Magnetic susceptibility and palaeomagnetic collection of rocks from central and western North Greenland

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Some 1900 orientated palaeomagnetic samples were collected from 372 sites in central and western North Greenland in 1985 covering the complete rock sequence from the Precambrian crystalline basement to the Upper Cretaceous dolerite dykes. More than 1100 susceptibility measurements from 91 sites were measured *in situ* on as many rock units as possible with susceptibilities above 10^{-4} SI units. The susceptibilities in the region span 4 orders of magnitude, but the geometrical mean values of major rock groups are well clustered and well defined suggesting that indirect subsurface mapping by aeromagnetic surveying may be a feasible tool for future investigations.

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The field season of 1985 in central and western North Greenland had two main objectives: (1) collection of *in situ* susceptibility values (*k*-values) of induced magnetisation for a variety of rock types; and (2) collection of a wide variety of orientated rock samples for laboratory determination of magnetic remanence directions and intensities. The susceptibility as well as the NRM (natural remanent magnetisation) will be used as background for aeromagnetic anomaly interpretation, whereas the magnetic remanence will be used for palaeomagnetic investigation of magnetostratigraphy and palaeomagnetic pole determinations. Apparent polar wander curves established from this area will be studied in relation to similar data from other parts of Greenland and the Laurentian craton (Beckmann, 1983; Marcussen & Abrahamsen, 1983; Piper, 1982, 1984; Van der Voo *et al.*, 1984).

An almost complete palaeomagnetic collection through the exposed rock sequence was established in 1985, and this will complement and enhance the palaeomagnetic magnetostratigraphic and polar wander investigations based on collections made during GGU's work in eastern North Greenland in 1979 and 1980 (Abrahamsen, 1980; Abrahamsen & Marcussen, 1980; Marcussen, 1981a, 1981b; Marcussen & Abrahamsen, 1983; Funder *et al.*, 1985). The sum total of the palaeomagnetic collections from North Greenland covers isolated Precambrian age intervals (Archaean?, 1400–1200 Ma, 800–600 Ma), and a complete Vendian? to Silurian interval (600–400 Ma). In addition some younger time intervals are rep-

Table 1. Summary of the 1985 palaeomagnetic sampling and the scientific objectives

Formation/unit name	Susceptibility measurements	Total number of sites	Total number of samples	Objectives and questions to be answered
A. Upper Cretaceous dolerites (3 generations: E – W, NW – SE, N – S)	Yes	28	234	Palaeomagnetic pole determinations and their bearing on Cretaceous – Tertiary plate tectonics of Baffin Bay and the North Atlantic.
B. Metamorphic rocks in the fold belt in Nansen Land (Polkorridoren & Paradisfjeld Groups)	Yes	27	117	Attempts to constrain or establish the age of folding and/or post-metamorphic cooling.
C. Cambrian – Silurian sediments				
C1. Shelf sequence (Portfjeld Fm – Ryder Gletscher Gp: Permin Land Fm, Johansen Land Fm, Morris Bugt Gp, Washington Land Group)		245	1024	Early Palaeozoic apparent polar wander determinations for North Greenland and, by inference, for Laurentia, and attempts to establish reversal magnetostratigraphy for this time.
C2. Deep-water sequence (Lafayette Bugt & Un-named slope sequence)	Yes	46	241	Early Palaeozoic apparent polar wander determinations: possible tests for timing of deformation and/or reheating-cooling in the area.
D. Moræneso Formation (Vendian)	Yes	4	31	To strengthen previously obtained results from Peary Land and to test palaeolatitude questions related to Vendian glaciations.
E. Proterozoic dolerite dykes 1200 Ma (?)	Yes	12	104	Palaeomagnetic pole determination and correlation/dating.
F. Archaean crystalline basement	Yes	15	136	Palaeomagnetic pole determination and attempts to relate these to Archaean plate tectonics (if any).
Totals	91 sites 1134 measurements	372	1887	

resented by collections from rocks affected by Ellesmerian (Devonian–Carboniferous) deformation, from Late Cretaceous dykes, and from Pliocene–Pleistocene and Quaternary sediments.

Palaeomagnetic collections

The palaeomagnetic samples were mainly collected by portable, gasoline-powered, water-cooled drills. The cylindrical (2.5 cm diameter) core samples were orientated mostly with a solar compass, although in about 10% of cases during cloudy weather a Brunton magnetic compass was used. At one locality, in the Precambrian crystalline basement, orientated hand-samples were collected when the drill was out of action. Depending on the objectives of the sampling programme at a given locality (see Table 1), sampling was undertaken either stratigraphically or areally, in so far as outcrop and access conditions permitted. Sampling from a given area around a camp site is referred to as a 'locality', whereas rocks sampled from a given unit (a sedimentary bed, a basement outcrop of some 4 × 8 m, or an outcrop of a dyke) are referred to as a 'site'. A total of 14 localities, 372 sites, and 1887 individually orientated samples are included in the present collection. For a given site, at least four, and often up to ten, individual samples were collected.

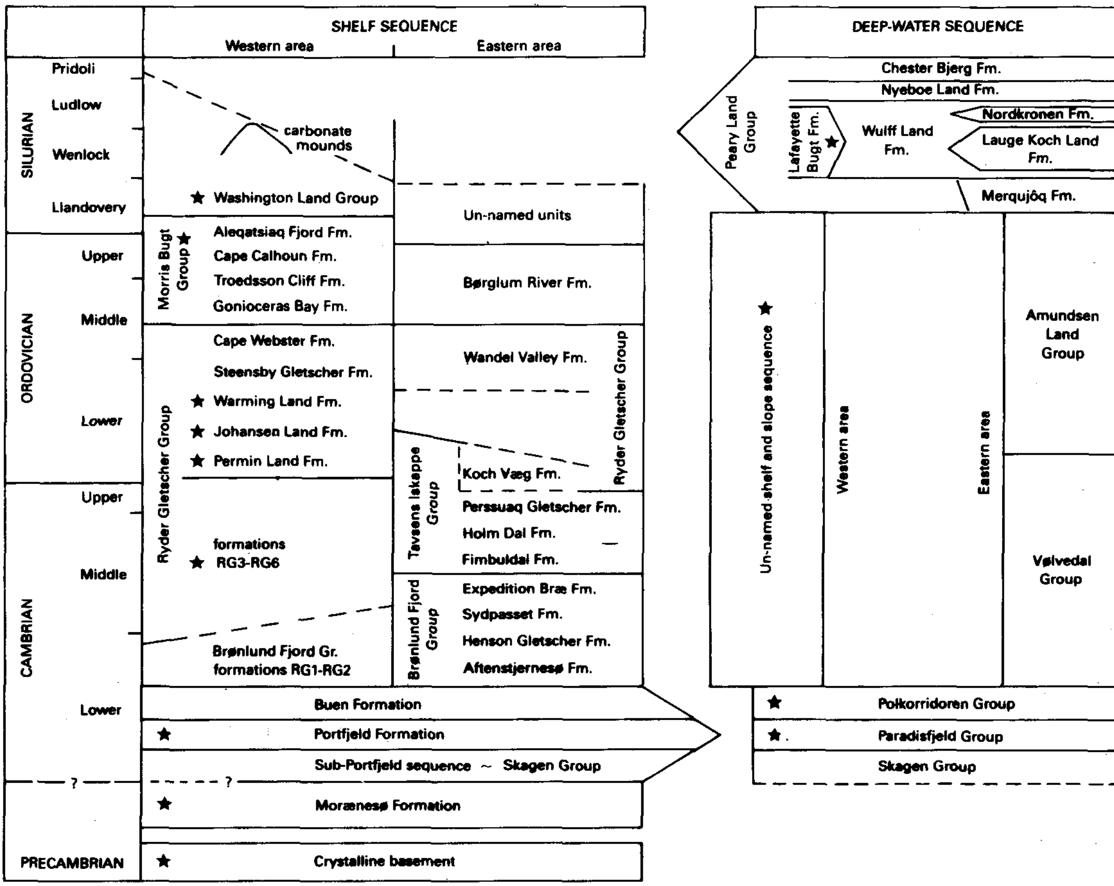

Fig. 1. Schematic stratigraphical division of the geology of central and western North Greenland. Asterisks indicate palaeomagnetically sampled units, detailed in Table 1.

For reference purposes the objectives of the magnetic field work and a summary of the material collected are given in Table 1. The table presents a list of formations, sequences, dykes and metamorphic suites collected during the 1985 season, the relevant number of sites and samples, and the particular purpose of each sampling programme.

In fig. 1 a stratigraphic scheme is presented with the collected units marked with an asterisk. The figure, when used together with Table 1, provides an overview of the whole programme.

As is typical for any palaeomagnetic study, the collections made during the field season constitute only a first step in the study, and despite the greatest care in our selection of the most promising materials, there is no guarantee of the magnetic properties of the samples. It is not uncommon to encounter magnetic resetting in sediments and igneous rocks alike, and secondary magnetisation may be encountered in parts of the collection. This is to be expected for the more highly deformed and slightly metamorphosed formations in the northern parts of the area, and can be used to 'date' (i.e. constrain the age of) the folding or heating-cooling cycle of the Ellesmerian orogeny.

Table 2. Susceptibility mean values for rock groups measured in situ

Rock group	Number of sites (N)	Number of meas. (Σ n)	Type mean susc. (log) 10^{-5} SI	Mean error (log) low %	Mean error (log) high %
Upper Cretaceous dolerites					
3rd generation (E – W)	10	109	1940	– 14	+ 17
2nd 〃 (NW – SE)	12	127	4000	– 11	+ 13
1st 〃 (N – S)	6	78	1730	– 20	+ 26
Precambrian dolerites	10	142	3125	– 11	+ 12
Average all dolerites	38	456	2710	– 8	+ 10
Sediments					
Group 1: Portfjeld Fm, unnamed shelf & slope seq., Moræneso Fm	12	156	4.7	– 18	+ 21
Group 2: Paradisfjeld Gp, Polkorridoren Gp, Silurian turbidites	11	137	22	– 9	+ 10
Average all sediments	23	293	9.7	– 18	+ 22
Precambrian crystalline rocks					
Gneiss	20	251	125	– 25	+ 35
Quartz diorite	4	51	32	– 44	+ 79
Amphibolite	6	83	66	– 11	+ 12
Average all crystalline rocks	30	385	92	– 20	+ 25

Magnetic susceptibility

Magnetic susceptibility (k) measurements were made *in situ* on the outcrops using a Czech kappameter (model KT-5 susceptibility bridge) with a sensitivity of 10^{-5} SI units). Typically 13 measurements were made per site. Logarithmic averages are summarised with information for each locality and/or rock type in Table 2.

To obtain a simple parameter for the expected mean error (i.e. 'accuracy') of the logarithmic mean value of a certain rock type, the range of the logarithmic mean error (the confidence interval of 1σ) was calculated by the formula

$$\log^{-1}(\log \bar{k} - m(\log k_i)), \log^{-1}(\log \bar{k} + m(\log k_i))$$

and is indicated on Table 2 as a percentage (low and high) of the mean susceptibility of each major rock type.

The susceptibility site mean values indicated on Table 2 are illustrated in fig. 2 on a logarithmic scale, with rock type mean values and error bars.

The highest scatter in susceptibility was found in the Precambrian crystalline basement at the head of Victoria Fjord, where the site mean values for the gneisses cover more than two orders of magnitude, with a mean value for all gneiss determinations of $1.2 \cdot 10^{-3}$ SI ± 35 to 25%. This is about one order of magnitude above the values of the sediments and more than one order of magnitude below the various generations of dolerite dykes.

Amphibolites occur as conformable sheets in the gneisses. The measured susceptibilities are somewhat lower than the gneisses and show close clustering. Magnetically the amphi-

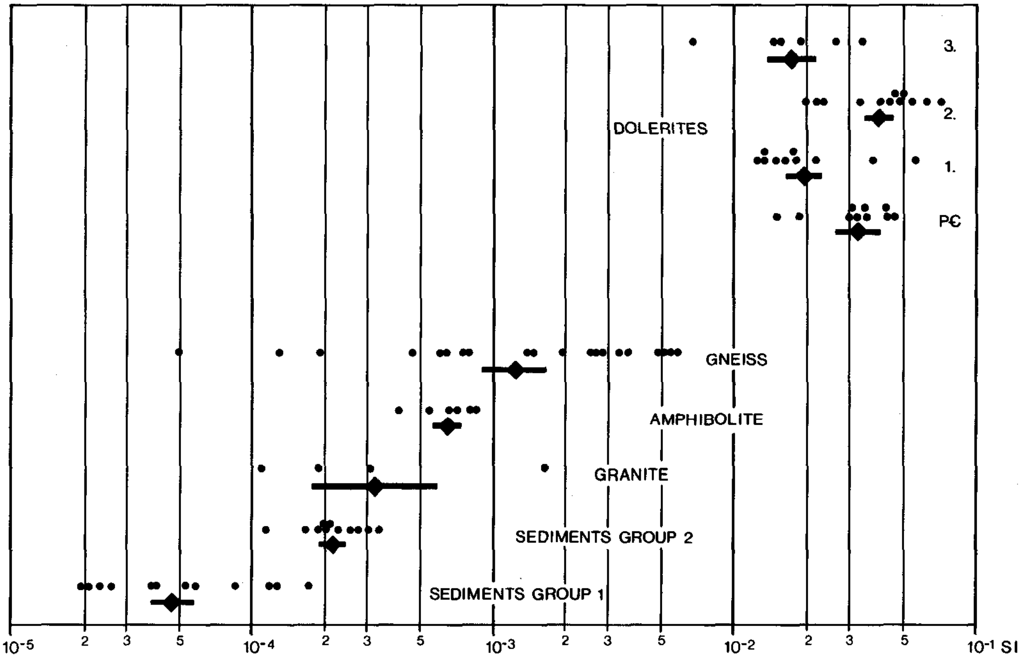

Fig. 2. Geometrical mean values of individual sites (dots) and rock type means (diamonds) with error-bars of logarithmic mean error (1σ), as specified in Table 2. Dolerites are divided into a Precambrian group (P-Є) and three generations of Upper Cretaceous dyke swarms (1, 2, 3). See also Table 1.

bolites should probably be considered a part of the gneiss complex, as they would not be separable from the orthogneisses in an aeromagnetic survey, although their *in situ* measured type mean values are significantly different.

Four sites of late kinematic quartz diorites were measured on two minor intrusions of limited extent. Although the values are scattered, the mean value of $3 \cdot 10^{-4}$ SI is likely to be of the right order of magnitude being on the low side for the gneiss and amphibolite mean values, and on the high side for the sediments.

The sediments are classified into two groups. Sediments with low susceptibilities between 0.2 and $1 \cdot 10^{-4}$ SI are allocated to group 1 and include carbonates from the Portfjeld Formation and rocks from the unnamed shelf and slope sequence. Sediments with a moderate susceptibility around 2 to $3 \cdot 10^{-4}$ SI are placed in group 2, and include low metamorphic rock types from the Paradisfjeld Group and Polkorridoren Group. The tillite of the Morænesø Formation is (arbitrarily) included in group 1, although the susceptibility values of the tillites bridge the gap between the two groups of susceptibility values. The remaining carbonates of the region, which have not been specifically measured, belong to susceptibility group 1, but they were considered to be too weakly magnetic to give meaningful measurements in the field using the kappameter.

The dolerites give site mean susceptibility values in the range 1.5 (or 0.7 in one abnormal case) to $7.2 \cdot 10^{-2}$ SI, which are the highest values known in this region. Four groups of dykes have been measured; one set of middle Proterozoic dolerites found in the basement gneisses and three generations of Late Cretaceous basic dykes found in Nansen Land (Friderichsen & Bengaard, 1985). The susceptibility mean values of the four groups of dykes are rather well clustered with relative mean errors of typically ± 10 to 20%. A systematic high (*c.* × 2) mean value of the intermediate (NW–SE) generation of the Late Cretaceous dykes probably indicates a systematic higher content of Fe_3O_4, because high magnetic values are typically caused by a higher content of titanomagnetites. Combined with the systematic difference in strike (and hence stress field) of the three generations of dykes (Table 1), the high magnetic values of the intermediate NW–SE generation of dykes may hint at a slightly different type of parent magma than the other generations, e.g. caused by differential melting at different levels in the upper mantle.

Conclusion

In conclusion it may be mentioned that the maximum peak-to-peak vertical magnetic anomaly ΔBz obtained when crossing a vertical contact between two semi-infinite and very thick homogeneous formations (Δk is the contrast in susceptibility, and Bz is the vertical geomagnetic field intensity) is $\Delta Bz \leq \frac{1}{2} \cdot \Delta k \cdot Bz$ (Parasnis, 1979). With $Bz = 0.6 \cdot 10^{-4} T$ we may therefore expect any aeromagnetic anomaly greater than about 3 nT (gamma) to be caused by geological structures involving rock types with contrasting susceptibilities $\Delta k \geq 10^{-4}$ SI.

The values in fig. 2 and Table 2 therefore offer important ground-based information about the relationships between susceptibilities and rock types, which may be useful in present as well as future aeromagnetic surveying and interpretations (e.g. Langel & Thorning, 1982; Thorning, 1982, 1984).

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