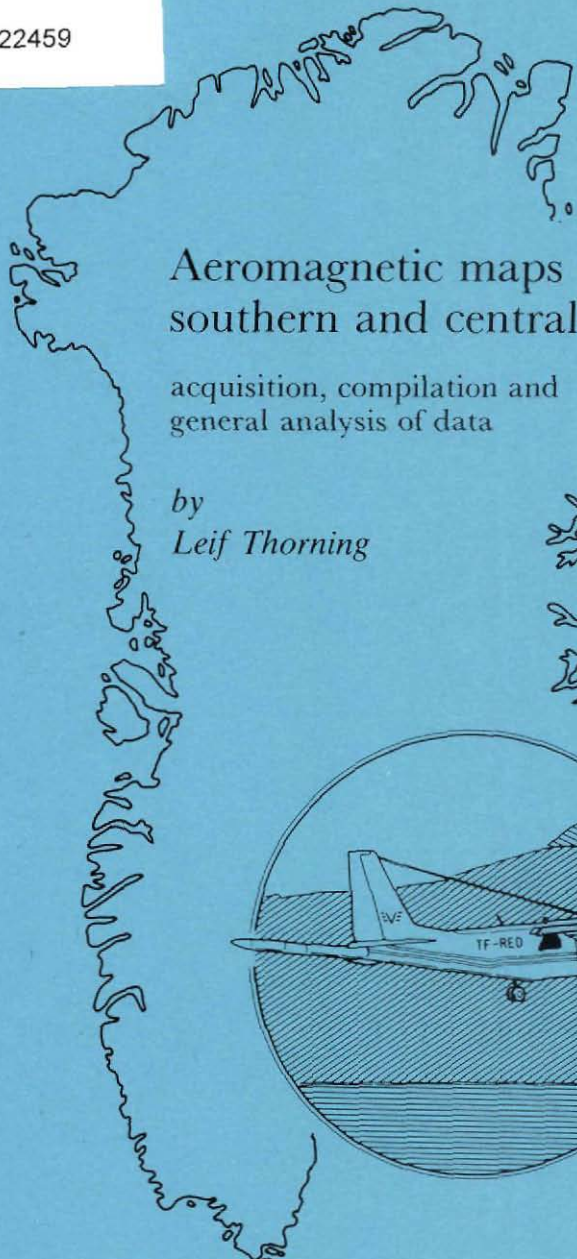


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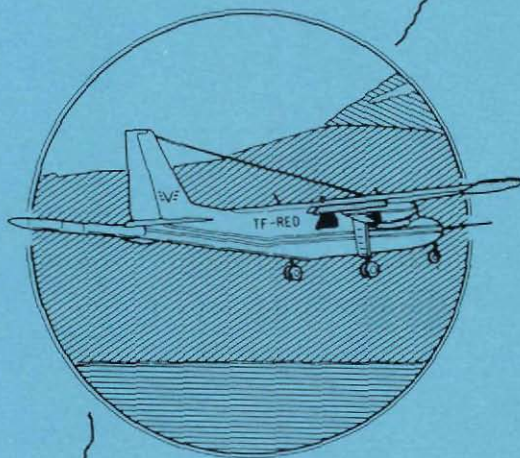
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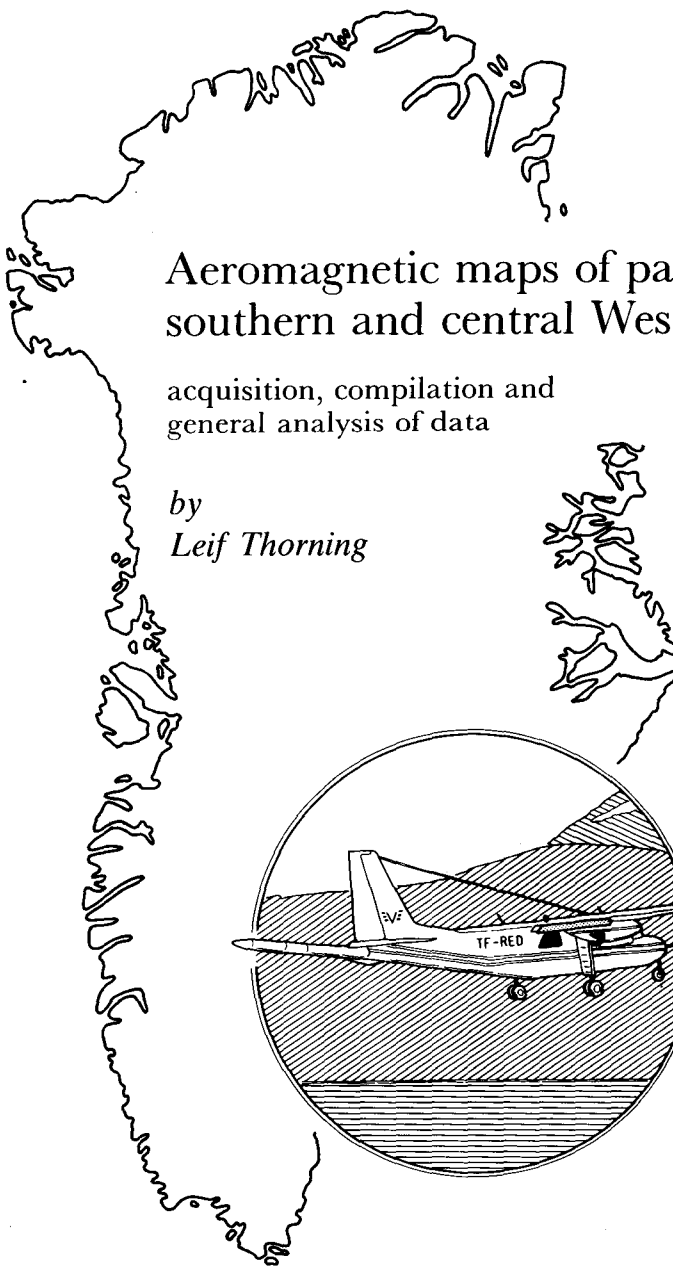


Aeromagnetic maps of parts of  
southern and central West Greenland:

acquisition, compilation and  
general analysis of data

by  
*Leif Thorning*

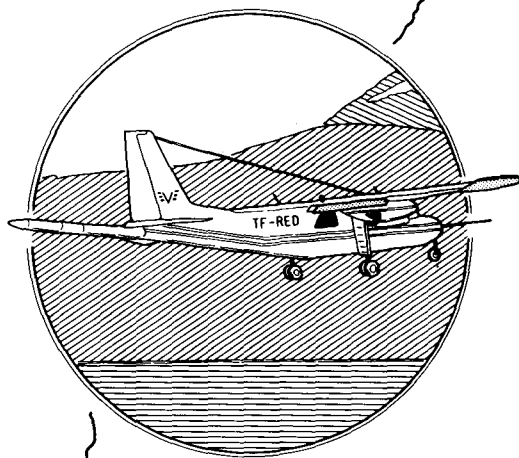


A large, hand-drawn outline map of Greenland, showing its characteristic shape and major fjords. The map is positioned on the left side of the page, with the title and author information overlaid on it.

# Aeromagnetic maps of parts of southern and central West Greenland:

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### **Abstract**

Approximately 52 000 line km of aeromagnetic data were acquired in 1975 and 1976. The data are mainly compiled from six survey areas between 64°N and 68°15'N, and from reconnaissance lines flown over several regions of West Greenland between 62°30'N and 72°N. The compilation involved editing and cleaning of data, first order correction of diurnal variation by use of a filtered base station magnetic field, further magnetic levelling using tie lines, and finally gridding of data. From the gridded data a coloured contour map has been produced at a scale of 1:500 000 together with black and white contoured maps at 1:250 000. The report contains a general discussion of the major anomalies. The major elements in the discussion are the relationships between the aeromagnetic field and geological features such as metamorphic facies boundaries, lithological units and structural lineaments.

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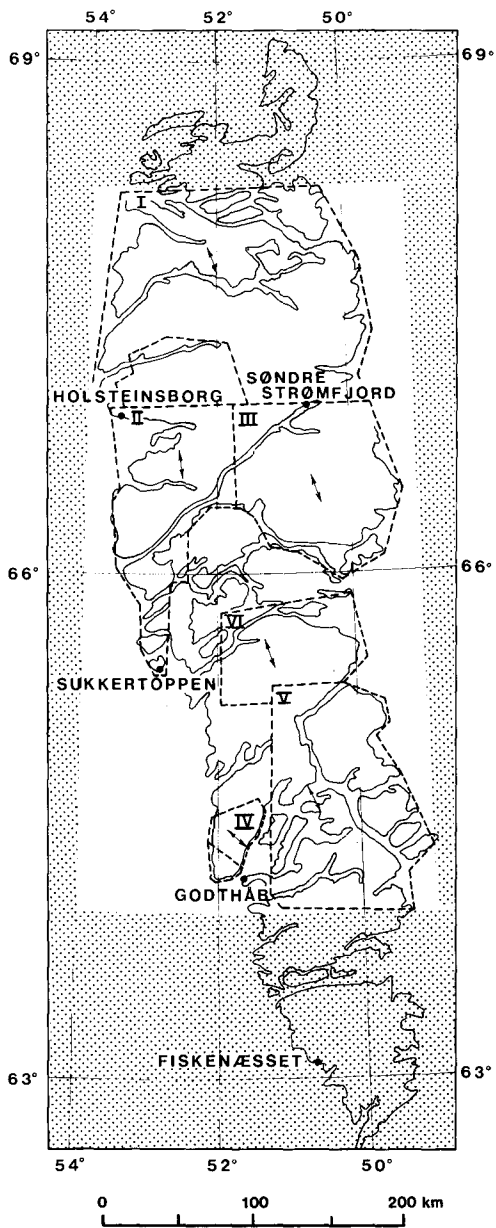


Fig. 1. Index map to the map at scale 1:500 000 (not shaded on figure). The arrows indicate direction of flight lines perpendicular to the main geological structures. Information on other survey parameters are given in Table 1. (I) The Nagssugtoqidian mobile belt survey, (II) and (III) the western and eastern Søndre Strømfjord surveys respectively, (IV) the Nordlandet survey, (V) the Godthåbsfjord survey, and (VI) the Majorqag survey.

## INTRODUCTION

In 1975 and 1976 the Geological Survey of Greenland (GGU) carried out airborne operations in central and southern West Greenland in which aeromagnetic data (Thorning, 1976, 1977a), and radiometric data (Secher, 1976, 1977), were acquired in a joint operation using the same aircraft. Since then the aeromagnetic data have been cleaned and compiled into preliminary versions of contoured maps. Following the airborne operations magnetic anomalies were investigated on the ground to determine the source of the anomalies (Thorning *et al.*, 1978; Thorning, 1979; Mielby & Svendsen, 1979; Secher & Thorning, 1981).

At the time of acquisition of the aeromagnetic data few facilities were available at GGU for the compilation and presentation of the data. These facilities were developed parallel with the use of the data in such a way that later aeromagnetic data acquired from other areas using other techniques could also be handled (e.g. Larsen & Thorning, 1980). The data from West Greenland served as test material for the development of computer programs. The first programs were described in Thorning (1977b), and since then an increasing number of computer programs have been produced and integrated into a flexible system for compilation, interpretation and presentation of aeromagnetic data (Thorning, 1982).

The aeromagnetic data are published as a colour map at a scale of 1:500 000, and in the near future more detailed contoured maps at 1:250 000 will be published.

This report briefly reviews the acquisition of the data and gives background information on the compilation techniques used in the preparation of the maps. Some of the major magnetic trends and anomalies and their geological significance are discussed; detailed and quantitative interpretation of the data in terms of geological structures will be the subject of separate reports.

## SURVEY OPERATIONS

The acquisition of the aeromagnetic data in the field was carried out as a cooperative venture between the Sections for Ore Geology and for Geophysics of GGU, responsible for the radiometric and the aeromagnetic work respectively, and a group from the Electronics Department, Risø National Laboratory, responsible for the instrumentation of the aircraft.

The survey was restricted to a number of selected areas (fig. 1 and Table 1) as it was not possible to carry out a systematic coverage of the total area which could be reached from the base of operations. Additional reconnaissance lines were flown over areas which could not be surveyed systematically (fig. 2).

The airborne operations were based in Søndre Strømfjord. A few natural landing strips were used for refuelling to increase the operational range of the aircraft. An average of 210 flight hours/year were used, including ferry flights.

The instrumentation was fitted in a twin engine (STOL) Britten-Norman Islander, char-

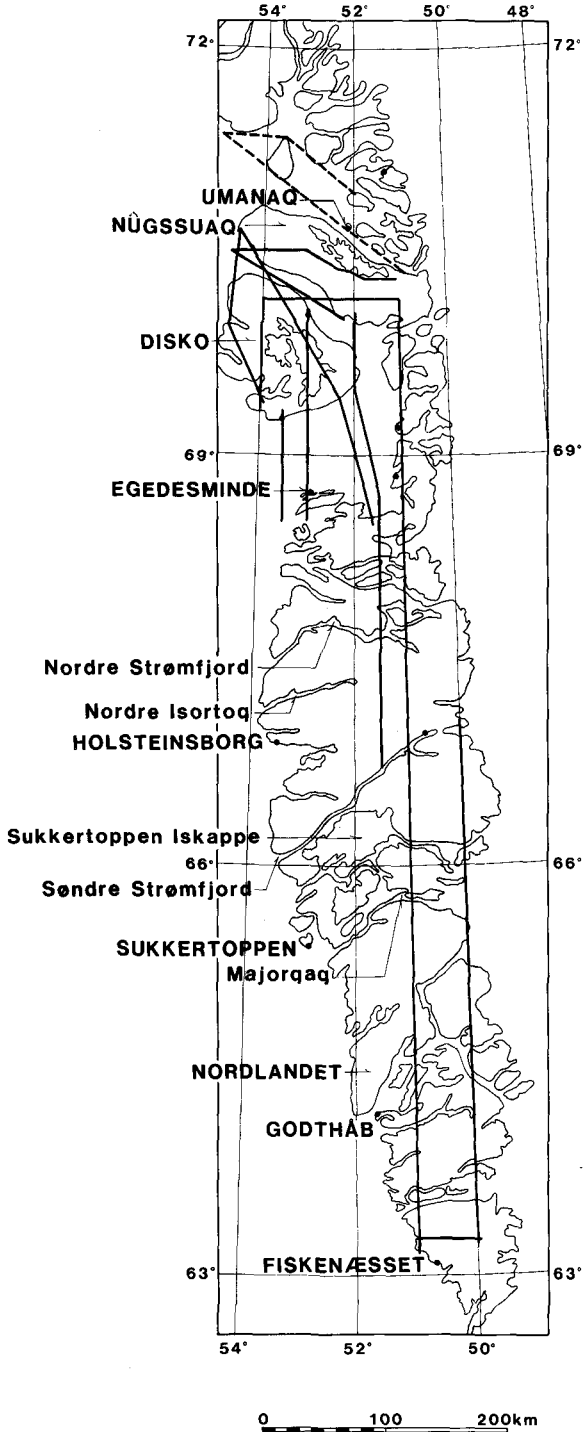


Fig. 2. Aeromagnetic reconnaissance flight lines in addition to the survey areas of fig. 1. The figure does not show the various groups of profiles over Nügssuaq, Sukkertoppen Iskappe or the region around Fiskenäset. The flight line along 51°W is shown on fig. 7 and is discussed in the text.

*Table 1. Summary of survey parameters, including production of main survey areas*

Area	Production km	Line spacing km	Altitude m a.s.l.
I	18000	1.5	915
II	6000	2.0	1830
III	7000	1.5	915-1830
IV	1800	1.0	450
V	7200	2.0	1525
VI	3300	2.0	1525
Nügssuaq	1140	3.0	1980
Ice Cap	190	10	2300
Fiskenæsset	630	5	300-1500
Miscellaneous	6200	-	-

tered from Vængir Airtransport, Iceland, and fitted with Risø/GGU instrumentation. The aircraft had an endurance of 8–9 hours and was operated at an air speed of 200–210 km/h. The magnetometer was a Geometrics G-801 proton precession magnetometer with a sensitivity of 1 nanotesla (nT) at a sampling interval of 1 sec., corresponding to a distance of 40–60 m between sampling points. The instrument was fitted for digital recording and in-flight analog display of data. A similar magnetometer, also with digital recording of data, was used as a ground station magnetometer, placed at exactly the same position in Søndre Strømfjord both years. This was operated at a 10 sec. sampling interval. Time was the common parameter for the two systems, obtained from synchronously working quartz clocks. Magnetic data, time, barometric and radar altitudes were digitally recorded.

The surveys were flown after preplotted flight lines by visual navigation with the flight path registered by single frame photography.

Diurnal variations of the geomagnetic field poses a severe problem at the latitudes of southern and central West Greenland. The short period of time available for the operation did not allow strict adherence to some diurnal variation specification. However, there was no flying during severe magnetic disturbances, and ongoing flights were abandoned on the onset of such disturbances. It was attempted, in every way possible, to keep to a minimum the effects of diurnal variations on the data.

## SURVEY AREAS

Six areas (fig. 1) were selected for systematic aeromagnetic coverage. They encompass most of the major geological boundaries and structures between 64°N and 68°15'N. Logistic considerations were taken into account in the selection of the areas such as distance to the area from the airport and the topography of the areas. Different combinations of survey parameters were applied (Table 1), chosen to give information on geological structures and at the same time test the applicability of a certain set of survey parameters in relation to the geology and topography. Some general comments on each of the areas are given below. Roman numbers in brackets refer to fig. 1.

The northernmost survey area (I) was intended to cover some of the main features of the Nagssugtoqidian mobile belt (Escher & Watt, 1976; Korstgård, 1979). The survey was flown in 1976, and based on experience of the previous year a fixed barometric altitude of 915 m (3000 ft) was maintained throughout the area. A small area north-east of Holsteinsborg could not be flown at this altitude, and there is a gap in the data coverage at this location. The constant flight altitude of 915 m means that the distance to the sources of the magnetic anomalies varies considerably. Over the north-west corner of the area, around Agto, the surface is at a distance of 900–1000 metres depending on height of terrain and depth of water. Over the south-east corner, especially in the highlands around Kingatsiaq, the distance is a couple of hundred metres, less over individual peaks. This is noticeable in the data, and should be taken into account when using the map on a regional scale. Similar comments are applicable to the other survey areas.

The region just south of 67°N has been covered by two separate surveys in 1975. The survey of the part west of 51°45'W, the western Søndre Strømfjord survey (II), has been extended southward along the coast to Sukkertoppen to obtain a continuous N–S coverage here. This area was flown at a constant barometric altitude of 1830 m (6000 ft) clearing the peaks in the mountainous region around Søndre Strømfjord. The eastern part, the eastern Søndre Strømfjord survey (III) east of 51°45'W, and north of the small ice arm of the Inland Ice north of Majorqaq, was flown using a technique often referred to as 'drape-flying'. The northern end of the flight lines was flown at 915 m (3000 ft), the southern end at up to 1830 m (6000 ft) altitude.

Two surveys cover the major part of the Godthåbsfjord region. The peninsula of Nordlandet (IV) was covered in 1975 and 1976 by a relatively detailed survey at 450 m (1500 ft) altitude, partly designed to see how low and close it was practical to operate. The survey of the area east of 51°20' from 64°N to 65°20'N (V) flown in 1975 at an altitude of 1525 m (5000 ft) is of a more regional type.

On ferry flights to these two areas the existence of a large anomaly just south of Majorqaq (65°40'N, 51°10'W) was noticed. Part of the available resources in 1975 were redirected in the field to extend the 1525 m survey over the Godthåbsfjord region north into the region around Majorqaq (VI) using similar survey parameters there.

A number of reconnaissance lines were flown in areas not surveyed in a systematical manner including some long N–S profiles together reaching from Fiskenesset to Nûgssuaq (fig. 2). Several lines were acquired over three main regions: Nûgssuaq, the Sukkertoppen Iskappe, and around Fiskenesset. Since no aeromagnetic contour maps will be produced from these areas the data have been included in this report in the form of profile maps and will be discussed together with the aeromagnetic maps.

## COMPILATION OF DATA

The aeromagnetic data of this report served as test material for the development of software for the compilation and presentation of aeromagnetic data. The following description of the compilation procedure only includes the methods of processing accepted for general use, and contained in the system of programs now being used (Thorning, 1982). The process diagram of fig. 3 illustrates the main steps in the compilation process.

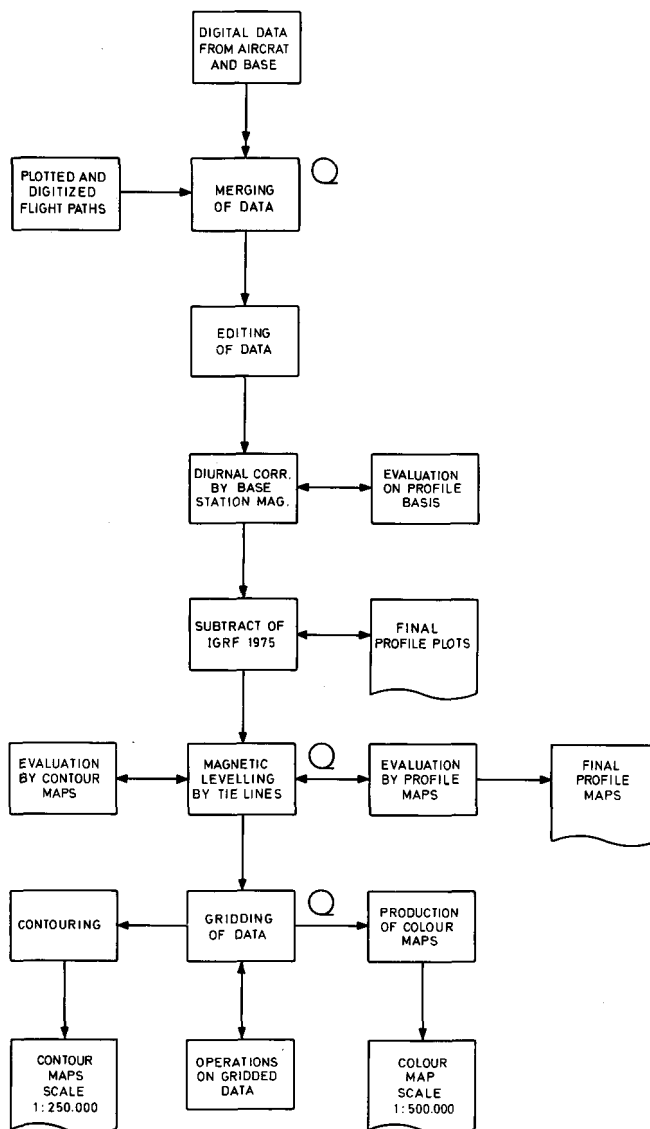


Fig. 3. Schematic process diagram showing the main steps of the compilation process. Details are given in the text.

### Navigational data

Flight paths were recorded by single frame photography, and later plotted on stable 1:100 000 topographic maps (enlargements of 1:250 000 maps).

The accuracy with which individual points can be identified on the photographs depends on the altitude above ground and thus varies considerably. For the surveys described in this

report the position accuracy is usually a few metres. Such points could be transferred to the base map with an accuracy corresponding to approximately 50 m.

Some caution was necessary in the plotting of points: aircraft groundspeed was calculated along flight lines and abrupt changes in speed were often related to inaccuracies in the base maps. Most points were plotted with sufficient accuracy for the scale of the work and were then digitized. Linear interpolation was used between the plotted points. Taking all inaccuracies into account the digitized flight path positions can be expected to lie within 100 m and probably better along flight lines.

The digitized flight path data were merged with the digital magnetic data, using time as a common parameter, and the total bulk of data organized in a magnetic tape data base (ADT, Thorning, 1982).

### **Correction of magnetic data**

It is advantageous that geologically interesting anomalies are of high frequency and considerable magnitude, and thus dominate the smaller low frequency 'anomalies' caused by diurnal effects. This diurnal noise has to be eliminated during compilation of the magnetic data. After the data had gone through a simple editing for spikes, erroneous time or date etc., at least two steps were necessary to remove diurnal effects. The first deals with long period variations often causing the average level of the geomagnetic field to change hundreds of nanotesla from day to day, superimposing a similar bias on the profile data, also on days where there are no or few short period variations. The second deals with the shorter period variations superimposing lesser variations in the level of the profile data.

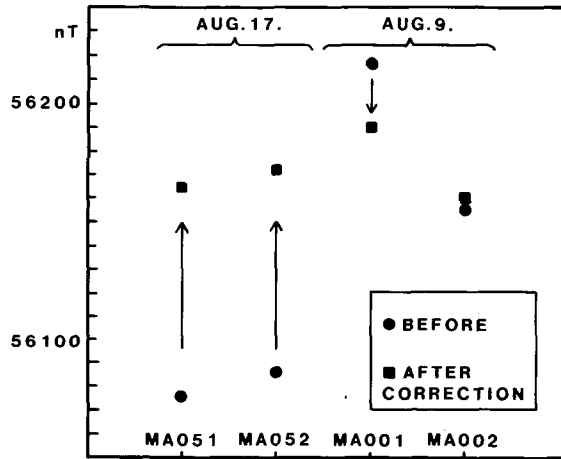
The first correction to the magnetic data was the subtraction of a smoothed geomagnetic field, calculated as the difference between the base station magnetic field and an all summer average of the geomagnetic field at the base station. This procedure was only adopted after a considerable number of tests as the distance between some of the survey areas and the base station is such that lateral amplitude and phase variations of the geomagnetic field could be expected.

The effect of this correction was checked profile by profile by superimposed plots of profile data before and after correction, and the corresponding base station data using time as one axis. In most cases the result was a significant improvement of the correspondance between neighbouring profiles, e.g. fig. 4.

The distribution of the intersection difference data also improved statistically, even in the areas farthest away from Søndre Strømfjord. In fig. 5 histograms of intersection differences from the Godthåbsfjord survey (175–300 km from Søndre Strømfjord) before and after correction are shown to illustrate this. A final, more subjective test, was also applied by contouring the data before and after the first correction.

This method of a first correction of the data worked well for most of the data, and in all survey areas a considerable improvement in the appearance of the contour maps was noted after correction. In a few cases, however, the process introduced noticeable errors into the profile data. These errors were eliminated by careful editing in each individual case, and if this was not possible the profile in question was not used in the compilation process. Undetected errors of small magnitude may have been introduced, but the second step in the correction procedure eliminated these.

Fig. 4. The effect of subtraction of diurnal variation illustrated by four profiles (MA051 – MA002) located next to one another approximately 125 km from Søndre Strømfjord in the Majorqaq survey area but recorded on different dates. The means of all measurements on a profile are plotted before and after correction.



The second correction of the data utilized the tie lines flown in each survey area. These were flown during the best possible diurnal conditions, but even so some diurnal variation remained in the tie lines. Due to this and the inaccuracies in positioning mentioned above it was not possible to attempt a perfect levelling aimed at zero intersection differences at all intersections between tie lines and profiles.

A technique by Yarger *et al.* (1978) was adopted after a number of tests and has been used in all areas. The method reduces in a statistical sense the overall intersection differences through a correction of the profile data, calculated by polynomial approximation of intersec-

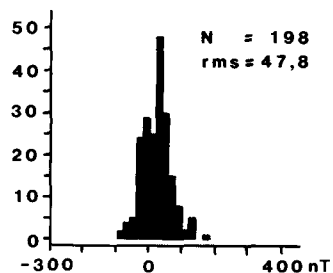
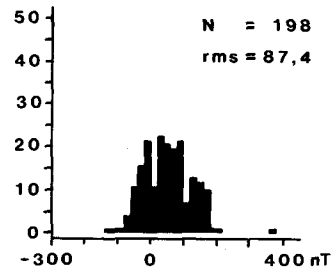


Fig. 5. Histograms of intersection differences in the Godthåbsfjord survey (175–300 km from Søndre Strømfjord) before (top) and after subtraction of smoothed diurnal variations.



tion differences. In some cases it was necessary to except single intersection points from the analysis, because they were so much in error (placed at a gradient, or through incorrect positioning) that they seriously hindered the method in producing good results. The method resulted in significantly reduced intersection difference values in all survey areas and greatly improved the appearance of the contour maps. The tie lines have not been used in the contouring, which is therefore based only on the corrected profiles. Figure 6 shows an example of the effect of this correction.

A more detailed explanation of the use of this method is given in the description of the programs NIVEL1 and NIVEL2 in Thorning (1982).

### Reference field

The International Geomagnetic Reference Field (IGRF) has been used with the 1975 coefficients, subtracted on a point to point basis along individual profiles. Several sets of coefficients were tested, but the IGRF 1975 set was used, because it seemed satisfactory in these areas and was internationally accepted. The DGRF 1975 (e.g. Peddie, 1983) came too late to be of use in this study.

### Gridding and contouring

The corrected data were used for contouring and construction of profile maps. The gridding of the data was done by one or other of the two methods described in Thorning (1982) producing very similar results. Contouring of the gridded data into contour line maps was used as a last quality control. In some areas traces of diurnal or navigational disturbances not completely eliminated by the processing carried out so far, was removed by a

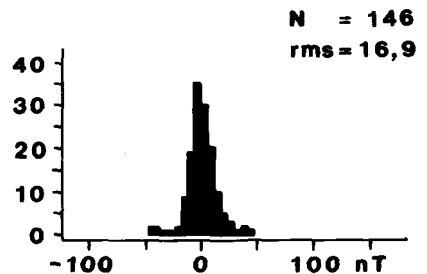
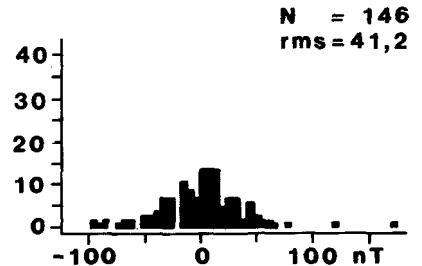


Fig. 6. The effect of the second step in the correction of the data, the magnetic levelling, illustrated by histograms of intersection differences from the Majorqaaq survey area (125 km from Søndre Strømfjord) before (top) and after correction. Note the horizontal scale is different from that of fig. 5.

light ellipsoidal filtering of the gridded data (different cut-off wavelengths in two perpendicular directions). The final accepted grid files were transferred into a raster type format used directly for the production of colour contour maps (Applicon Jet Ink plotter) of each survey area, later joined together to form the 1:500 000 map in colour.

### *Profile maps*

Reconnaissance lines not suitable for contouring were subjected to the same compilation process and the data plotted as profile maps (TRACK, Thorning, 1982). Note that both the horizontal and magnetic scales vary from area to area.

## REGIONAL SURVEYS

A qualitative discussion of the main aeromagnetic features and their relation to the geology of the area is presented below. Recent accounts of the geology can be found in Escher & Watt (1976), Korstgård (1979) and Kalsbeek (1981). The area is covered by GGU's 1:500 000 geological map sheets Frederikshåb Isblink – Søndre Strømfjord and Søndre Strømfjord – Nûgssuaq. The geological features treated in this discussion are best illustrated by the 1:500 000 magnetic anomaly map in colour, but for easy reference profile maps of the magnetic data have been included in this discussion.

### **Regional aeromagnetic profile**

The long aeromagnetic profile from Hellefiskeøer near Fiskenæsset to Boyes Sø on Nûgssuaq (c. 800 km) is presented in fig. 7. Numbers in brackets refer to the numbers on fig. 7.

The magnetic profile (composite of two) has been plotted along a topographic section and a geological section (taken from the 1:500 000 geological maps) for easy comparison. The profiles were flown at an altitude of 1980 m (6500 ft) along the 51°W longitude, but slightly higher over the ice cap around 66°N. Thus the anomalies are mostly fairly smooth in appearance.

The anomaly at the northern end of the profile over the Atâ Sund area (1) is associated with the supracrustal rocks in the area (Escher & Pulvertaft, 1976). The anomaly is situated over metasediments and metavolcanics on the northern flank of the Talorssuit dome, and its source is a small banded ironstone occurrence (L. Keto, personal communication, 1983). The anomaly can also be seen on the profiles from Nûgssuaq (fig. 8) where it is seen to extend into an easterly direction along the coast. The Talorssuit gneiss dome itself leaves little impression on the magnetic field.

The sinistral transcurrent fault zone at Påkitsoq, north of Jakobshavn, taken to be the boundary between the Nagssugtoqidian and Rinkian mobile belts is not readily apparent in the magnetic data, although variations are present (2) which may be attributed to the fault zone.

A significant magnetic maximum (3) can be seen near Christianshåb. This is an area with various granodioritic gneisses, and mica schists with garnet, sillimanite and muscovite in

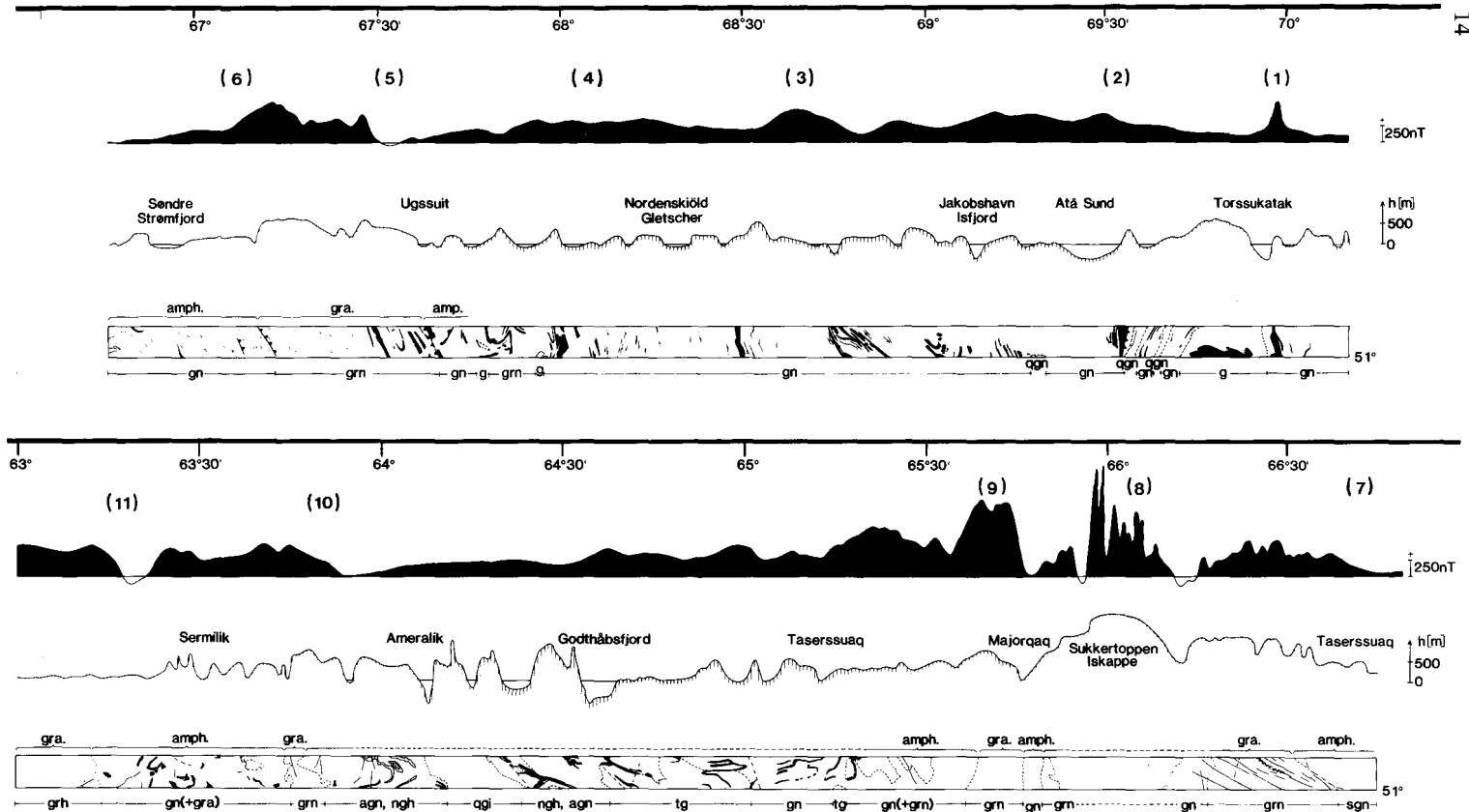


Fig. 7. Regional aeromagnetic profile along 51°W. Vertical exaggeration of topography approximately 12.5. Geological section is a 5 km strip west of 51° W. Magnetic measurements solid black curve (relative to IGRF75). Numbers in brackets refer to anomalies discussed in the text. Granulite (gra) and amphibolite (amph) metamorphic facies rocks are indicated. Rock types are those given on 1:500 000 geological map.

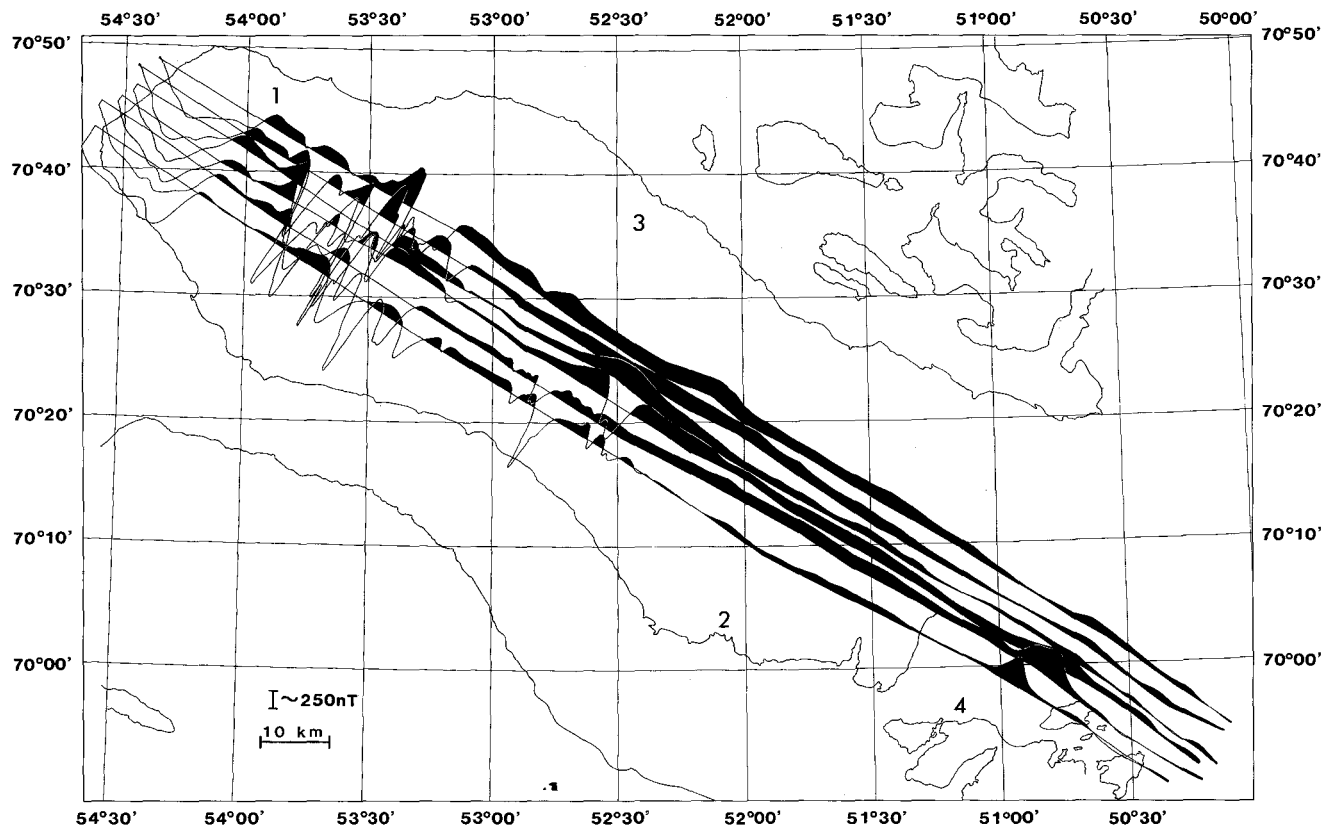


Fig. 8. Profile map of data from Nûgssuaq with outline of topography. 1: Northern end of Itivdle valley. 2: Sarqaq. 3: Kûk. 4: Torssukátak.

amphibolite facies. The anomaly may be an indication of other rock types at depth, or there may be an as yet undetected variation in metamorphic facies. Further investigation is warranted here.

Many of the geological features of the Nagssugtoqidian mobile belt can be seen on the profile. The Nordre Strømfjord shear zone is distinguished as a slight minimum (4), although the effect from a nearby quartz diorite intrusion obscures the anomaly making it less obvious here than further to the west. The effect of the various metamorphic and deformational boundaries dominates the field further south. Sometimes there is good agreement, as at the southern boundary of the Isortoq complex (6), and at other localities the relationship seems to be of a different nature (e.g. 5). These features will be discussed later.

The boundary between the Nagssugtoqidian mobile belt and the Archaean craton, a few kilometres south of Søndre Strømfjord, can be seen in the magnetic data as a well-defined change in magnetic level and expression (7).

The variations in the aeromagnetic field south of the boundary are of higher amplitude and shorter wave length, culminating under the Sukkertoppen Iskappe (8), partly because of the proximity of the magnetic sources here. The belt of granulite facies rocks just south of Majorqaq results in a significant anomaly (9), and further southwards variations in composition and metamorphic facies of the basement are reflected in the magnetic anomalies (discussed further later). The magnetic field is very smooth over the Godthåbsfjord region, but south of Ameralik two anomalies (10 and 11) correlate well with the position of known metamorphic amphibolite granulite facies boundaries. If these anomalies, and the considerably higher magnetic levels south of both of them, really are caused by granulite facies rocks then the amphibolite facies rocks mapped in the Sermilik region may be a thin layer on top of granulite facies rocks below.

There is thus evidence that metamorphic facies boundaries play an important role for the magnetic field in parts of West Greenland. In a number of cases there seems to be good agreement between mapped facies boundaries and anomalies (6, 7, 9, 10, 11), in other regions discrepancies exist (5, south of 9, between 10 and 11). Some possible reasons for this will be discussed in the following sections.

### Profiles over Nûgssuaq

Six profiles were flown over Nûgssuaq along the length of the peninsula (fig. 8). The negative anomalies associated with the Tertiary lava flows of Nûgssuaq are the dominant feature on the profiles. These indicate that the basalts are reversely magnetized to such an extent that this component of magnetization dominates over the induced component of magnetization. East of Itivdle the flows of the upper basalt formation mainly occur on the top of the mountains, near to the flight altitude of 1830–1980 m a.s.l., and the anomalies are sharp and precisely limited to the basalt areas. West of the Itivdle valley the larger, more massive, block of the lower basalt formations gives rise to a more broad negative anomaly. The Itivdle fault is clearly demarcated.

Reconnaissance profiles over Disko (not shown here) exhibit similar negative anomalies associated with the reversely magnetized basalts.

Where the anomalies of the Tertiary lavas do not dominate, the anomalies reflect variations in the Precambrian basement, partly below the Cretaceous–Tertiary sediments. The fault structures limiting the Cretaceous basin to the east, Sarqaqdalen, leave no impression

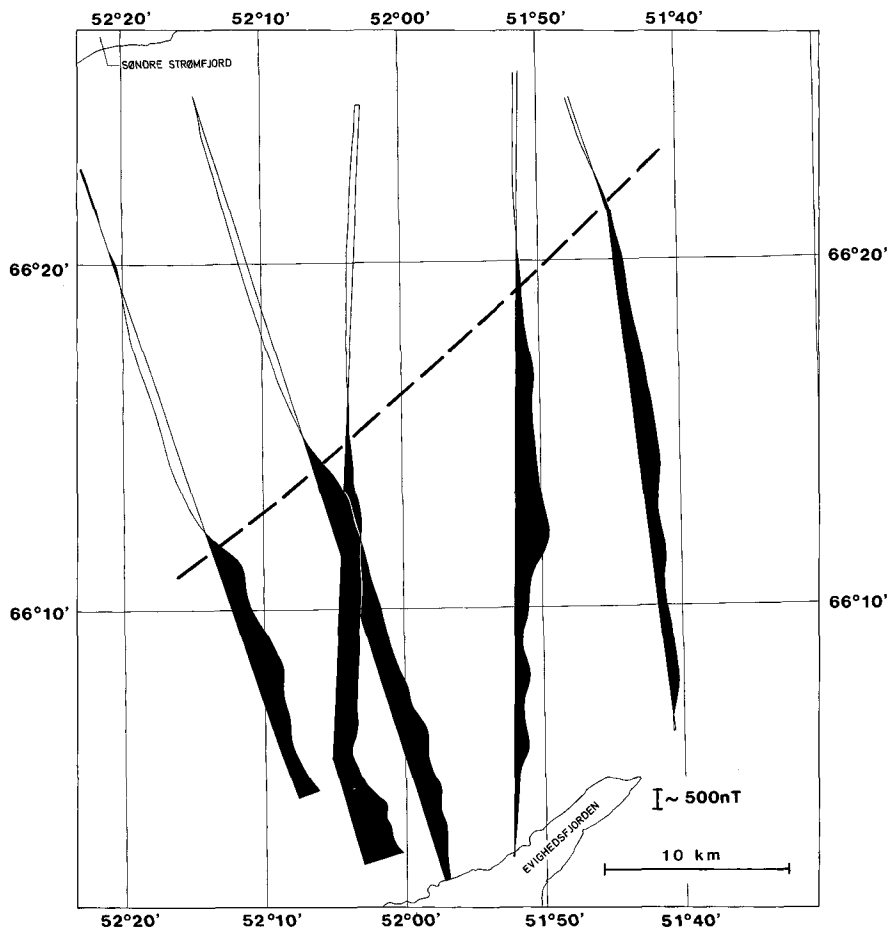


Fig. 9. Profile map of data from the Sukkertoppen Iskappe with outline of topography. Inferred geological boundary between granulite facies rocks (to the south) and amphibolite facies rocks shown by stippled line.

on the magnetic field at this altitude. The anomaly near Torssukátak has already been discussed (fig. 7 around 1).

### Profiles over Sukkertoppen Iskappe

High level profiles over Sukkertoppen Iskappe (fig. 9) show the magnetically significant boundary between the Nagsugtoqidian mobile belt and the Archaean craton in a manner similar to that observed further east along the boundary in the Søndre Strømfjord survey area (also seen in fig. 7, anomaly 7).

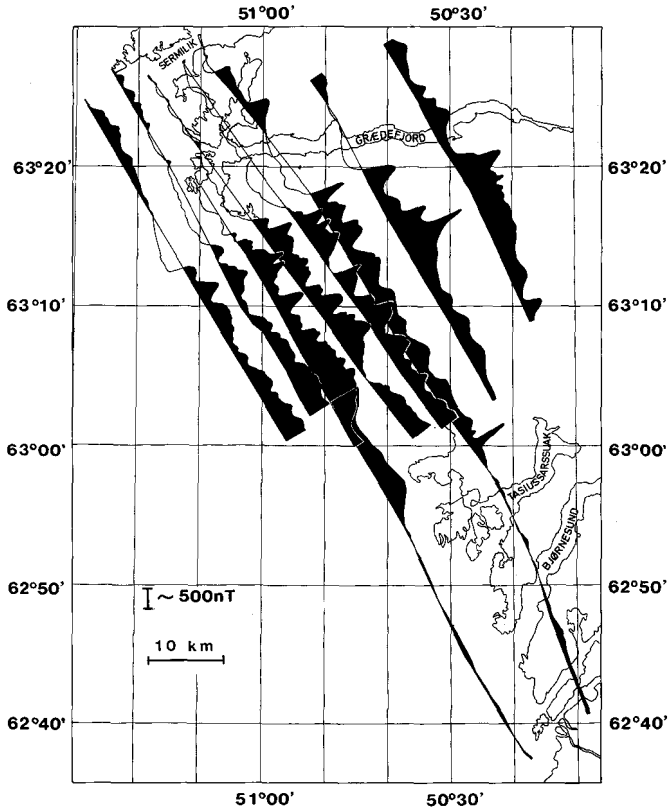


Fig. 10. Profile map of data from the Fischenæsset region with outline of topography.

### Profiles over the Fischenæsset region

Several profiles were flown in the Fischenæsset region (fig. 10) at various altitudes depending on the terrain. Therefore, the shape of corresponding anomalies varies from line to line. The most significant feature is the increase in the magnetic field just south of Grædefjord, the same as anomaly (11) in fig. 7. This corresponds exactly to a mapped facies boundary separating amphibolite facies rocks in the northern part from granulite facies rocks further south (Kalsbeek, 1976).

### The Nagssugtoqidian mobile belt survey

The data coverage in this area is good. The profile map of fig. 11a contains only half of the profiles flown, yet there is good continuation of both major and minor anomalies from line to line, and there is more detail available than can be treated in the context of this report.

The northern part of the survey area is dominated by a linear minimum which can be followed from the coast just north of Nordre Strømfjord (67°34'N, 53°45'W) to the edge of the Inland Ice (68°10'N, 50°10'W). This magnetic anomaly correlates with the mapped part of the Nordre Strømfjord shear belt, (Bak *et al.*, 1975; Olesen & Sørensen, 1976), and it can

be assumed that the continuation of the shear belt to the east can be traced by the narrowing magnetic minimum. This demonstrates that the magnetite content of the rocks in the shear belt is less than that of the rocks outside the shear belt in agreement with the suggestion of Bridgwater & Myers (1979) that titanomagnetite becomes unstable in the shear zone and less magnetic hydrated ferrous oxides form. The variation in magnetite content is most clearly defined in the western part, where the rocks in the shear belt contrast with the surrounding rocks in granulite facies. Further east the surrounding rocks are in amphibolite facies, at least at the present erosion surface, and consequently the difference in magnetic properties is less pronounced.

The aeromagnetic field exhibits a number of positive and negative linear anomalies semiparallel with the Nordre Strømfjord shear belt, and it is likely they reflect the smaller shear zones occurring in the area (see Korstgård, 1979).

South of the eastern end of the shear zone an isolated magnetic maximum correlates with the southern part of the quartz diorite intrusion, just north of and partly below the glacier Usugdlûp sermia ( $67^{\circ}58'N$ ,  $50^{\circ}15'W$ ), indicating that this part of the Proterozoic intrusion (Kalsbeek, personal communication, 1983) is significantly different from the remaining part of the intrusion. This is supported by the high magnetic susceptibilities reported from this particular area contrasting with lower susceptibility values in the northern part of the intrusion (Thorning *et al.*, 1978).

In the north-west corner of the survey area near Agto the magnetic anomalies correlate well with metamorphic facies boundaries although the boundaries are not so clearly defined as in some examples described later. Two magnetic minima ( $67^{\circ}50'N$ ,  $53^{\circ}42'W$ , and  $68^{\circ}02'N$ ,  $53^{\circ}06'W$ ) are situated over granodioritic gneisses (amphibolite facies), and the magnetic level is significantly higher over the nearby hypersthene gneisses (granulite facies). Further east ( $68^{\circ}01'N$ ,  $52^{\circ}10'W$ ) a magnetic minimum corresponds to a small area with granodioritic gneiss, but the maximum (distorted by Alángordleq and Arfersiorfik fjords), just east of this, is also situated over the same gneiss. The reason for this 'inverted' relationship is not known.

The general trend of the magnetic anomalies in the southern part of the survey area follows the dominant trend of the geology. A band of highly magnetic rock types can be followed from the coast south of Holsteinsborg (see discussion of the Søndre Strømfjord surveys) to the Inland Ice, although a gap in data coverage prevents direct observation in part of the area. The southern limit of this magnetic band corresponds to the Holsteinsborg thrust zone or the boundary between the Ikertoq and Isortoq complexes. This boundary has been placed at various positions. The 1:500 000 geological map places its intersection with the edge of the Inland Ice approximately 10 km north of the Isunguata sermia glacier at Akuliaruserssuk ( $67^{\circ}20'N$ ,  $49^{\circ}45'W$ ), whereas the more recent work of Escher *et al.* (1976) and Korstgård (1979) puts it at the northern limit of the Isunguata sermia glacier. Trends corresponding to both these positions can clearly be observed in the magnetic map, but the latter position is favoured by the magnetic data. Furthermore, an even more southerly position of the geological boundary may be indicated for the easternmost part of the boundary. The detailed structure of this deformational and metamorphic boundary at the coast south of Holsteinsborg has been discussed by Grocott (1979). He demonstrates that facies and deformation boundaries do not necessarily coincide, although the different types of boundaries are usually subparallel. The details in the aeromagnetic field over the approximate position of the boundary near the Inland Ice may be related to a similar structure of the boundary.



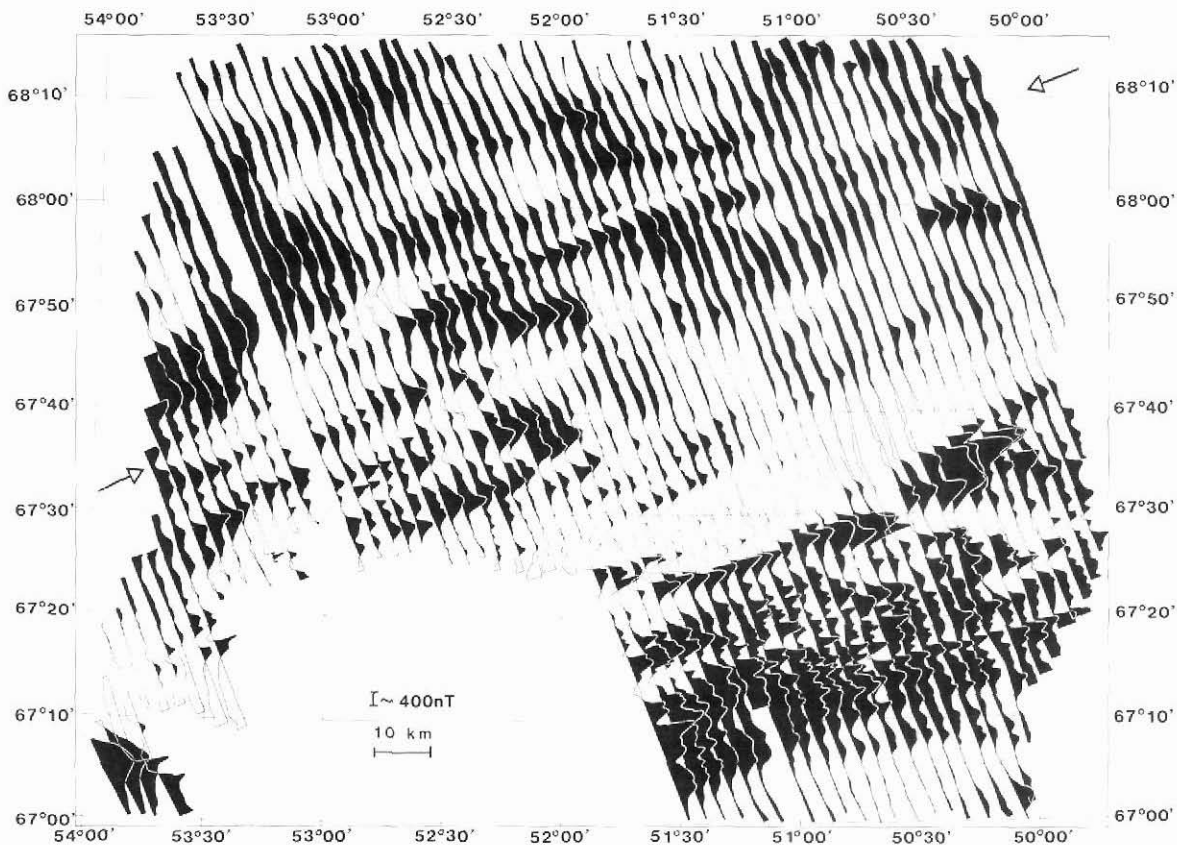


Fig. 11a. Profile map of the Nagssugtoqidian mobile belt survey with every second profile shown. Arrows indicate approximate position of the Nordre Strømfjord shear belt.

The northern limit of the band of highly magnetic rocks is exceedingly well defined and cuts the Kûk valley at  $67^{\circ}33'N$ ,  $50^{\circ}35'W$ , but at a position where the geological map gives no indication of a significant geological boundary.

The geological map indicates a more northerly position of the boundary between granulite and amphibolite facies, and if this is correct an alternative explanation is necessary for the magnetic anomaly pattern. However, it is also possible that the magnetically defined boundary is the facies boundary and that the geological map consequently is in error here. In the profile map of fig. 11 the form of the anomalies at the boundary indicates a fairly sharp magnetic boundary, i.e. a fault or sharp lithological boundary. From the details in the anomalies over the northern part of the band of highly magnetic rocks it appears that there is an elongated magnetic body situated at or near the boundary. The anomaly culminates in the southern part of Eqalungmiut nunât ( $67^{\circ}35'N$ ,  $50^{\circ}15'W$ ), partly over an area of granodioritic gneisses which are in amphibolite facies. A few days reconnaissance work was carried out in the area in 1977 (Thorning *et al.*, 1978), but results were inconclusive. The anomaly may be caused by a deep-seated and as yet unknown body.

A general feature of the aeromagnetic field in the Nagssugtoqidian mobile belt survey is

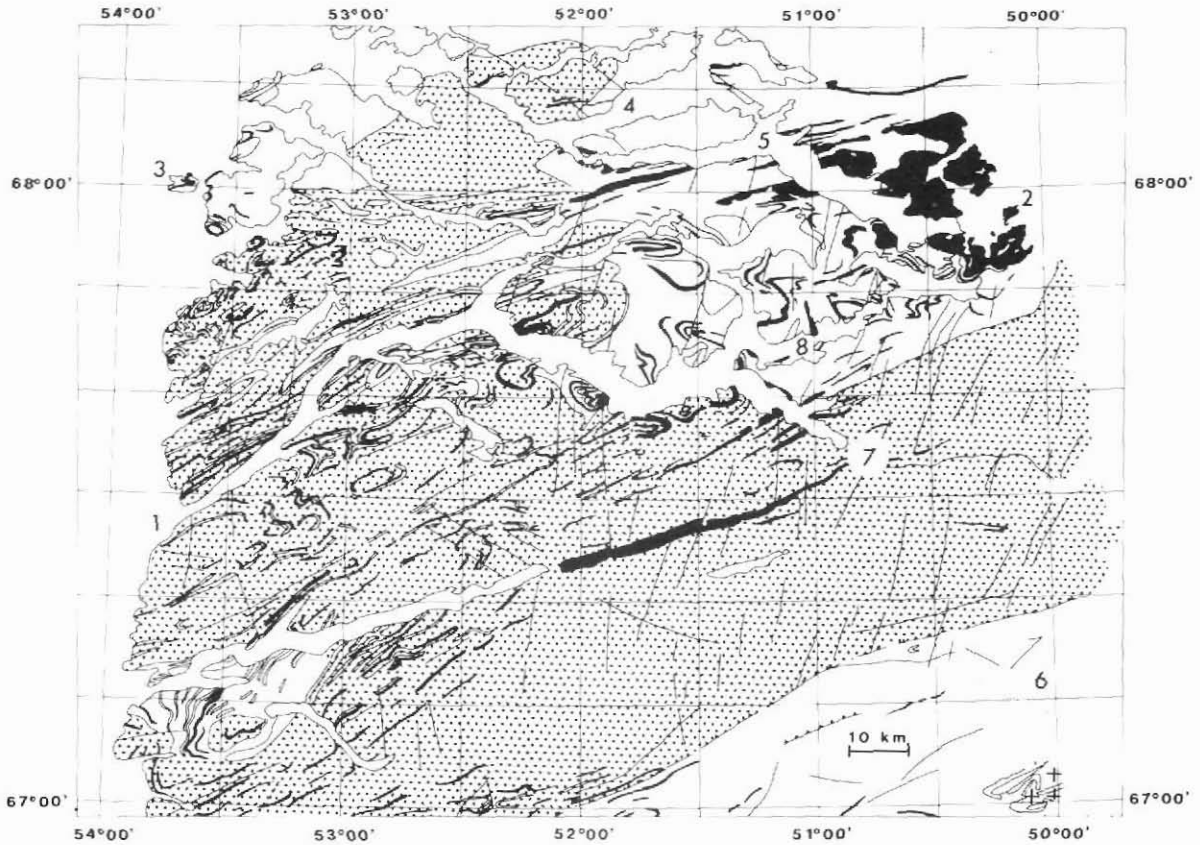


Fig. 11b. Simplified geological map of same area. On this and following maps granulite facies areas are indicated by shading. Numbers show approximate position of localities mentioned in the text. 1: Nordre Strømfjord. 2: Usugdlúp sermia. 3: Agto. 4: Alángordleq. 5: Arfersiorfik. 6: Isúnguata sermia. 7: Kúk. 8: Ugssuit.

worth mentioning. It cannot easily be seen in the profile map of fig. 11, but can be observed on a detailed magnetic contour map. The presence of the Inland Ice has resulted in a tilting of the ice-free land leading to a higher rate of erosion near the coast. The present surface consequently represents an inclined section through the crust, exposing amphibolite facies rocks in the eastern part and the more deeper-seated granulite facies rocks in the western part of the area around Nordre Strømfjord–Arfersiorfik–Ugssuit. Consequently the N–S exposed facies boundary is positioned where the inclined facies boundary is cut by the present day surface. This boundary can be seen in the magnetic field, but in a manner distinctly different from what has been observed about the mainly E–W facies boundaries associated with shear belts etc. The N–S boundary is difficult to place exactly from the magnetic data. It is gradual with many minor and major magnetic anomalies cutting across, and can only be perceived if the different character of the magnetic field as a whole is taken into account with a general tendency towards higher amplitudes and shorter wavelength anomalies in the west, and a more smooth pattern in the east.

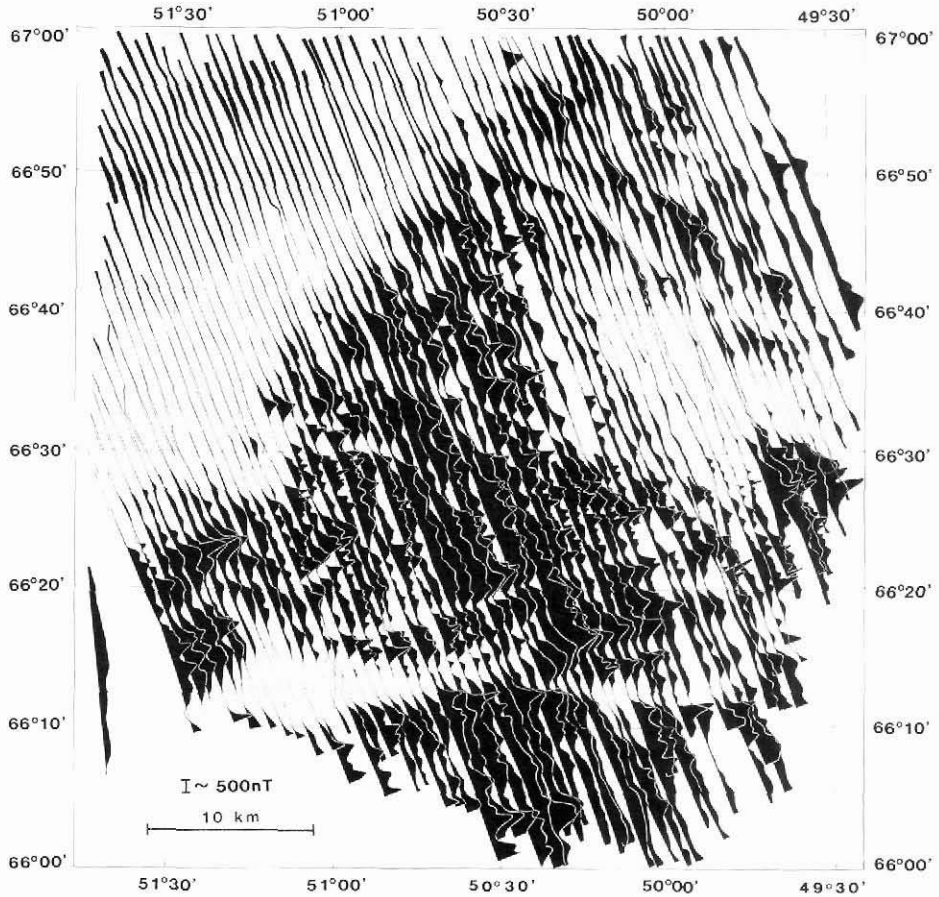


Fig. 12a. Profile map of the eastern Søndre Strømfjord survey area.

### The Søndre Strømfjord surveys

The two survey areas making up the Søndre Strømfjord surveys cover the major geological boundary between the Archaean craton and the Nagssugtoqidian mobile belt. The boundary is an obvious feature on the aeromagnetic map and the profile maps of figs 12 and 13. In the eastern survey area (fig. 12) the Archaean granulite facies gneisses to the south of the boundary are mostly highly magnetic, and the effect of topography is significant because the magnetic sources are at the surface. The amphibolite facies gneisses in the Ikertoq shear zone of the Nagssugtoqidian mobile belt north of the boundary are only weakly magnetized, and the topography hardly affects the magnetic field. It is not easy to place the boundary exactly using the magnetic data, but there is a good correlation with the geological boundary, and both the mapped thrust zone and the transitional boundary between amphibolite and granulite facies gneisses seem to affect the magnetic field.

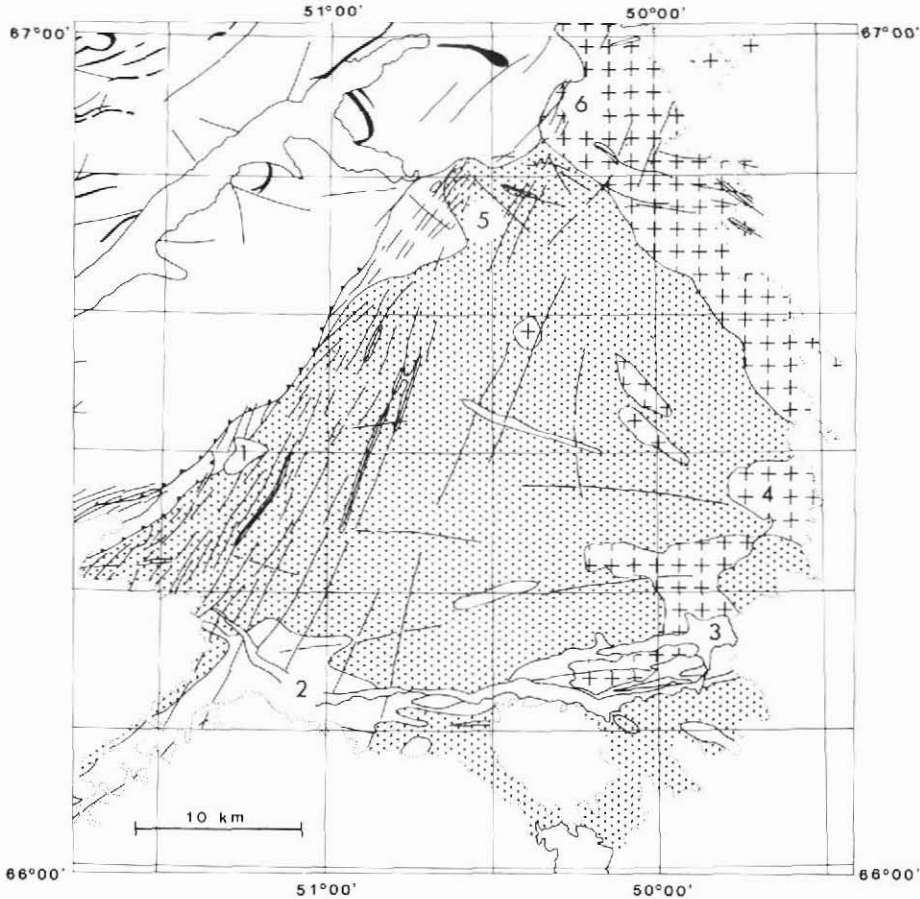


Fig. 12b. Simplified geological map of same area. Numbers show approximate position of localities mentioned in the text. 1: Sarfártoq carbonatite. 2: Tasersiaq. 3: Tasersiap qalia 4: Torssúp nunã. 5: Qórnup nunã. 6: Angmalortup nunã. Granite areas indicated by crosses.

No details were obtained from the aeromagnetic data from north of the boundary in the eastern Søndre Strømfjord survey. South of the boundary, in the Archaean craton, a number of features are visible in the magnetic data. The Cambrian Sarfártoq carbonatite (Larsen *et al.*, 1983) can be seen just on the boundary as a small maximum surrounded by a zone of relatively non-magnetic rocks ( $66^{\circ}30'N$ ,  $51^{\circ}15'W$ ). A detailed magnetic investigation was carried out by Secher & Thorning (1981).

The amphibolite facies gneisses around the western end of the lake Tasersiaq ( $66^{\circ}15'N$ ,  $51^{\circ}10'W$ ) extending along the lake to the east is revealed as a magnetic minimum. A linear minimum extends along the valley of Kangimut kúgtoq ( $66^{\circ}10'N$ ,  $50^{\circ}30'W$ ), where there are elongated exposures of amphibolite facies gneisses, all possible indications of the existence of a linear belt here. In the eastern part of the area along the edge of the Inland Ice granites of various compositions are exposed. In the south around Tasersiaq and Tasersiap qalia ( $66^{\circ}17'N$ ,  $49^{\circ}55'W$ ) they are generally less magnetic than the granulite facies gneisses, but

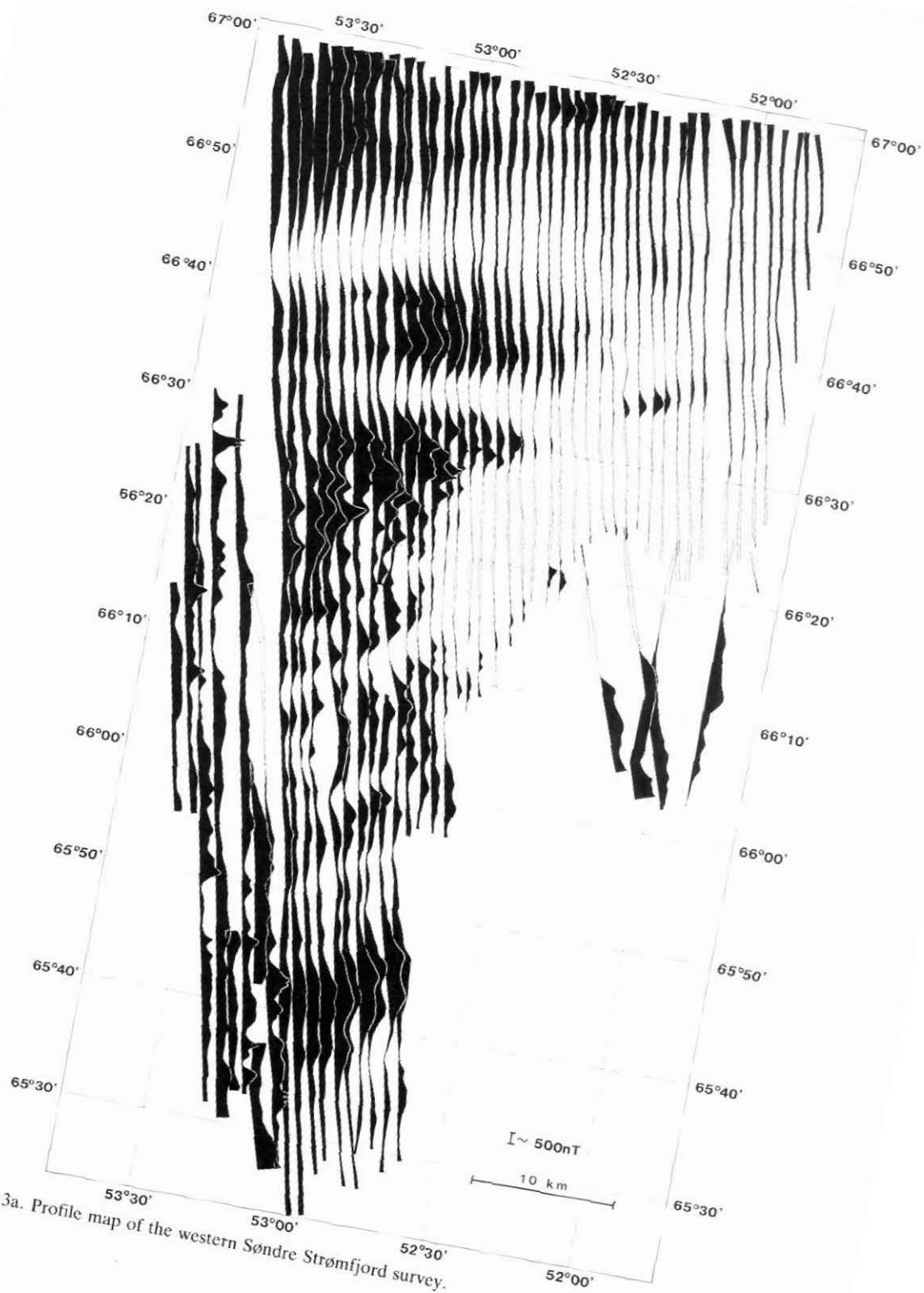


Fig. 13a. Profile map of the western Søndre Strømfjord survey.

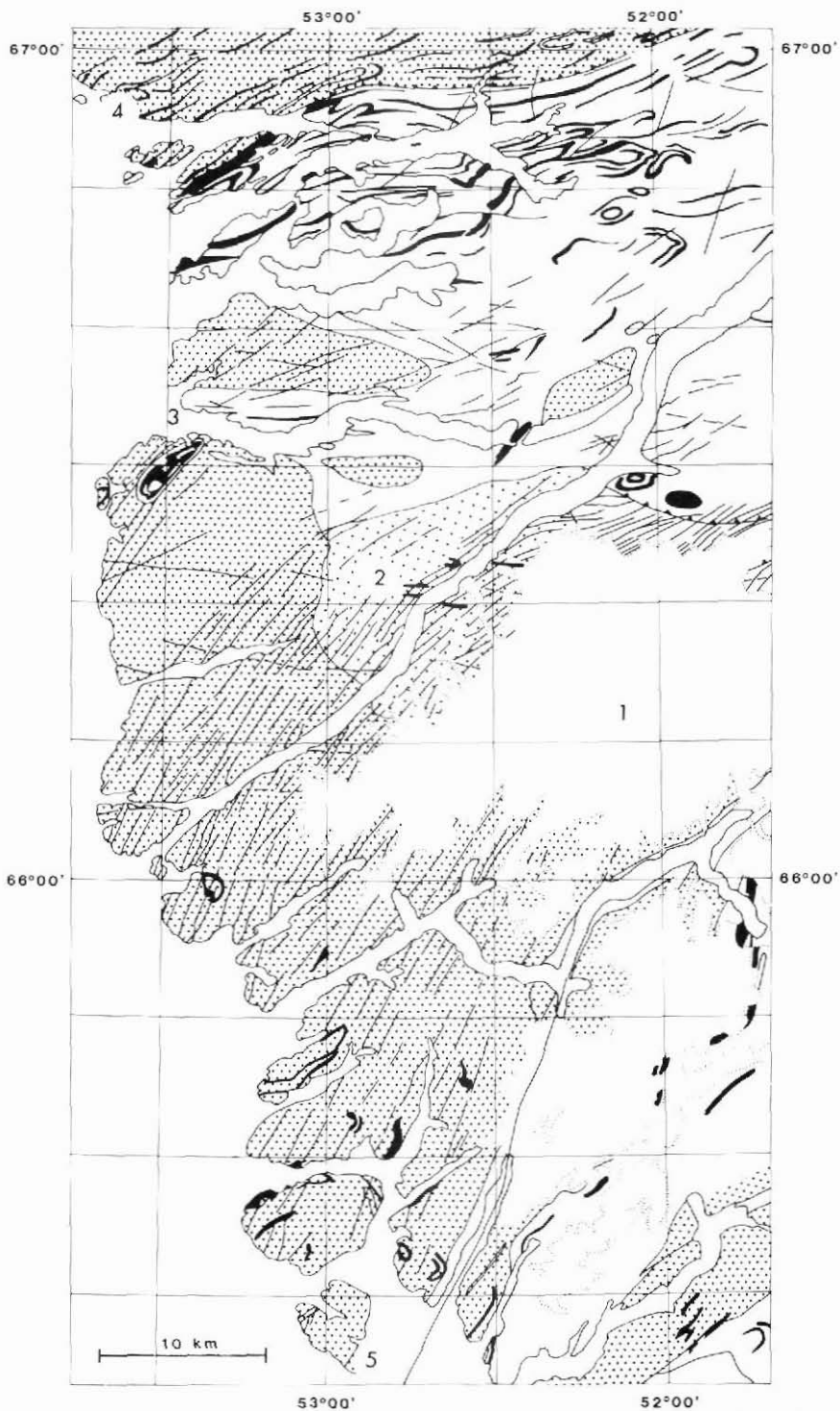


Fig. 13b. Simplified geological map of same area. Numbers show approximate position of localities mentioned in text. 1: Sukkertoppen Iskappe. 2: Søndre Strømfjord granodiorite. 3: Itivdle. 4: Hols-teinsborg. 5: Sukkertoppen.



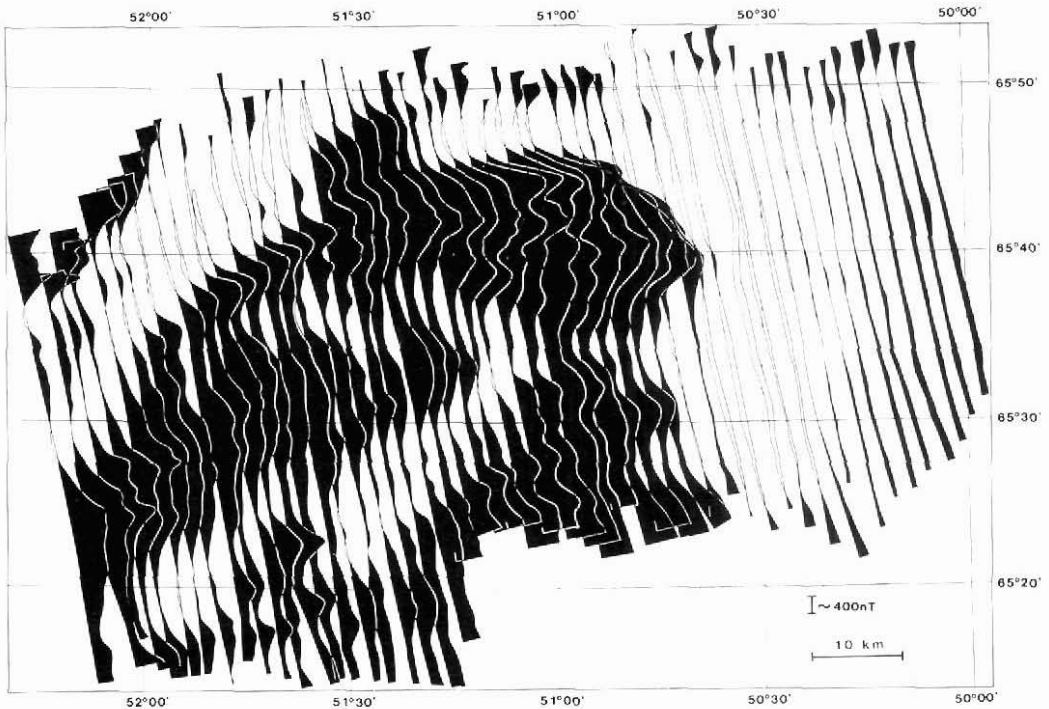


Fig. 14a. Profile map of the Majorqaaq survey area.

more magnetic than the amphibolite facies gneisses. Just north of here in the Torssúp nunâ area (66°27'N, 49°40'W) another granite exhibits a large positive magnetic anomaly, but further north again the magnetic character of the granite seems to be similar to that further south. The trend of the main Archaean Nagssugtoqidian boundary can be traced continuously into the granites and across the Angmalortup nunâ area (66°55'N, 50°25'W) to the edge of the Inland Ice. The boundary between the granites along the edge of the ice and the granulite facies gneisses is obscured by NW–SE trending anomalies of unknown origin subparallel to many valleys in the area. The area between Qôrnup nunâ (66°46'N, 55°35'W) and Torssúp nunâ has been mapped as mainly enderbitic gneisses (granulite facies gneisses) with isolated exposures of granites. However, magnetically this area is very different from similarly mapped areas to the west: there are hardly any anomalies, and the average magnetic level is well below that of both the granites to the east and the gneisses to the west. The reason for this is not yet known.

Four reconnaissance profiles over Sukkertoppen Iskappe, although lacking in detail, make it possible to follow the magnetic Nagssugtoqidian boundary below the ice. It appears to follow the southern thrust zone at Sarfârtoq and join up with the boundary between granulite facies gneiss and the Søndre Strømfjord granodiorite west of the ice cap, cross Søndre Strømfjord and continue to the north. The aeromagnetic data from the western survey area clearly define the last part of this boundary. The Søndre Strømfjord granodiorite is apparently completely non-magnetic, and thus the boundary can be followed from where

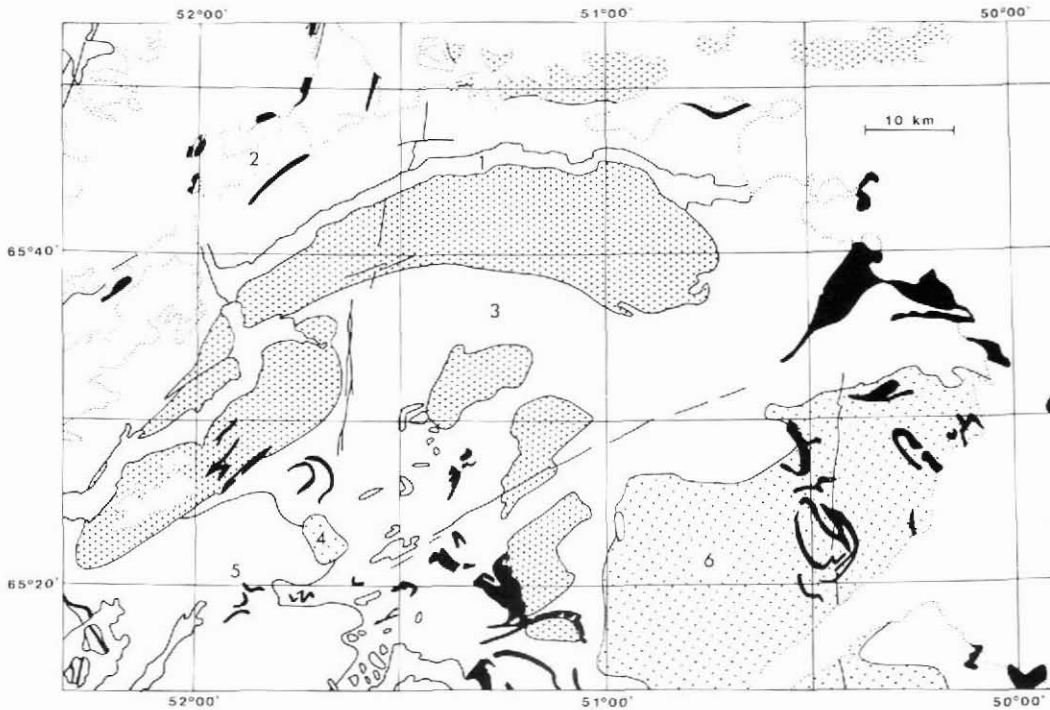


Fig. 14b. Simplified geological map of same area. Numbers show approximate position of localities in text. 1: Majorqaq. 2: Iluliagdilup tasia. 3: Isuitsup kua. 4: Qaqarsuk carbonatite. 5: Finnefjeld gneiss. 6: Taserssuaq tonalite.

it crosses Søndre Strømfjord and north to the Itivdleq fjord. The magnetic highs in the western Søndre Strømfjord survey all correlate with granulate facies gneisses, where also the topography is clearly reflected in the magnetic data. The Itivdleq shear belt amphibolite facies gneisses create a linear minimum here. The area of granulate facies gneisses north of Itivdleq and the small area of similar character just north of the anorthosite between Itivdleq and Søndre Strømfjord are clearly delineated by magnetic maxima. The fault zone and facies boundary just south of Holsteinsborg, the western continuation of the similar boundary discussed above, are also visible.

The southern part of the western survey area reaches south to Sukkertoppen and exhibits a number of positive anomalies which can be correlated with the topography. The source of the anomalies is mostly the granulate facies rocks exposed at the surface in this area.

### The Majorqaq survey

The data from this area also demonstrate the relationship between the amphibolite-granulate metamorphic boundary and the aeromagnetic anomalies (see fig. 14). The area with granulate facies rocks just south of the Majorqaq valley is perfectly delineated by the large positive magnetic anomaly, investigated in some detail by Thorning *et al.* (1978) and Mielby & Svendsen (1979). North of this at the edge of the ice cap granulate facies rocks are exposed at the surface, and along most of the northern limit of the survey area there are



corresponding magnetic anomalies, from which the amphibolite granulite facies boundary can be placed, also where it is not exposed.

East of the ice dammed lake Iluliagdilup tasia there is a positive magnetic anomaly in an area mapped as being in amphibolite facies ( $65^{\circ}45'N$ ,  $51^{\circ}30'W$ ). The cause of this anomaly is not known, but it may be an undetected or unexposed area of granulite facies rocks. The relative minimum between this anomaly and the Majorqaq anomaly is probably a topographic effect from the Majorqaq valley, and not an indication of two separate magnetic bodies.

South of the valley of Isuitsup kûa isolated spots of granulite facies gneisses occur in an area of amphibolite facies gneisses. The aeromagnetic anomalies indicate that the granulite facies rocks are more widespread and interconnected below the surface. A possible explanation for this is that the amphibolite gneisses mapped at the surface may be only a relatively thin layer. The granulite facies gneisses occur at some of the topographically highest areas, e.g. the Majorqaq anomaly, and the amphibolite gneisses at the topographically low areas, e.g. Isuitsup kûa, and it is therefore necessary to picture the granulite–amphibolite boundary as an undulating surface only partly exposed. An alternative explanation, assuming a more horizontal boundary and retrogressive metamorphism along tectonically active trends, e.g. the Majorqaq and Isuitsup kûa valleys, is also compatible with the magnetic data.

The Qaqarssuk carbonatite intrusion appears as a circular magnetic anomaly over the carbonatite body ( $65^{\circ}22'N$ ,  $51^{\circ}38'W$ ). The anomaly is situated in a linear magnetic low which trends SW–NE and cross cuts the boundary to the Finnefjeld gneiss. The cause of the linear minimum is unknown.

In the south-east corner of the survey area the effect of the Taserssuaq tonalite can be seen as a magnetic maximum. The amphibolites and metasediments near the boundary of the Inland Ice leave no impression in the aeromagnetic field.

### The Godthåbsfjord survey

The northern half of the aeromagnetic map of this survey area is dominated by a large positive anomaly associated with the Taserssuaq tonalite (fig. 15). Topographic effects from e.g. the glacier Sarqap sermerssua, the lake Taserssuaq, and the large Narssarssuaq plain, create relative minima over these localities, but otherwise the Taserssuaq tonalite, only affected by granulite facies metamorphism in some parts (Allaart *et al.*, 1977), is characterized by a fairly high magnetic level caused by compositional differences between the tonalite and the gneisses. The magnetic anomaly follows the limits of the tonalite along the Ataneq fault in the area between Ilulialik and Isukasia, studied in detail by Mielby & Svendsen (1979), but in the northern part of the Godthåbsfjord the positive anomaly seems to extend southwards across the south-east continuation of the Ataneq fault and out into the fjord.

Smaller isolated anomalies are located over the suite of supracrustal rocks at Ivisârtoq and Isukasia. At Isukasia the arc of supracrustal rocks is clearly delineated by the positive anomalies associated with the banded ironstone. The main ironstone deposit of Isukasia is at the limit of the aeromagnetic map, and here the amplitude of the magnetic residual anomaly is around 30 000 nT at an altitude of 300–400 m over the deposit. The source of the linear anomaly at Ivisârtoq has been shown to be a suite of amphibolites and ultrabasic rocks with magnetite and chlorite (Mielby & Svendsen, 1979). In the Ujaragssuit nunât area similar

anomalies have been detected near other bands of amphibolite, where small occurrences of ultrabasic rocks have also been mapped.

The most common rock types in the Godthåbsfjord area are the Amîtoq (3700 Ma) and Nûk (3000 Ma) gneisses. Field investigations (Thorning, 1978) have shown that these do not differ noticeably in magnetic properties, and consequently the magnetic anomaly map reveals little about the relative distribution of these rock types. In one region of mainly Amîtoq type gneisses between Isukasia and Ivisârtoq the average magnetic level is lower than e.g. that of the dominantly Nûk type gneisses to the south of Ivisârtoq, but this low magnetic level also continues to the north of Isukasia across the Ataneq fault, where the gneiss is of the Nûk type. Thus compositional differences between the Nûk and Amîtoq gneisses of this region are hardly the cause of the anomaly pattern.

An alternative explanation for the fairly high magnetic level over the area of the inner Godthåbsfjord (Nunatarssuaq, Kangiussap nunâ, Kapisigdlit timât) must be sought. The magnetic field is smooth, and the rugged topography with deep fjords and peaks up to 1500 m a.s.l. usually has only a small effect on the magnetic field, indicating that no significant near surface magnetic sources exist. The distribution of anomalies bears little relation to the surface geology with the exception of Qardlit nunât, which is in granulite facies. These observations force the conclusion that the source of the magnetic anomalies is a subsurface body of considerable bulk and extent, perhaps of the same kind as the Taserssuaq tonalite, and that this subsurface magnetic body is absent in the Isukasia–Ivisârtoq area. Deeper levels of intrusions related to the Qôrqt granite may be an alternative explanation. It is also possible that the deep sources of the anomalies are related to the domming of the area south of Ivisârtoq required by Brewer *et al.* (1983) and Chadwick *et al.* (1983) in their structural analysis of the area.

The Qôrqt granite occurs in an elongated area around the Ūmânap suvdlua fjord. A magnetic anomaly with slightly smaller amplitude than the one described in the preceding paragraph covers the same elongated area. A limited number of field measurements of magnetic susceptibilities (Thorning, 1979) did not allow a statistical separation of Qôrqt granite from the Nûk and Amîtoq gneisses based on magnetic susceptibility, but it appears from the aeromagnetic map that the bulk magnetic properties of the Qôrqt granite, including deeper levels of the intrusion, add up to a well defined, albeit small, positive regional anomaly.

The magnetic trend corresponding to the Ataneq fault is well defined between Isukasia and Ilulialik, and further to the south-west there are subtle variations in the magnetic anomaly pattern indicating an extension of the fault in a south-west direction across Godthåbsfjord to the coast of Storø, somewhere north-west of Ūmânaq. The strike is similar to the strike of the Ūmânap suvdlua fjord, and to the mylonite zones of James (1975). Another trend in the magnetic anomalies can be picked up on Storø: a fault with a slightly different strike cuts across the Amîtoq gneiss near the central part of Storø. This aligns perfectly with a magnetic trend going from here in an ENE direction across Kangiussap nunâ to Ivisârtoq, where it is parallel with the fold axial traces of Hall & Friend (1979) or the south-west Ivisârtoq synform of Chadwick *et al.* (1983), separating the magnetically different regions to the north and south. The trend is also parallel with another fault cutting across Ilulialik and the southern part of the exposed Taserssuaq tonalite. This indicates that the geologically mapped lineaments (mylonites, faults and fold axes) may be a partial surface expression of major structures at deeper levels of the crust. The origin of these structures may be related

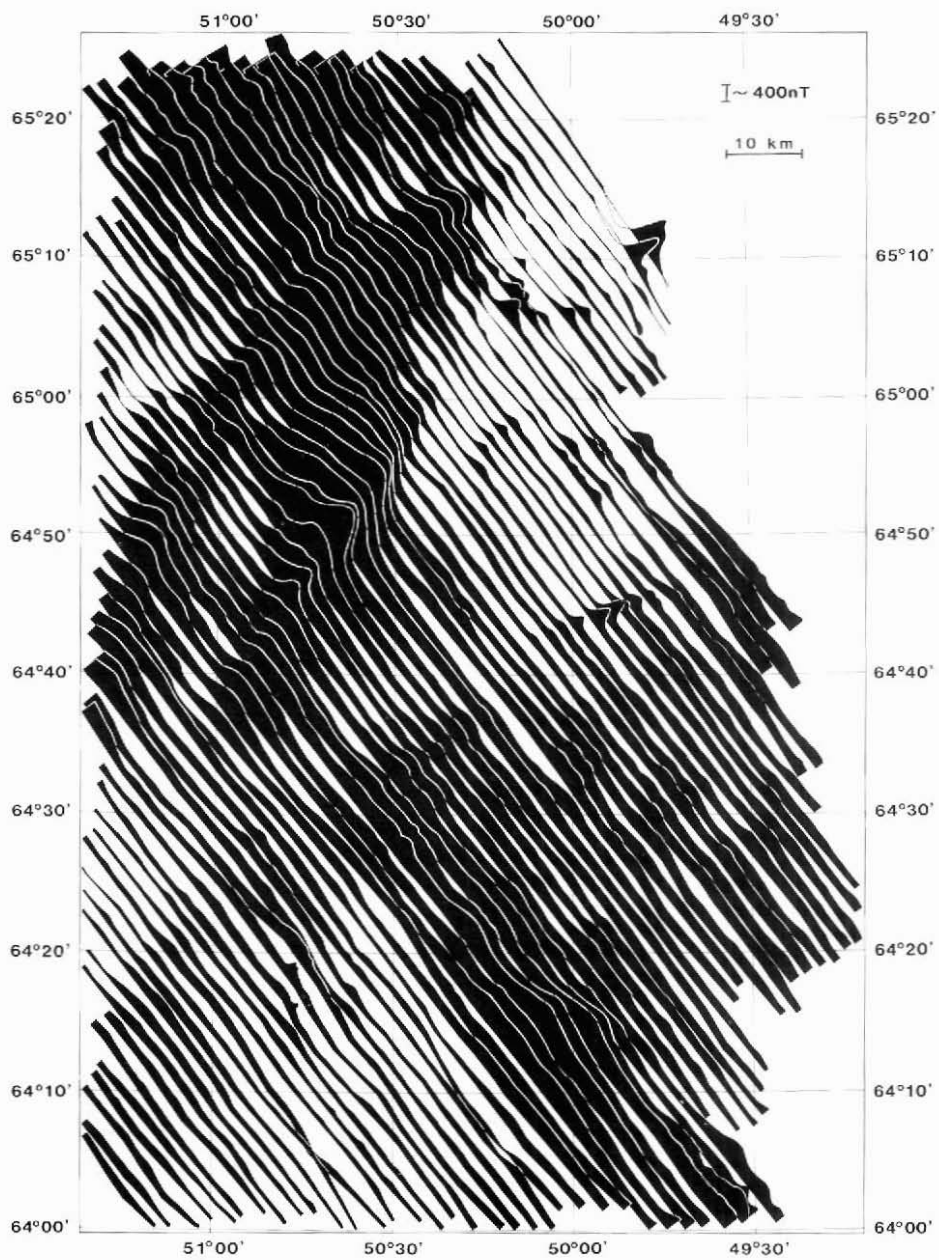


Fig. 15a. Profile map of the Godthåbsfjord survey area.

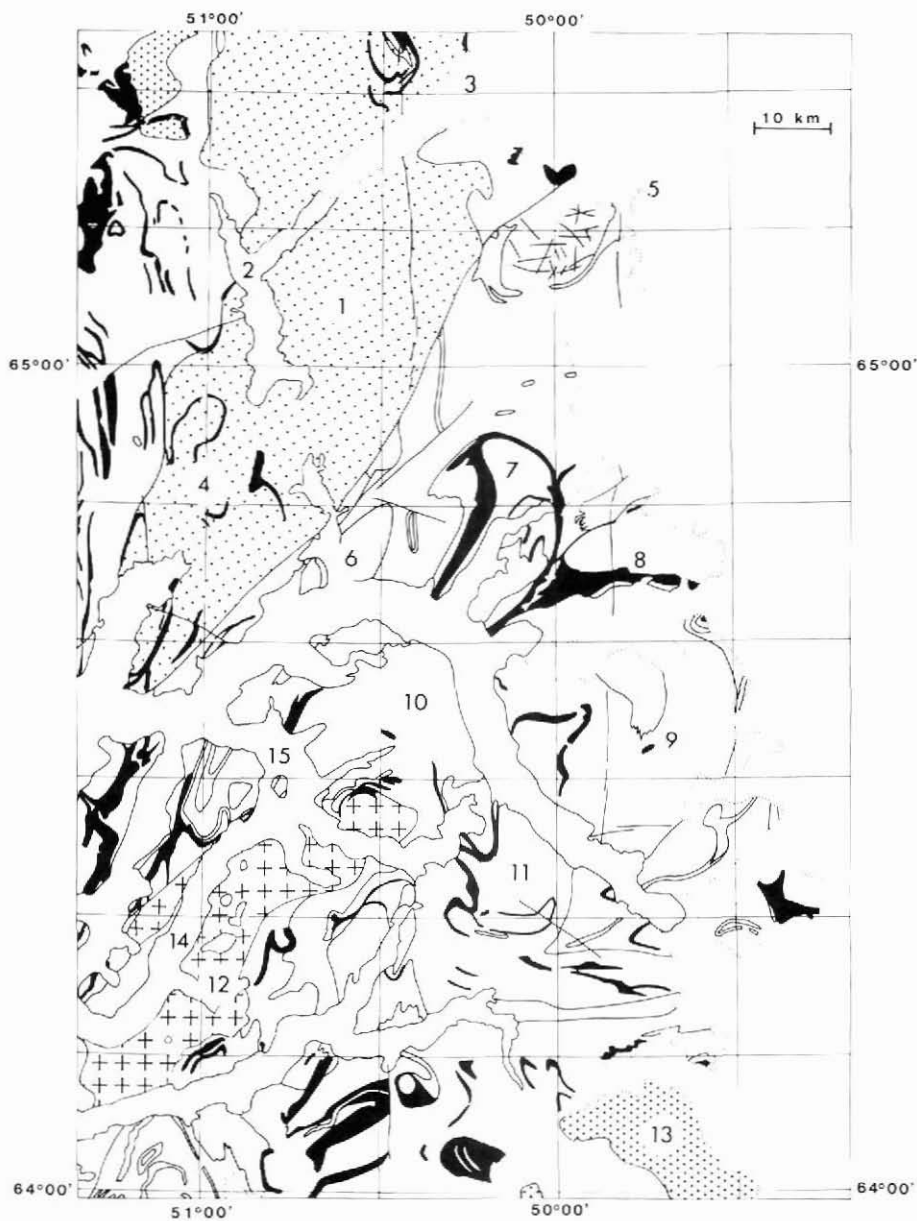


Fig. 15b. Simplified geological map of same area. Numbers show approximate position of localities mentioned in text. 1: Taserssuaq tonalite. 2: Taserssuaq. 3: Sarqap serserssua. 4: Narsarssuaq. 5: Isukasia. 6: Ilulialik. 7: Ujaragssuit nunât. 8: Ivisârtoq. 9: Nunatarssuaq. 10: Kangiussap nunâ. 11: Kapisigdlit timât. 12: Ôórqt granite. 13: Qardlit nunât. 14: Ūmânap suvdlua. 15: Ūmânaq. Altitude

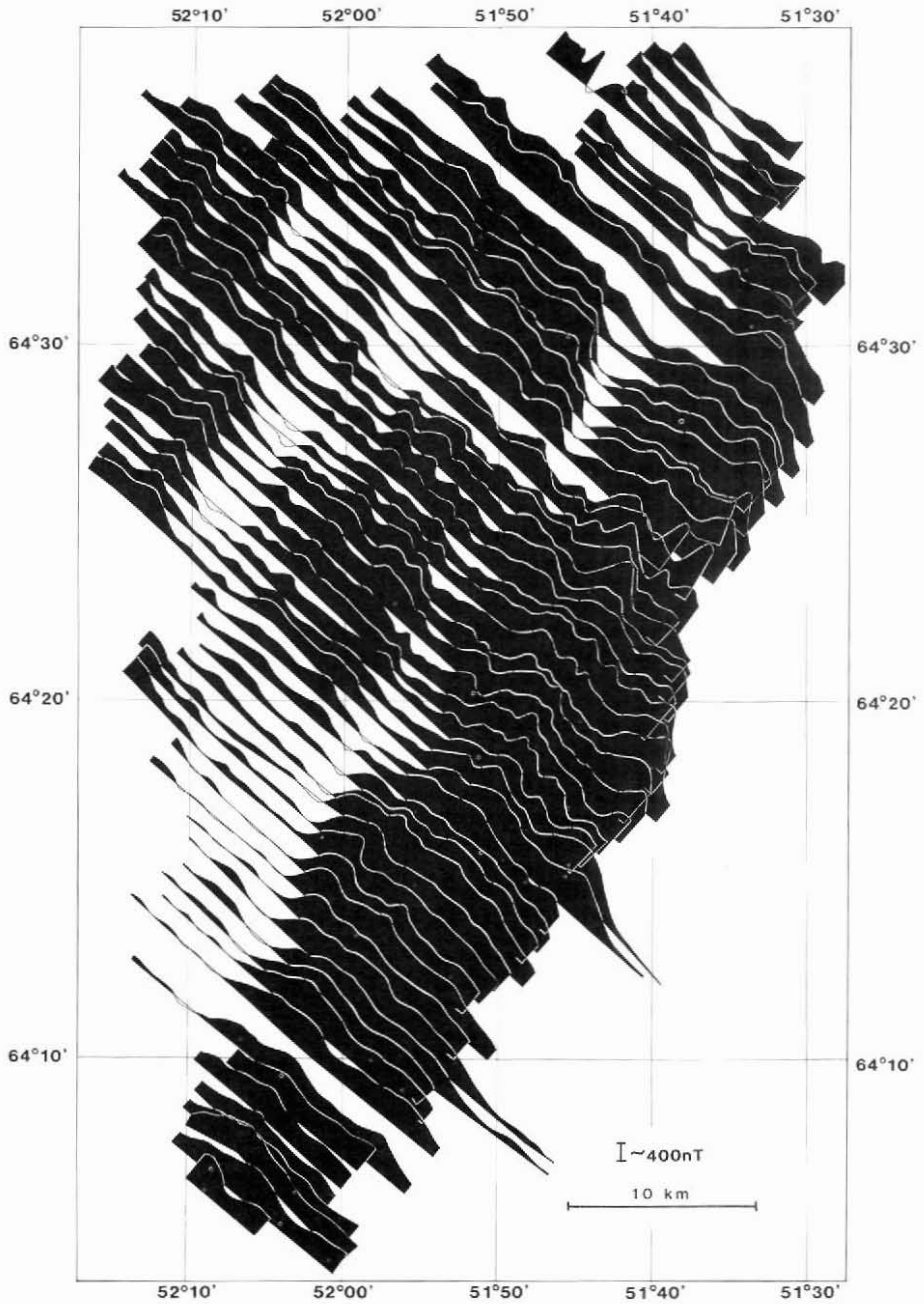


Fig. 16a. Profile map of the Nordlandet survey area.

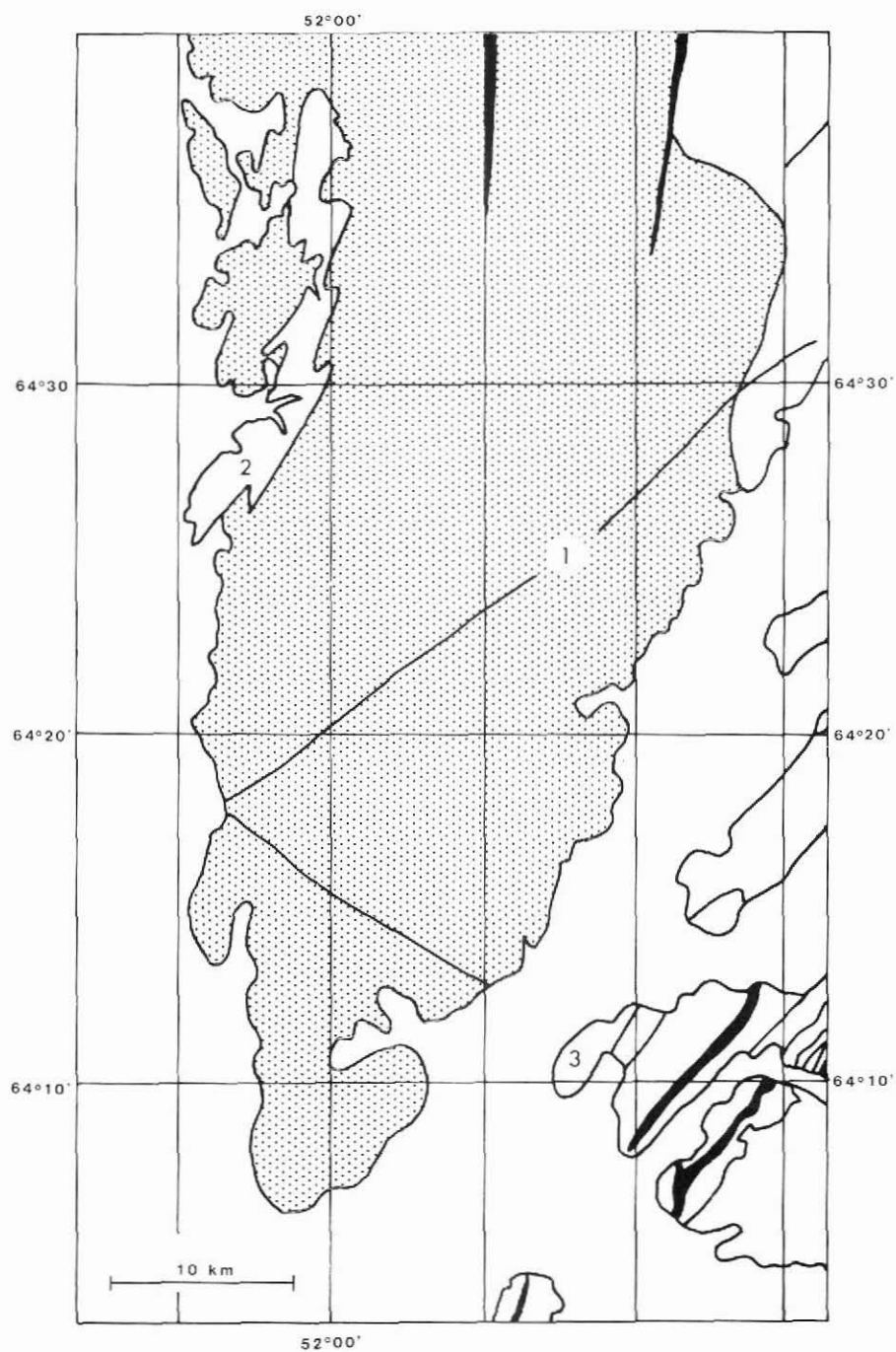


Fig. 16b. Simplified geological map of same area. Numbers show approximate position of localities mentioned in text. 1: Sardlup taserssua. 2: Anorthosite body. 3: Godthåb.

to transcurrent faulting within the West Greenland Archaean craton 2000–1800 Ma ago (e.g. Smith & Dymek, 1983).

### The Nordlandet survey

The part of Nordlandet covered by the aeromagnetic survey is shown on the 1:500 000 geological map to consist almost exclusively of hypersthene gneiss, with the exception of an anorthosite body in the north-west corner of the survey area and Nûk gneiss in the north-east corner. Nevertheless, the relatively detailed aeromagnetic measurements (fig. 16) indicate significant variations in physical properties.

The boundary towards the Nûk gneiss in the north-east corner leaves little trace in the magnetic data indicating that it may be just a thin superficial layer. Along the entire east coast of Nordlandet a major magnetic anomaly exists. It is bordered towards the NNW by an almost linear minimum, and towards the SSE the anomaly disappears 2–3 km away from the coast. The linear band of highly magnetic rock is thus 10–15 km in width. The south-west corner of the survey area is magnetically smoother at a lower level, but no geological explanation is known to account for this. Around 64°25'N, 51°48'W the magnetic anomalies form a pattern, resembling a large 'V' open to the north around a minimum just west of the lake Sardlup taseressua. According to James (1975) an intrusive elliptical granite body here forms the core (at the magnetic minimum) of a domal antiform. The V-shaped anomaly reflects variations or folds in the gneiss, and the same trend can be seen further to the north-west. Many details are visible in the north-west corner of the survey area mapped as variable granulite facies gneiss (Garde & McGregor, 1982). Static retrogression to amphibolite facies occurs locally. Thus, the aeromagnetic field over Nordlandet reflects quite subtle variations in the composition and metamorphic state of the gneisses, and therefore provides a means for their mapping. The anorthosite body in the north-west part of the survey area is revealed by a magnetic minimum and an associated linear maximum to the north-west of this. The minimum is less well developed over the northern part of the anorthosite body.

The dominating magnetic trend on Nordlandet is NNE–SSW. This is also the trend of the mylonite zones described by James (1975).

## CONCLUSIONS

The discussion in the previous section has been qualitative. More information is, of course, contained in the data, and detailed results will be reported elsewhere. Whereas a number of conclusions concerning specific geological problems have been stated in the discussion, conclusions of a more general type are summarized below.

(1) Aeromagnetic anomalies can be used to map various rock units defined in terms of different composition (e.g. the Taseressuaq granodiorite) or in terms of tectonic-metamorphic processes (e.g. structures in the Nagssugtoqidian mobile belt). This difference in magnetic pattern has recently been used in a successful attempt to map the course of geological units across the Inland Ice to the east coast of Greenland (Thorning *et al.*, 1984).

(2) Metamorphic facies boundaries play an important role for the pattern of aeromagnetic anomalies, and it has been demonstrated that the type of facies boundary has an influence on the details in the magnetic expression. However, it still remains to be analysed how details in

the original rock compositions and in the metamorphic process, e.g. retrogressive or progressive, influence the content of magnetic minerals, and what is the relative importance of coincident metamorphic and tectonic boundaries.

(3) Shear zones of various types can be mapped over large distances by these aeromagnetic patterns. Subsurface expressions of such zones are also visible in the magnetic data, and this allows correlation of the partial expressions of these structures mapped at the surface. There are indications that such zones are numerous in the Archaean craton.

(4) In some cases the aeromagnetic data reveal local features, some of direct economic interest, e.g. the Sarfártoq and Qaqarssuk carbonatites and the Isukasia banded ironstone. Further detailed geophysical and geological work is nearly always necessary over such local features because of the regional character of the aeromagnetic data acquired.

(5) The aeromagnetic data are thus a useful addition to the geological mapping, and it would be worth while in the future to combine aeromagnetic surveying and geological mapping more closely, as the two methods are complementary.

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# AEROMAGNETIC ANOMALY MAP OF GREENLAND

(64°N - 68°15'N, 49°W - 54°W)

1:500 000

Compiled by L. Thorning  
The Geological Survey of Greenland  
Copenhagen, Denmark

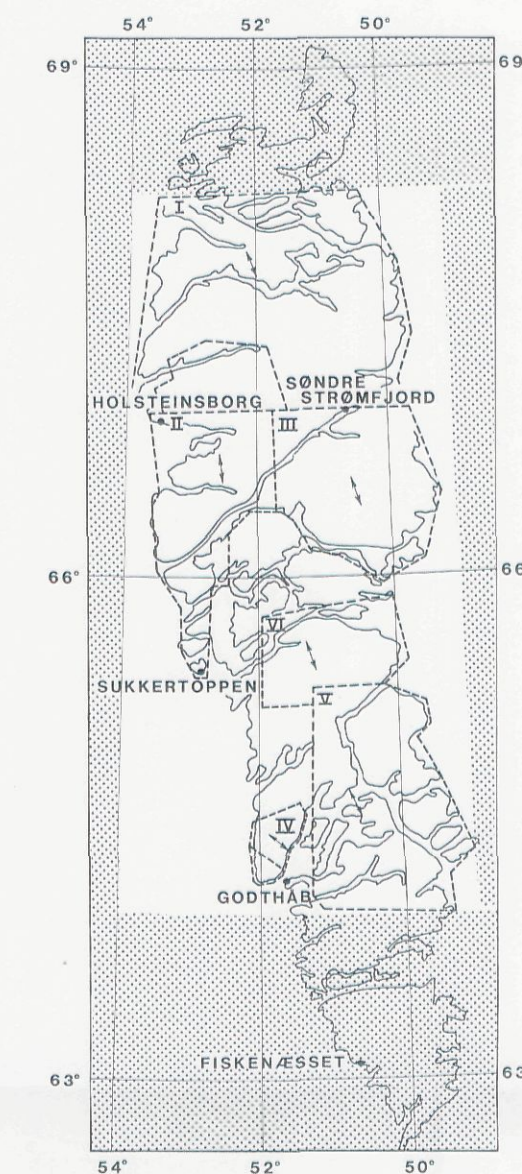
The map is based on data acquired in 1975 and 1976 by the Geological Survey of Greenland (GGU) using a Geometrics G-801 proton precession magnetometer, stinger mounted in a Britten-Norman Islander aircraft.

The magnetic anomaly map contains data from several separate surveys. No attempt has been made to remove discontinuities in the magnetic field between the various areas. Survey specifications are shown in the table and index map below.

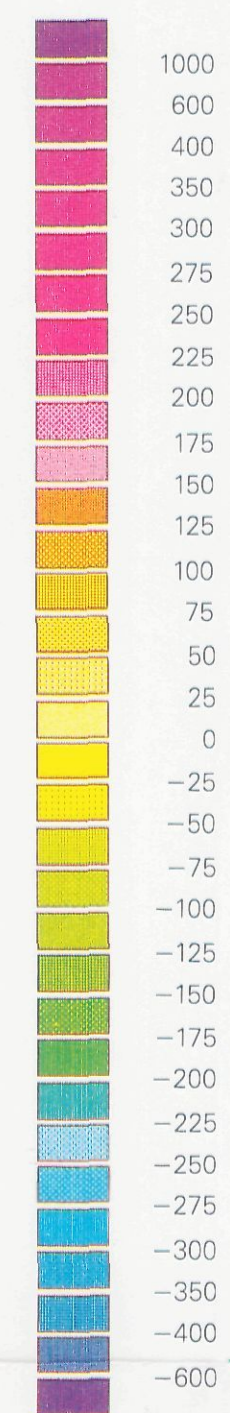
Area	Altitude (m a.s.l.)	Flight line spacing (km)
I	915	1.5
II	1830	2.0
III	915-1830	1.5
IV	450	1.0
V	1525	2.0
VI	1525	2.0

The magnetic data within each area has been corrected using tie lines and ground station magnetometer data (GGU, Søndre Strømfjord), and the International Geomagnetic Reference Field (1975 coefficients) has been subtracted.

For further information, see Thorning (1984): 'Aeromagnetic maps of parts of southern and central West Greenland: acquisition, compilation and general analysis of data.' Copenhagen, the Geological Survey of Greenland.



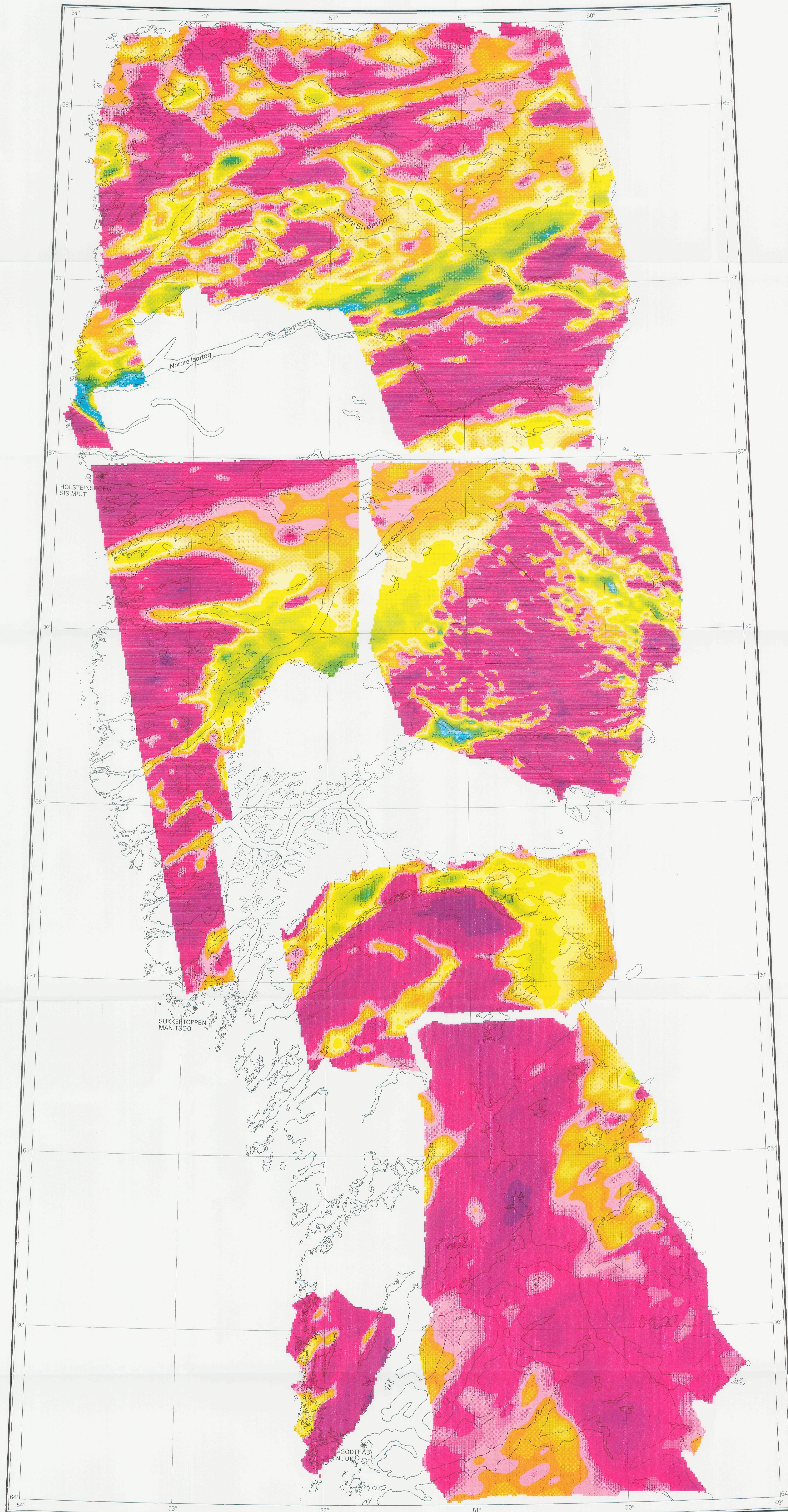
nanotesla



1:500 000



Map projection: Lambert conformic conic, standard parallel 66°10' N, scale factor 0.99966.  
Ellipsoid: International Hayford, Earth's radius 6378388 m, flattening 1/297, Datum: Densmod.  
Topography from maps of the Geodetic Institute, Copenhagen, with permission A 495/79.  
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