Various magnetic properties of about 200 Tertiary basalt samples from the coasts on both sides of Baffin Bay have been measured. The main collections are from (i) three profiles representing over 30 lava flows on southern Disko Island, West Greenland, and (ii) one profile of six flows near Cape Dyer on Baffin Island. In both areas, the natural remanence (NRM) of the samples is predominantly stable, being reversed in Disko and normal in Cape Dyer, but unstable components dominate in some of the samples. The stable component of magnetization appears to be primary, i.e. acquired when the lavas cooled from a molten state. A paleomagnetic pole position at 62°N, 169°W, with an error oval of $\delta p = 8^\circ$, $\delta m = 9^\circ$, was obtained from two of the South Disko profiles; the significance of this result to local paleogeography is discussed.

Various magnetic properties of Baffin Bay Archean metamorphic rock samples have been measured and are discussed, with other available results on the magnetism of local Tertiary and Precambrian rocks, in the context of magnetic anomaly interpretation.

INTRODUCTION

The basic volcanic rocks found on both sides of the Davis Strait (Fig. 1) have been described by Rosenkranz and Pulvertaft (1969), Clarke and Upton (1971) and Henderson (1972), among others. From fossil evidence and K-Ar dating, these volcanics are believed to be mostly of Paleocene-Eocene age, and they are probably related to the opening of Baffin Bay by a process of sea-floor spreading. The Baffin Island volcanics, exposed only along a narrow coastal strip between Cape Dyer and Cape Searle, consist of a few hundred metres thickness of olivine-rich basalt breccia and lavas, with minor intrusives in the north. The much thicker volcanic suite in West Greenland consists mainly of olivine lava flows overlain by olivine-poor, usually feldspar-porphyritic lavas. It rests partly on Precambrian basement and partly on Cretaceous-Tertiary sediments, subaqueous breccia often occurring as the first volcanic facies. Much intrusive activity and faulting has taken place in west Greenland, and distinct interbasaltic beds are rare, which makes regional stratigraphic mapping difficult.
Figure 1. Index map of southern Baffin Bay and nearby regions.
EARLY TERTIARY PALEOMAGNETISM IN BAFFIN BAY

Volcanics on Cape Dyer, Baffin Island

In 1968, a Memorial University expedition collected 38 oriented samples from six horizontal lava flows at Cape Dyer (Fig. 1). The following account is mainly a summary of results from a more detailed description by Deutsch et al. (1970).

Except for three samples out of six from one flow, the samples were all magnetized in the same (normal) sense and with a similar direction as the Earth's present magnetic field, i.e., their natural remanence (NRM) was inclined steeply downward. The three anomalous samples were reversely polarized, with steep upward NRM directions that were not very stable to alternating-field (AF) or thermal demagnetization; we suspect that they have suffered secondary magnetization in situ, although otherwise all samples appeared to be fresh and unaltered. The normal NRM directions were found to be very stable to AF and thermal treatment and are therefore believed to be primary remanence directions.

The average paleomagnetic field direction, obtained from 5 of the 6 Cape Dyer flows after treatment to 400 pack Oersteds, corresponds to a pole position at 83°N, 55°W, with a 95 per cent confidence oval of mean radius 12 degrees. Because of the small number of flows used in this and in other published Lower Tertiary paleomagnetic studies from North America, no definite conclusions about the paleogeography of Baffin Bay can yet be drawn from these results.

Thermomagnetic and AF curves and microscope examination indicate that the remanence of the Cape Dyer lavas resides in titanomagnetite. Both in our samples and in several samples of olivine-rich basalt from Baffin and Svartenhuk examined by Clarke (1968), this mineral constitutes 2 per cent or less of the rock by volume. The arithmetic average intensity of our samples (excluding one exceptional value of 59 x 10^{-3} Gauss) is about 4 x 10^{-3} Gauss, a Gauss being the c.g.s. electromagnetic unit of magnetic moment per unit volume. Their average susceptibility in c.g.s. units is 0.6 x 10^{-3} Gauss/Oe; therefore remanent magnetization dominates induced magnetization in situ. Buildup of viscous remanence on storage in the laboratory over a period of 1-2 months was small (< 5% of the NRM).

We have also made magnetic experiments on eight unoriented samples from Tertiary basalt outcrops north of Cape Dyer, collected and kindly given to us by Dr. D.B. Clarke of Dalhousie University. Their NRM intensities (average 2.3 x 10^{-3} Gauss) and susceptibilities (average 0.5 x 10^{-3} Gauss/Oe) and high magnetic stability are comparable to those obtained from the Cape Dyer samples just described.

Aeromagnetic maps of the Cape Dyer coastal area, published by the Geological Survey of Canada (1970) show positive magnetic anomalies at almost all the twenty or so main exposures of Tertiary basalts (as identified from aerial photographs). The amplitude of these anomalies averages about 1,000 Y at 300 metres above ground. We conclude that the Tertiary volcanics outcropping at Cape Dyer are predominantly normally magnetized, and were probably extruded during one geomagnetic epoch of normal polarity.
Volcanics at Disko Island, West Greenland

In the summer of 1970, a Memorial University expedition collected oriented samples from feldspar-porphyrctic basalt lavas in three profiles, GL, GM and GK of Figure 2, on the south coast of Disko Island. Samples were also obtained from the underlying breccia and from basalt intrusives. Most of the samples were obtained using a portable core drill and were spaced several metres apart where possible. They were oriented either by suncompass or geographic sightings, depending on weather conditions; the orientation is believed to be accurate within 2 degrees in inclination and 3 degrees in azimuth on the average. Few or no lavas were missed within the profiles where sampled, but on the plateau above both profiles GL and GM, a few poorly exposed lavas were not sampled. The massive parts of the lava flows are fresh and almost free from zeolites, and they are horizontal within 1-2 degrees.

The remanent magnetization of 110 samples (one specimen per sample) from the lava profiles, and of about 30 samples from the breccia and intrusives was measured with a PAR spinner magnetometer. We also used an AF demagnetizer (Pearce, 1967); a pendulum balance (Deutsch et al., 1971).
for obtaining strong-field thermomagnetic curves; a Scintrex SM-4 1000-Hz bridge to measure susceptibility; and a Zeiss Universal Standard microscope for petrographic work.

The NRM directions of the Disko basalts were of both polarities, but were mainly reversed, and on progressive AF demagnetization in steps of 50 Oe (Fig. 3), all samples were found to possess a stable or very stable reverse component of remanence. Treatment to 200 peak Oe appeared to give the best grouping of remanence directions, the r.m.s. value of the within-site dispersion angle $\delta_w$ (Sanver, 1968) then being about 5 degrees in the lava profiles. The low value of this dispersion as compared to the between-site dispersion $\delta_k$ (Fig. 4 and Table 1) clearly indicates that this stable component is a primary remanence.

All mean site paleofield directions are shown in Fig. 4. Table 1 gives the mean overall directions and statistical parameters for the lava flows of profiles GL and GM. As the lavas are nearly horizontal and these profiles are only 4 km apart, they probably were extruded during the same interval of time, which appears to span at least several secular variation cycles of that magnetic epoch. As it has not been possible to correlate the magnetic field directions in these two profiles, we will assume that no flow occurs in both of them, i.e. that the horizontal extent of each flow is less than 4-6 km. On this assumption the last entry in Table 1 represents the best average local paleofield for the time interval. This field corresponds to a geocentric magnetic dipole with a northern pole at 62°N, 169°W, which has error oval semi-axes $\delta_p = 8^\circ$, $\delta_m = 9^\circ$. The pole is shown in Figure 4 along with a pole from the reversely magnetized Lower Tertiary basalts in East Greenland (Tarling, 1967), and a pole from the Faeroe Islands basalts (Tarling, 1970), which are also Lower Tertiary but of mixed polarities. A mean pole from various British Tertiary formations has also been given by Tarling (1970) and is very near the Faeroes pole position.

Figure 4 shows the site mean field directions obtained from most of our sites in the breccia, intrusives and in profile GK in Disko. Their mean field direction is seen to be similar to that of GL and GM, but its significance is low, both because of the occurrence of shallow directions in GK due to the uncertain age of the intrusives, and because the breccia sampling sites were spaced unevenly in the sampling area. Table 2 lists other averaged magnetic properties for all these formations.

In profiles GL and GM, the samples collected seem to fall into two magnetically distinct groups. The larger group has a much higher intensity of primary remanence than the other and has less secondary magnetization (compare GL 10-1 and GL 8-2 in Fig. 3), lower mean susceptibility, higher oxidation state in polished section, and higher strong-field Curie point (560°C vs. 520°C). In any particular flow, however, both these types of magnetic behaviour may occur within metres of each other horizontally or vertically. This points to variable oxidation conditions within the flows during or subsequent to cooling, and it may preclude the application of magnetic properties other than paleofield directions and polarities, to stratigraphic correlation in Disko. About a half of the samples collected from profile GK, the breccia and intrusives fitted these two magnetic groups, but the rest behaved differently, possibly because of rapid cooling, and will be discussed below.

In several polished sections of South Disko lava samples we find a titanomagnetite content of 5-8 per cent by volume, and similar values have been reported by Clarke (1968) from the feldspar-porphyrhythic basalts of Svartenhuk Peninsula.
### Table 1

Mean remanence directions for two lava profiles on Disko Island, west Greenland

<table>
<thead>
<tr>
<th>Profile</th>
<th>N</th>
<th>n</th>
<th>D</th>
<th>I</th>
<th>α95</th>
<th>δk</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL</td>
<td>20</td>
<td>3</td>
<td>133</td>
<td>-64.4</td>
<td>7.0</td>
<td>16.6</td>
</tr>
<tr>
<td>GM</td>
<td>17</td>
<td>2</td>
<td>150</td>
<td>-69.2</td>
<td>9.6</td>
<td>20.5</td>
</tr>
<tr>
<td>Both</td>
<td>37</td>
<td>-</td>
<td>140</td>
<td>-66.7</td>
<td>5.7</td>
<td>19.0</td>
</tr>
</tbody>
</table>

All samples measured after AF treatment at 200 peak Oersteds:

- **N** = number of flow-mean directions averaged;
- **n** = number of samples measured per flow (usually one specimen per sample);
- **D** = declination; degrees east of north;
- **I** = inclination; degrees, positive down;
- **α95** = radius of 95 per cent confidence circle in degrees;
- **δk** = observed between-flow dispersion angle in degrees (Sanver, 1968).
TABLE 2

Some magnetic properties of igneous rocks on Disko

| Rock group       | N   | n  | \(| J_0 | (10^{-3} \text{ G}) | J_{200} | K  (10^{-3} \text{ G/Oe}) |
|------------------|-----|----|-----------------|--------|----------------|
| GL flows         | 20  | 3  | 2.9             | 2.3    | 3.4            |
| GM flows         | 17  | 2  | 3.5             | 2.7    | 3.1            |
| GK flows         | 8   | 2  | 8.6             | 3.0    | 2.4            |
| Breccia sites    | 7   | 1-3| 6.5             | 2.7    | 1.5            |
| 2 dykes and 5 sills | 7 | 2  | 6.6             | 1.7    | 2.4            |

Arithmetic averages of site-mean values are shown:

- **N** = number of sites averaged;
- **n** = number of samples measured per site (usually one specimen per sample);
- \(| J_0 | = \text{NRM intensity (averaged without regard to sign)};
- \( J_{200} = \text{remanence intensity after 200 Oe demagnetization (all directions have reverse polarity)};
- **K** = volume susceptibility.
Figure 3. Left: Remanent intensity $J$ as a function of AF demagnetizing field for three typical South Disko basalt samples. Right: Polar equal-angle projection of remanence intensities for the same samples. The declination of GK 9-1 has been altered by 180 degrees to avoid overlap. Numbers refer to demagnetizing fields. In both parts of the figure, open (filled) circles refer to reverse (normal) magnetization directions. Broken lines indicate that in the last step of each demagnetization, spurious components appeared in $J$.

Figure 4. Left: Paleomagnetic pole position for Disko, calculated from the overall flow-mean remanence direction of profiles GL and GM (Table 1), with 95 per cent confidence oval. Also shown are pole positions and 95 per cent confidence ovals from 28 Tertiary flows in East Greenland (Tarling, 1967) and from 253 flows in the Faeroe Islands (Tarling, 1970). Middle: Individual flow directions for profiles GL and GM, after 200 Oe treatment. Right: Individual site directions for profile GK, breccia and intrusive sites after 200 Oe treatment. Polar equal-angle projection.
Paleomagnetism and Rotation of Greenland

One possible use of magnetic data from rocks bordering Baffin Bay is paleogeographic, for example in a test of the proposed separation of Greenland from Canada (Wegener, 1929). In planning future field work, the minimum sampling required for such a test may be roughly estimated.

For this purpose we assume that (1) the pole reported here for Disko Island (62°N, 169°W) is the "true" early Tertiary pole relative to present-day Greenland; (2) the Tertiary rocks on Baffin Bay became magnetized in a geocentric axial dipole field of either polarity; (3) after the rocks were magnetized, Greenland rotated away from Canada according to the model by Bullard et al. (1965); and (4) no other crustal displacements involving these rocks occurred. Rotating Greenland back to Canada shifts the Disko pole into a new position that should coincide with the hypothetical early Tertiary pole for Baffin Island. The angular distance \( p \) between the latter pole and the original Disko pole then defines the limiting sensitivity of the test. For a specified rotation angle \( R \), \( p \) depends only on the paleocolatitude \( \theta \) of the rotation pivot and is given by (Deutsch, 1969):

\[
1 - \cos p = \sin^2 \theta (1 - \cos R).
\]

In the Bullard model for Greenland, \( R = 18.0° \) and the pivot is at 70.5°N, 94.4°W. The distance of the Disko pole from this pivot is \( \theta = 29° \), giving \( p = 9° \). Though small, \( p \) is more than twice the present distance between Cape Dyer and Disko.

One may judge the hypothetical poles for Greenland and Baffin Island to be distinct if their 95 per cent error ovals do not intersect. For a maximum pole separation \( p = 9° \), this means that the sum of the major semi-axis \( 2m \) of the two ovals should not exceed about nine degrees; hence, on average, the oval dimensions should not be more than one-half those of the present oval for Disko (\( 2m = 9° \)). We now assume for simplicity that the dispersion of the N remanence vectors averaged in calculating future pole positions will be the same as the dispersion we observed for Disko; then \( 2m \) varies approximately as \( N^{-1/2} \). A significant test would thus require on average four times the present number of Disko flows (\( N = 37 \)), i.e. 150 or so rock units, on each side of Baffin Bay. This minimum requirement is large, but probably can just be met. We conclude that a paleomagnetic test of the opening of Baffin Bay is marginally feasible, but that the same rock collections needed to investigate these purely directional features of the early Tertiary field can probably yield more significant results on other characteristics of that field, such as its secular variation, strength and polarity.

ROCK MAGNETISM AND MAGNETIC ANOMALIES

Magnetic surveys in the Baffin Bay area

In addition to the aeromagnetic mapping by the Geological Survey of Canada referred to above, several magnetic surveys have been carried out in Baffin Bay and nearby regions (Hood et al., 1967; Johnson et al., 1969; Mayhew et al., 1970; Haines et al., 1970; Park et al., 1971; Vogt, 1970; Hood and Bower, 1972). Attempts at interpreting anomalies found in these surveys have suffered from a lack of knowledge about the nature or magnetic properties of the causative bodies, since they are often submarine, subglacial or otherwise unexplored. Below, we will discuss two examples of how
such knowledge may provide constraints on the interpretation of magnetic surveys in the Baffin Bay area. The presently available rock magnetic results from the area are somewhat fragmentary (see legend to Fig. 5) but they may serve as guidelines for future work on establishing the origin of the magnetic anomalies.

Example 1: Disko Island anomalies

As stated above, all the samples collected in South Disko by Memorial University possess a stable reverse remanence of presumably primary origin, and one may therefore expect a broad negative aeromagnetic anomaly to occur over Disko. Such appears to be the case in the results of Hood and Bower (1972) but in the magnetic maps of Haines et al. (1970) a small positive anomaly in total field F occurs over the south coast. This anomaly may perhaps be explained by the following results from our profiles GL and GM:

The NRM of one sample from each flow (total 37) was measured soon after they arrived at Memorial University. They were then stored for a period of 4-6 weeks, remeasured and then AF demagnetized in steps of 50 Oe. It was found that in all samples the remanence shifted towards the reverse sense on storage, and still further, up to a maximum (Fig. 3) on AF treatment. The maximum usually occurred between 50 and 150 Oe. These results clearly indicate that on the primary remanence there was superimposed a very soft viscous remanence (VRM) due to the present field in Disko, and that this VRM decayed during storage, being replaced with one of the opposite polarity because the samples were stored upside down. By extrapolating the observed change in VRM back to the date of collection (assuming simple exponential decay, though the changes involved are mostly small and the choice of extrapolation method makes little difference), we were able to estimate the average in situ VRM and hence the in situ NRM. It was assumed that the maximum in each AF demagnetization curve (as in Fig. 3) represents the in situ primary remanence, i.e. that this remanence is unaffected by AF treatment to 50-150 Oe. The volume susceptibility K of all samples was also measured. The calculations shown in Table 3 then yield an estimate of the total in situ intensity of magnetization $J_s$ for each profile. Because the paleofield and present field directions are not far from the vertical, we have added all magnetization values as scalar quantities, with due regard to sign, but for improved accuracy in application to local magnetic surveys they may be multiplied by correction factors as indicated by Kristjansson (1970).

From the results of Table 3 it is seen that the lava flows of profiles GL and GM, although reversely magnetized to begin with, would cause a small positive anomaly in total-field geomagnetic intensity, as found by Haines et al. (1970), if surrounded by effectively non-magnetic material. If surrounded by similar basalts of a normal primary magnetization, the magnetization contrast would be twice the value of $J_p$ in Table 3, i.e. about $6 \times 10^{-3}$ Gauss.

Because the primary remanence in the other basalt formations sampled in South Disko, especially in those samples that appeared to have cooled rapidly, was often very soft to AF treatment (in intensity, e.g. GK 9-1 in Fig. 3; the direction of remanence was stable) their in situ VRM could not be estimated by extrapolation as described above, but only indirectly from repeat measurements after storage. As shown in Table 4, the VRM is small and the
mean primary remanence intensity in these formations is much higher than in profiles GL and GM, so that these formations could, by themselves, cause considerable negative magnetic anomalies.

Since the Tertiary areas in Greenland are partly made up of olivine-poor basalts as described above and partly of olivine lavas as described in the section on Cape Dyer, overlying a variable thickness of breccia, which in turn is partly made up of randomly magnetized material, it may prove difficult to correlate local geology and magnetic anomalies in detail.

Two other results from South Disko may have some relevance in this discussion: First, we have measured the susceptibilities of three samples of Cretaceous-Tertiary sediments underlying the lavas of profile GK (Fig. 2) and found them to be essentially non-magnetic (K≈0.01 x 10^{-3} Gauss/0e). Secondly, it is known that iron inclusions occur in the Disko basalts (e.g. Melson and Switzer, 1966) and these may be highly magnetic: selected and cut pieces (~1 cc) from two samples of basalt, kindly sent to us by Mr. E. Fundal, were found to have remanence intensities of the order of 500 x 10^{-3} Gauss. However, we believe that the iron inclusions are sufficiently rare and small as not to contribute appreciably to local aeromagnetic anomalies.

Example 2: Baffin Bay coastal and oceanic anomalies

Figure 5 summarized data available to us on the magnetism of Baffin Bay and nearby coastal rocks. Each dot represents a sample or a site average of NRM intensity, plotted without regard to sign, or of susceptibility. The lengths of the arrows indicate the magnitude of the present local geomagnetic field, i.e. the distance that the susceptibility values should be moved along the axis to become values of induced magnetization in Gauss.

It may be assumed that the Precambrian basement rocks bordering Baffin Bay consist predominantly of metamorphic rock types, magnetic results for which are shown in the bottom part of Figure 5a. It may also be assumed, as has been demonstrated by Puranen et al. (1968, Fig. 9), that the r.m.s. amplitude of magnetic anomalies observed over a region is directly related to the standard deviation of total-magnetization values in the underlying rocks. On comparing the gneiss values in Figure 5a with the values for Tertiary basalts shown in Figure 5b, it is apparent that the former will, under similar conditions, produce much smaller anomalies on the average. This has been used by Park et al. (1971) in mapping the extent of Tertiary volcanics off West Greenland. It must also be noted, however, that both in the metamorphic rock types and especially in the less common basic Precambrian rocks (Fig. 5a), magnetization values comparable to those in Tertiary basalts do occur. This observation is supported by the fact that magnetic anomalies of several hundred gammas are commonly recorded in magnetic surveys over areas where only Precambrian rocks are known to occur. Interpretation of single magnetic anomalies in regions of unexposed bedrock, such as on the Labrador Sea and Baffin Bay continental shelves, in terms of the age and lithology of the causative bodies, may therefore be rather speculative.

In such qualitative interpretation of magnetic anomalies over the presumed submarine basalts underlying the central parts of Baffin Bay and the Labrador Sea, it would be very useful to know their average remanence but this cannot be inferred directly from our own or from other subaerial basalt results. It is known that rapid cooling, such as would take place in...
TABLE 3

Estimated in situ intensity of magnetization of two Disko lava profiles

<table>
<thead>
<tr>
<th>Component</th>
<th>GL</th>
<th>GM</th>
<th>Net Sense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed NRM, $J_n^1$</td>
<td>1.7</td>
<td>2.1</td>
<td>reverse</td>
</tr>
<tr>
<td>Primary remanence, $J_p$</td>
<td>2.8</td>
<td>3.3</td>
<td>reverse</td>
</tr>
<tr>
<td>$\text{In situ VRM, } J_v$</td>
<td>1.5</td>
<td>1.8</td>
<td>normal</td>
</tr>
<tr>
<td>$\text{In situ NRM, } J_n$</td>
<td>1.3</td>
<td>1.5</td>
<td>reverse</td>
</tr>
<tr>
<td>$\text{In situ induced magnetization, } J_i$</td>
<td>2.2</td>
<td>2.0</td>
<td>normal</td>
</tr>
<tr>
<td><strong>Total in situ magnetization, } J_t</strong></td>
<td>0.9</td>
<td>0.5</td>
<td>normal</td>
</tr>
</tbody>
</table>

The arithmetic average of N flow intensity values in each profile (Table 1) is shown; one sample was measured per flow:

- $J_n^1$ is the mean of two measurements;
- $J_p$ is the maximum $J$ in the AF curve (Fig. 3);
- $J_v$ was obtained by extrapolation in time (see text);
- $J_n = J_p + J_v$;
- $J_i = KF$, where $K$ is volume susceptibility and $F$ the present field at Disko (0.56 Oe);
- $J_t = J_n + J_i$.

TABLE 4

Estimated average in situ magnetization of some igneous rocks on Disko

<table>
<thead>
<tr>
<th>Component</th>
<th>Intensity ($10^{-3}$ G)</th>
<th>Net Sense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary remanence, $J_p$</td>
<td>7.3</td>
<td>reverse</td>
</tr>
<tr>
<td>$\text{In situ VRM, } J_v$, estimated</td>
<td>0.5</td>
<td>normal</td>
</tr>
<tr>
<td>$\text{In situ induced magnetization, } J_i$</td>
<td>1.2</td>
<td>normal</td>
</tr>
</tbody>
</table>

The arithmetic average of 22 site-mean intensity values (lava profile GK, breccia and intrusives; Table 2) is shown.

For most sites, 2 samples were averaged. See also explanatory notes in Table 3.
extrusive submarine basalts, generally tends to produce high remanence intensities. Also, some of the samples collected by us in Disko show evidence of rapid cooling (pillow and block-jointed lava structures; small skeletal homogeneous titanomagnetite grains in a glassy groundmass) and these tend to have

![Diagram: Precambrian Rocks]

**PRECAMBRIAN ROCKS**

- **NRM** & **SUSC.** in emu/cc
- **DIABASE DYKES**
- **ANORTHOSITE & ULTRABASICS**
- **GNEISS & AMPHIBOLITE**

Top: Site mean values for 44 diabase dykes between Julianehab and Godthab, west Greenland, possibly including a few Mesozoic (TD) dykes (Bullock, 1967); plus 16 sites in north Baffin Island (Fahrig *et al.* 1971, and Dr. W. Fahrig, pers. comm.).

Middle: 18 anorthosite and ultrabasic samples, Fiskenaesset complex (Ghisler and Sharma, 1969); 29 anorthosite samples from Michikamau (Murthy, 1969), NRM only; 22 Michikamau anorthosite specimens (kindly lent by Dr. G. S. Murthy), susceptibility only; and 2 samples of basic rock near Julianehab.

Bottom: 31 gneiss samples collected by Memorial University between Julianehab and Godhavn, and in Frobisher Bay and two other localities on Baffin Island; 7 gneissic gravel samples from Baffin Bay (solid-rock susceptibility only, inferred by us from measurements on this gravel; 17 Fiskenaesset gneiss and amphibolite samples (Ghisler and Sharma, 1969); and 10 gneiss samples from the Labrador coast east of Michikamau (collected and kindly given to us by Dr. J. S. Sutton).

Figure 5a. NRM intensity and volume susceptibility of Precambrian basement rocks from Baffin Bay (Fig. 1).
remanence intensities a few times higher than the subaerial basalts of profiles GL and GM. Similar results have been obtained from the subglacial volcanics in Iceland (Kristjansson, 1970). On the other hand, the magnetic effects of magmatic oxygen fugacity and of secondary alteration mechanisms in suboceanic basalts are not well known.

An empirical approach to the problem of estimating the average magnetization of submarine Baffin Bay basalts may, however, proceed as follows. First, it may be found from Table 2 and the other data making up Figure 5b that the arithmetic mean remanent intensity (without regard to sign) in South Disko, Ubekendt Island and Cape Dyer (see Fig. 1) Tertiary basalts is everywhere of the order of $3-5 \times 10^{-3}$ Gauss. Secondly, the average NRM intensities of Tertiary subaerial basalts in East Greenland (Tarling, 1967) and in Iceland (Kristjansson, 1970) are also of similar magnitude. Thirdly, Irving (1970) has shown that the mean remanence of basalts dredged from the Mid-Atlantic away from the axial rift zone is of the order of $5-8 \times 10^{-3}$ Gauss.

**TERTIARY BASALTS**

- NRM & SUSC. (SVARTENHUK & UBEKENDT)
- NRM & SUSC. (SOUTHERN DISKO)
- NRM & SUSC. (BAFFIN ISLAND)

**Top:** Average values for 6 lava sites and 21 dyke sites, Ubekendt Island (Dr. D.H. Tarling, pers. comm.), plus 5 samples from Svartenhuk Peninsula (collected by Dr. D.B. Clarke).

**Middle:** One sample each from all sites of lava profiles GL and GK and 2 other lavas, 7 intrusives and 7 breccia sites, South Disko.

**Bottom:** 35 samples from the Cape Dyer lavas, plus 8 from other Tertiary basalt exposures on Baffin Island (see text).

Figure 5b. NRM intensity and volume susceptibility of Tertiary basalts from Baffin Bay (Fig. 1)
Since the exposed Baffin Bay and North Atlantic subaerial rocks are so similar in this aspect, one might, by analogy, expect the submarine Baffin Bay basalts to have an average remanence not very different from that of Mid-Atlantic rocks, i.e. $5-8 \times 10^{-3}$ Gauss, or slightly lower because of more advanced alteration.

Irving (1970) has proposed that the magnetic "smooth zones" bordering the North Atlantic are due to the presence of underlying intrusives and subaerial basalts, emplaced in the initial stages of continental drift. The average remanence of these, according to Irving's estimates, would be of the order of $0.6 \times 10^{-3}$ Gauss. As this is much less than the average NRM of the Tertiary basalts just mentioned, we conclude that any basic rocks underlying the smooth zone would resemble the Mesozoic volcanics tabulated by Irving, and not be Tertiary basalts. Because of the high susceptibilities occurring in some of the Tertiary rocks, this conclusion would be valid even if the smooth zones represent a time interval when the geomagnetic dipole moment was small, and even if alteration has taken place in the smooth zone rocks.

### The Magnetization of Gneiss

Finally, we consider the origin of the magnetization of the Baffin Bay basement gneiss. Strong-field thermomagnetic curves obtained by us from five unweathered gneiss samples were reversible (in air) with Curie points about 565°C, which is evidence that their magnetic properties reside primarily in pure magnetite. In polished sections made from the more magnetic of the gneiss samples, magnetite grains were indeed seen and have diameters of the order of 100μ. The remanence of Baffin Bay gneiss is weak (Fig. 5a) and of normal polarity, and is therefore most probably of viscous origin, though in some samples the median destructive field was found to exceed 200 Oe. Since magnetite crystal structure in gneiss may be expected to be much more uniform and ordered than in rapidly-cooled basalt, it is reasonable to look for correlations between magnetite content and susceptibility in the former. This we have done for gneiss samples from several widely-scattered sites around Baffin Bay, and the results are illustrated in Figure 6.

The magnetite percentage in each of these samples was estimated by counting 6000 or more squares in a 2-3 sq. cm. polished section with a square-grid microscope eyepiece. Our results, supplemented by results obtained with similar techniques by Ghisler and Sharma (1969), strongly indicate a linear relationship, and a best-fitting straight line through the data points and the origin has a reciprocal slope of $2.8 \times 10^{-3}$ units of susceptibility per volume percent of magnetite. As these gneiss samples are coarse-grained and often foliated, the possible error in the above value is $\pm 0.5 \times 10^{-3}$ Gauss/Oe/volume per cent.

Very similar relations, giving about $3 \times 10^{-3}$ units of susceptibility per percent of magnetite for magnetite contents of less than 5 per cent, have been obtained e.g. from Finnish Precambrian rocks by Puranen et al. (1968), from Quebec serpentinites by Gaucher (1965) and from Minnesota iron formation by Mooney and Bleifuss (1953). These authors also discuss many aspects of magnetic anomaly interpretation in Precambrian regions.

Theoretical and laboratory studies on the susceptibility of dispersed magnetite (e.g. Strangway, 1967) show that $3 \times 10^{-3}$ Gauss/Oe/volume per
Figure 6. Relation between volume percentage of magnetite and initial volume susceptibility for gneiss samples from the Baffin Bay coast. Each entry represents one sample. The broken line is a least-squares approximation, assuming direct proportionality between the variables.

cent is definitely an upper bound for the susceptibility of rocks containing magnetite as the only magnetic mineral, especially so in fine-grained or magnetite-rich rocks.

We conclude that where magnetic anomalies of the order of hundreds of gammas occur over Precambrian basement formations in the Baffin Bay area, they are most likely due to induced magnetization in local concentrations of magnetite, of the order of a few per cent by volume.

SUMMARY

The results presented above show that magnetic property studies in the Baffin Bay area may aid in the mapping of its geological structure in three ways. First, the study of magnetic polarities in the Tertiary and other igneous rocks is a valuable stratigraphic tool; secondly, magnetic pole positions derived from these rocks may furnish key information on continental displacements; thirdly, the study of magnetic remanence and susceptibility is a relatively inexpensive way of obtaining important constraints on the
interpretation of costly magnetic surveys. So far, however, only limited information of this nature is available from the Baffin Bay area, though the results are promising.

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