Bay are abruptly truncated against a large offshore magnetic low at 74 °W.

Boundary 4
defines the northern limit of exposed or near-surface crystalline basement and extends approximately from the northern coast of Knud Peninsula eastward to the southern edge of the graben on Bache Peninsula (BPGS). This graben has a central magnetic low, which separates the high frequency anomalies to the south from longer wavelength anomalies to the north. The northern edge of the Bache Peninsula graben is labeled BPGN in Figure 9. For the purpose of further description, the block between BBN and BPGS will be called the Bache Peninsula Basement High (BPBH).

Along the coastal area of Inglefield Land, in the area of Smith Sound, E–W-oriented linear anomalies correlate with coastal outcrops of the marble belts within the Etah metasedimentary complex (Dawes 1988). Similar E–W-oriented anomalies are observed along northern Inglefield Land and offshore. Onshore, the linear anomalies are produced by sources beneath the exposures of the Arctic Platform and Thule Supergroup rocks and are interpreted to be continuations of these marble belts.

In the total field anomaly map, the anomaly corresponding with offshore extension of the Kap Leiper Dyke is imaged, however due to its small amplitude, the lateral extent is uncertain. Magnetic modeling of several profiles crossing the anomaly (Denyszyn & Halls 2006) show significant variability of the dyke along strike that can be explained by a combination of variable width or magnetization. A second laterally continuous linear magnetic anomaly is observed north of the Kap Leiper Dyke anomaly (dashed black line). Due to it's similar magnetic character and identical orientation to the Kap Leiper Dyke, this feature is interpreted to be another dyke. This anomaly cannot easily be traced to the coastline of Inglefield land, and may terminate offshore.

Beneath Kane Basin and Princess Marie Bay the high frequency content of the magnetic anomalies decreases significantly. Since water depths are generally shallow over most of Kane Basin, the resulting decrease of high frequency anomalies is attributed to deeper magnetic source rocks rather than increased bathymetric depths. The areas of high-amplitude and low-amplitude anomalies essentially define the bulk magnetization of the underlying material. High-amplitude areas most likely correlate with ultramafic basement rocks, however, over low-amplitude areas, it is difficult to differentiate between thick non-magnetic sediments and the intrusion of non-magnetic igneous rocks. The high-amplitude anomalies associated with the Bache Peninsula basement high (BPBH) extend to the east beneath Kane Basin with systematic attenuation of the high frequency component, suggesting increasing depth, and terminate at 72 °W. Shown in Figure 9 is the Hood et al. (1985) interpretation (solid and dotted white lines) of the offshore continuation of structures east of Bache Peninsula. Their inferred location of sinistral offset corresponds with the easternmost end of the BPBH; however, with the new evidence of the offshore dyke system, it is not possible to place the Wegener Fault in this location. The eastern termination of the BPBH may represent a faulted boundary that pre-dates the emplacement of the dykes.

Interpretation of 2nd vertical derivative component

The 2nd vertical derivative component of the magnetic field preferentially defines the high-frequency component and maintains the spatial position of individual features. The map of the 2nd derivative component of the magnetic field (Fig. 10) clearly shows the difference between the complex high-frequency areas onshore and the subdued character of the offshore areas. The colour pallet and shadow illumination parameters for this map have been chosen to highlight subtle features within Kane Basin, rather than the extremely complex onshore areas. In Figure 11 the boundaries defined by the total field map are shown as well as the linear features interpreted from the 2nd derivative map. In the onshore area north of Princess Marie Bay, a systematic "noise" is observed, suggesting the existence of complex small-scale structures that cannot be properly imaged with the resolution of this survey. For the purpose of this text, we will discuss the lineations in the offshore areas rather than attempt to distinguish boundaries within the onshore Archean basement rocks.

Along the northern coastal area of Inglefield Land and easternmost Kane Basin, numerous E–W-oriented linear anomalies are imaged with the 2nd derivative component of the magnetic field, and are interpreted as multiple marble belts within the Etah meta-sedimentary complex. The frequence content of these lineations systematically decreases offshore north Inglefield Land, indicating that the source bodies are

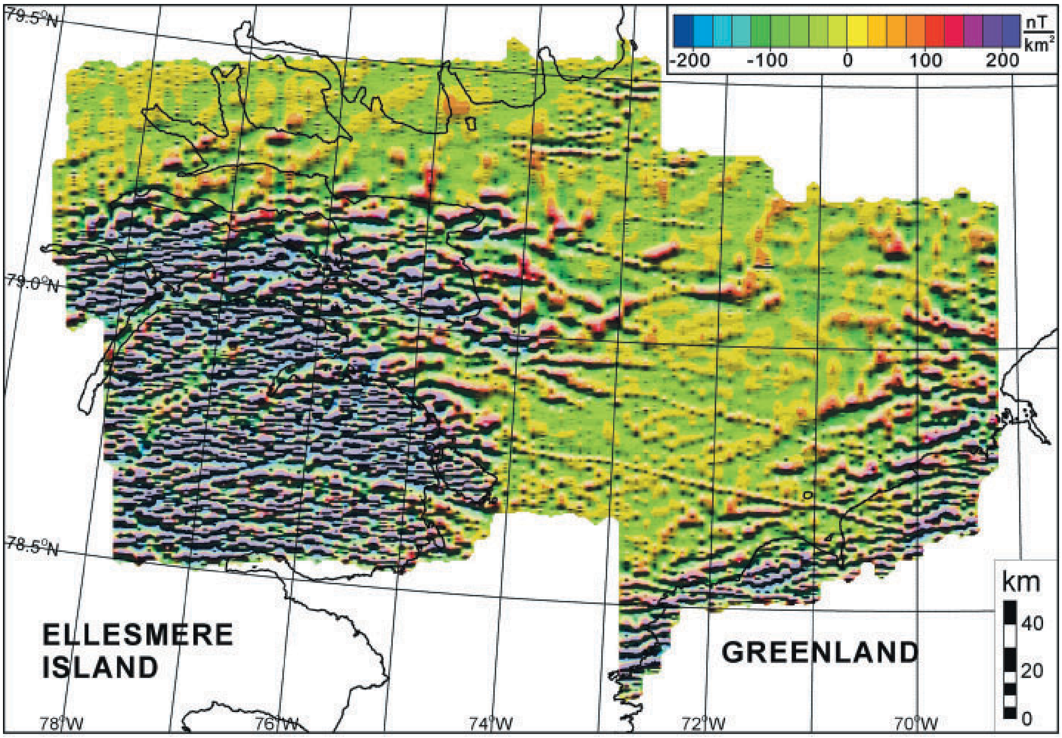

Fig. 10: Shadow illuminated 2nd vertical derivative map across Kane Basin between Greenland and Ellesmere Island. The high frequency component of the magnetic field resulting from shallow source-bodies are identified. Illumination is from the north.

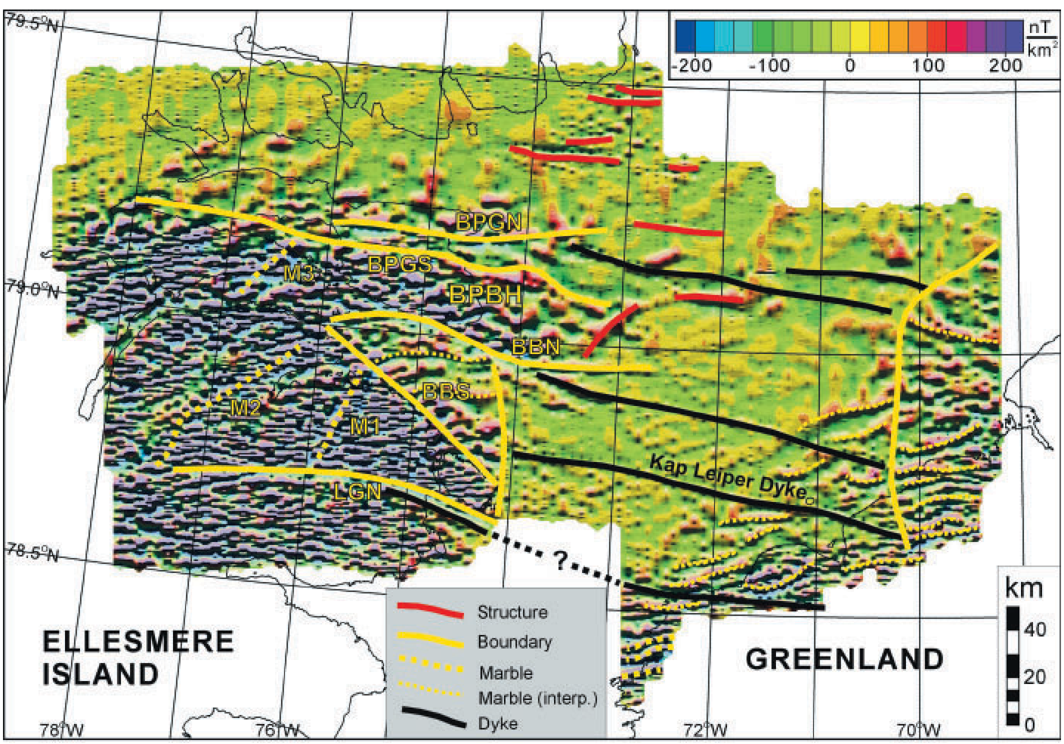

Fig. 11: Shadow illuminated 2nd vertical derivative map with interpretive overlay. Shown are the correlations with onshore marble belts (M1, M2, M3); Kap Leiper Dyke; inferred offshore dykes; inferred marble belts and interpreted structures; LGN = Leffert Glacier northern edge; BPGN = Bache Peninsula graben north; BPGS = Bache Peninsula graben south; BPGH = Bache Peninsula basement high; BBN = Buchanan Bay northern shore; BBS = Buchanan Bay southern shore.

increasing in depth. Near the eastern edge of the survey, these lineations are truncated by a N–S-oriented boundary identified by a dramatic decrease in frequency content. This boundary does not directly correlate with changes in bathymetric depth, and likely represents a faulted boundary. The southern end of this fault boundary appears to terminate both the Kap Leiper Dyke and the parallel dyke to the north. As such, the age of this fault is uncertain.

In southern Kane Basin, the 2nd derivative component images the Kap Leiper Dyke and the parallel dyke to the north as coherent features with minimal lateral variability, indicating that the source depth is consistently shallow. The Kap Leiper Dyke is mapped to the coastline of Ellesmere Island. The identification of these dykes over an area with virtually no other high frequency magnetic anomalies suggests that the crystalline basement is much deeper than the dykes and is likely covered by non-magnetic rocks. Considering the coastal exposure of the Thule Supergroup and cross-cutting field relationship of the Kap Leiper Dyke with the Rensaller Bay Formation on northern Inglefield Land, it is possible that the Thule Basin extends beneath southern Kane Basin.

Within Buchanan Bay, the 2nd derivative component images two E–W-oriented magnetic lineations. The eastern ends of these features are truncated by a boundary (approximately at 74 °W, Fig. 11), again defined by a dramatic decrease in frequency content. The orientation of these lineations are not consistent with the orientation of the marble belts on Ellesmere Island, and are more characteristic of the lineations offshore Inglefield Land. Although these features are labelled as possible marble belts in Figure 11, their true nature is uncertain.

Although the eastern end of the magnetic high associated with the Bache Peninsula crystaline basement rocks (defined by the total field anomaly) (Fig. 9) continues to 72 °W, the 2nd derivative component shows a pronounced NE-oriented discontinuity at 73 °W (red "structure" in Fig. 11). This may represent an offset in the basement rocks, with a significantly deeper source bodies east of the BPBE. Over northern Bache Peninsula, the 2nd derivative component identifies isolated magnetic highs with a reduced frequency component, suggesting that deeper crystalline basement extends slightly north of Bache Peninsula graben. Whether this crystalline basement terminates abruptly or deepens very rapidly in uncertain.

In the northern-most area of Kane Basin, near Allman Bay (ALB from Fig. 3), several E–W-oriented linear anomalies (red lines) are identified. Although their orientation is similar to the dykes identified further south, their lateral continuity is limited. The location of these anomalies corresponds with the southern portion of the Franklin-Pierce Basin, and are interpreted as Eurekan structures. The source of these anomalies may be slivers of up-thrusted basement rocks.

EASTERN TERMINATION OF THE KAP LEIPER DYKE

Although the Kap Leiper Dyke can be traced across southern Kane Basin, it does not appear to have an onshore outcrop on Ellesmere Island (Fig. 12). A possible correlation with a linear magnetic anomaly over a small island (Cocked Hat Island), a few kilometres north of Pim Island provide a speculated onshore exposure. However, geological field-work in the summer of 2003 by the University of Toronto disproved this location as a dyke exposure (Halls and Denyszyn pers. comm.). Whether the dyke simply terminates or is offset by a coastal fault is unknown, however multiple high-amplitude magnetic anomalies from shallow sources surrounding coastal Ellesmere Island make direct mapping inconclusive.

DISCUSSION: IMPLICATIONS FOR PLATE GEOMETRY

This aeromagnetic surveying program provides new insight on the onshore/offshore continuity of geology in the Kane Basin region. Archean basement extends beneath Kane Basin, deepening to the north. The identification of dikes over areas with virtually no other high frequency magnetic anomalies suggests that the crystalline basement is much deeper than the dikes and is likely covered by non-magnetic rocks, possibly Thule Supergroup strata.

The magnetic data map the offshore extension of the Kap Leiper Dyke from the exposure onshore Greenland to the coastline of Ellesmere Island. The continuity of this feature refutes the interpretation of extending the Wegener Fault through central Kane Basin (Hood et al. 1985). If the western end of the mapped Kap Leiper Dyke represents a faulted bounded termination, then it can be argued that the Wegener Fault lies just off the Ellesmere Island coast. However, if the Wegener Fault represents an Eocene compressive boundary, then a compressive zone (equivalent to Judge Daly Promontory) would be expected. This is not consistent with the presence of undeformed Proterozoic and Paleozoic sedimentary sequences on Bache Peninsula. Conversely, if the Wegener Fault represents a simple Paleocene strike-slip boundary, then offsets of other structures should be observed. The magnetic data also identify offshore extensions of basement structures from Ellesmere Island (Bache Peninsula Basement High) further east than the position of the dyke termination and no clearly defined N–S-oriented fault boundary is observed. The inability to define a simple Wegener Fault boundary and the possible continuity of base-

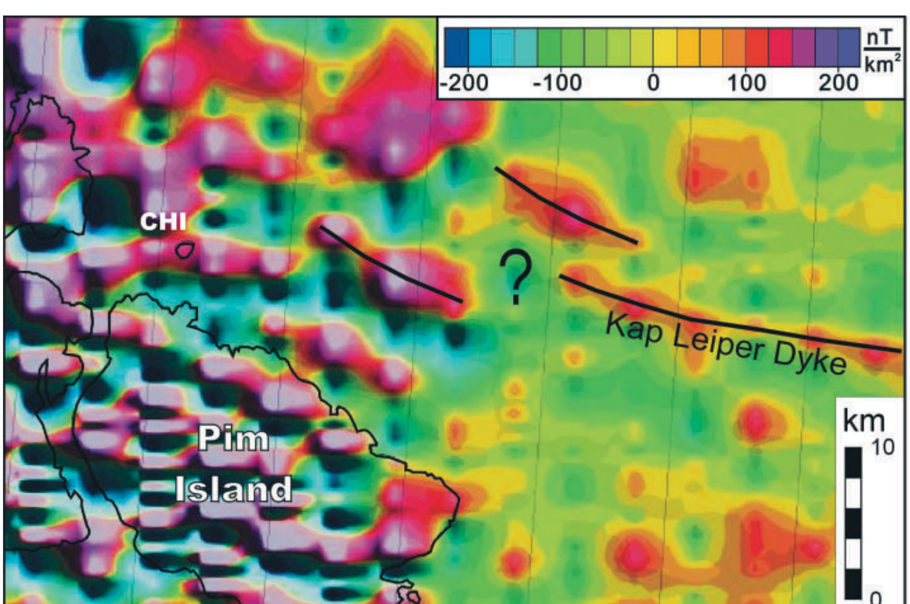

Fig. 12: Western extent of Kap Leiper Dyke near Pim Island. Correlation to the west is uncertain. Short (<10 km) linear magnetic highs (bold black lines) have been speculated positions. The possible exposure on Cocked Hat Island (CHI) was checked by Henry Halls and Steve Denyszyn (pers. comm. 2003) and disproved this as dyke exposure.

ment structures across southern Bane Basin suggest that the Archean block of southeastern Ellesmere Island may be part of the rigid Greenland plate.

The implication that the Greenland plate may include southeast Ellesmere Island has significant regional implications on the development of the Eurekan Orogen. This interpretation requires that the plate boundary wraps around the Archean block of southeast Ellesmere Island. This is consistent with the E–W-oriented thrust fault systems north of Princess Marie Bay linking the Eurekan Frontal Thrust in northern Nares Strait with the central Ellesmere deformation zone. However, this scenario also raises new questions regarding the nature of the plate boundary in southernmost Nares Strait.

A simplified (pre-Eocene) plate reconstruction is shown in Figure 13 to illustrate the problems of the new geometry along Nares Strait. The Eocene convergence of up to 250 km between northern Greenland and Ellesmere Island (Phase 2 of the Eurekan Orogeny) is accommodated along a non-linear frontal thrust, with the Archean block on southern Ellesmere Island moving with the Greenland plate, acting as a ram or "indentor block". Along the southern edge of the indentor block, sinistral strike-slip faulting is predicted. This is shown as a single fault in the illustration, corresponding roughly with the location of a NW-oriented seismic discontinuity (surface waves or LG-component) defined by WETMILLER & FORSYTH (1982); however, the offset could be accommodated across a broad zone. This NW-oriented plate boundary is in conflict with the evidence of N–S-oriented "flower-structures" in southernmost Nares Strait (JACKSON et al. 1992). The convergence direction defined by the kinematic model is slightly oblique to the frontal thrust, suggesting an overall component of sinistral transpressional thrusting, however, along the northern edge of the indentor block transpressional thrusting should have a dextral component. Shortening across Ellesmere Island would be confined to the region directly in front of the Frontal Thrust, preferentially deforming the eastern Sverdrup Basin. Details of the earlier (Phase 1) component of the Eurekan Orogen cannot be resolved with the new aeromagnetic data due to the limited area covered by the survey.

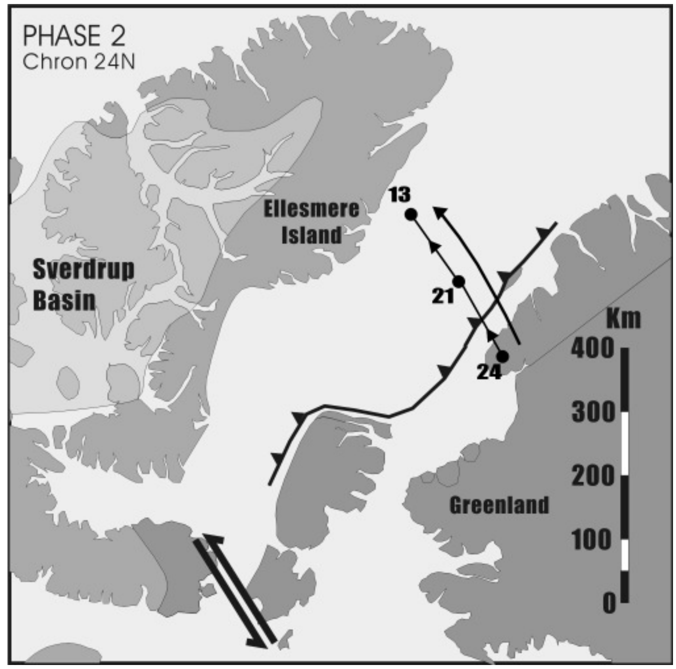

Fig. 13: Plate reconstruction for Eocene (Phase 2) component of the Eurekan Orogen with new geometric constraints. SE-Ellesmere Island has been moved as part of the rigid Greenland Plate. Eocene flow-lines for the Greenland Plate are from OAKEY & CHALMERS (2001). Eocene plate convergence is accommodated along a frontal thrust fault. Sinistral motion is predicted along the southern edge of the Greenland Plate.

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References

Bullard, E., Everett, J. & Smith, A.G. (1965): The fit of the continents around the North Atlantic.- In: P.M.S. Blackett, E. Bullard & S.K. Runcorn (eds), A symposium of continental drift, Phil. Trans. Roy. Soc. London 258A: 41-51.

Damaske, D. & Oakey, G.N. (2006): Volcanogenic sandstones as aeromagnetic markers on Judge Daly Promontory and Robeson Channel in the northern Nares Strait region.- Polarforschung 74: 9-19.

Damaske, D., Marcinkowski, V. & Möller, H.-D. (2005): Aeromagnetic survey in central Dronning Maud Land, East Antarctica, during the GeoMaud expedition 1995/96: Lay-out, execution, and data processing.- Geol. Jahrbuch B97: 53-83.

Dawes, P.R. (1988): Etah meta-igneous complex and the Wulff structure: Proterozoic magmatism and deformation in Inglefield Land, North Greenland.- Geol. Surv. Greenland Rep.139: 1-24.

Dawes, P.R. & Kerr, J.W. (1982): Nares Strait and the drift of Greenland: a conflict in plate tectonics.- Meddel. om Grønland, Geosci. 8: 1-329.

Dawes, P.R., Peel, J.S. & Rex, D.C. (1982): The Kap Leiper basic dyke and the age of the dolerites of Inglefield Land, North-West Greenland.- Geol. Surv. Greenland Rep.110: 1-19.

Denyszyn, S.W. & Halls, H.C. (2006): Paleomagnetic, petrographic, and geochemical results from the Thule (Greenland) and Devon Island (Canada) dyke swarms and their relevance to the Nares Strait Problem.- Polarforschung 74: 63-75.

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

Harrison, J.C, Brent, T. & Oakey, G.N. (in press): Development of a new geology map of the Nares Strait Region.- Geol. Surv. Canada, Open File.

Hood, P., Bower, M.E., Hardwick, C.D. & Teskey, D.J. (1985): Direct geophysical evidence for displacement along Nares Strait (Canada-Greenland) from low-level aeromagnetic data: A progress report.- Current Res. Part A, Geol. Surv. Canada 85-1A: 517-522.

International Association of Geomagnetism and Aeronomy (IAGA) Division V, Working Group 8 (2000): International Geomagnetic Reference Field 2000.- Geophys. J. Internat. 141: 259-262.

Jackson, H.R. Dickie, K., & Marillier, F. (1992): A seismic reflection study of northern Baffin Bay: Implication for tectonic evolution.- Can. J. Earth Sci. 29: 2353-2369.

Jackson, H.R., Hannon, T., Neben, S., Piepjohn, K. & Brent, T. (2006): Seismic reflection profiles from Kane Basin to Hall Basin, Nares Strait: Evidence for faulting.- Polarforschung 74: 21-39.

Mayr, U. & de Vries, C.D.S. (1982): Reconnaissance of Tertiary structures along Nares Strait, Ellesmere Island, Canadian Arctic Archipelago.- 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: 167-175.

Miall, A.D. (1991): Late Cretaceous and Early Tertiary basin development and sedimentation, Arctic Islands. Ch.15.- In: H.P. Tretttin (ed), Geology of the Inuitian Orogen and Arctic Platform of Canada and Greenland, Geology of Canada No. 3, Geol. Surv. Canada, (also Geol. Soc. Amer., The Geology of North America, E): 437-458.

Oakey, G.N. & Chalmers, J.A. (2001): Constraints on the kinematic model of Tertiary motion of Greenland.- Geol. Assoc. Canada Ann. Meeting, St. John's 2001, Abstr. Vol.: 109.

Peel J.S. & Christie, R.L. (1982): Cambrian-Ordovician platform stratigraphy: Correlation around Kane Basin.- 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: 117-135.

Piepjohn, K., Tessensohn, F., Harrison, C. & Mayr, U. (2000): Involvement of a Tertiary foreland basin in the Eurekan foldbelt deformation, NW Coast of Kane Basin, Ellesmere Island, Canada.- Polarforschung 68: 101-110.

Pittman, W.C. & Talwani, M. (1972): Sea-floor spreading in the North Atlantic.- Geol. Soc. Amer. Bull. 83: 619-646.

Roest, W.R. & Srivastava, S.P. (1989): Sea-floor spreading in the Labrador Sea: A new reconstruction.- Geology 17:1000-1003.

Smith, W.H.F. & Wessel, P. (1990): Gridding with continuous curvature splines in tension.- Geophysics 55: 293-305.

Stemp, R.W. & Thorning, L. (1995): Airborne and electromagnetic survey of Inglefield Land, North-West Greenland: Results from project AEM Greenland, 1994.- Geol. Surv. Greenland, Open File Ser. 95/1: 1-45.

Srivastava, S.P. (1978): Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic.- Geophys. J. Royal Astron. Soc. 52: 313-357.

Srivastava, S.P. & Tapscott, C.R. (1986): Plate kinematics of the North Atlantic.- In: P.R. Vogt & B.E. Tucholke (eds), The Geology of North America, The western North Atlantic region, Geol. Soc. Amer., Geology of North America M: 379-404.

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. (1915): Die Entstehung der Kontinente und Ozeane.- Friedrich Vieweg & Sohn, Braunschweig, 1-94.

Wetmiller, R.J. & Forsyth, D.A. (1982): Review of seismicity and other geophysical data near 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: 261-274.