

Aeromagnetic survey in central West Greenland: project *Aeromag 2001*

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The series of government-funded geophysical surveys in Greenland was continued during the spring and summer of 2001 with a regional aeromagnetic survey north of Uummannaq, project *Aeromag 2001* (Fig. 1). The survey added about 70 000 line kilometres of high-quality magnetic measurements to the existing database of modern airborne geophysical data from Greenland. This database includes both regional high-resolution aeromagnetic surveys and detailed surveys with combined electromagnetic and magnetic airborne measurements.

High-quality magnetic data are now available for all the ice-free area of West and South Greenland from the southern tip of Greenland to Upernavik Kujalleq/Søndre Upernavik (Fig. 1). The total surveyed area with high-resolution magnetic data is 250 000 km² and corresponds to a total of 515 000 line kilometres. Detailed surveys with combined electromagnetic and magnetic measurements were carried out in six separate surveys in selected areas of high mineral potential during project *AEM Greenland 1994–1998*, a total of 75 000 line kilometres. Descriptions of the previous surveys can be found in Thorning (1993), Stemp & Thorning (1995), Thorning & Stemp (1996, 1998), Stemp (1997), Rasmussen & Thorning (1999), Rasmussen & van Gool (2000) and Rasmussen *et al.* (2001).

The primary objective of the government-funded airborne geophysical programme is to provide the industry and the geoscientific community with modern data that are relevant to the exploration for mineral resources and for the general understanding of the geology of Greenland. Most of the previous surveys have covered onshore areas. However, the survey in 2001, like the survey in 1997 in the Disko Bugt region, also included significant offshore areas. Approximately one third of the 2001 survey region is offshore, and includes an area well known for its hydrocarbon potential (Christiansen *et al.* 1995, 2000).

The *Aeromag 2001* survey block in central West Greenland extends between latitudes 70°30' and 72°12' N, covering the entire ice-free land area together with a part of the offshore area and the border of the

Inland Ice (Figs 1, 2). The 2001 survey was flown for the Bureau of Minerals and Petroleum, Government of Greenland by Sander Geophysics Ltd, Ottawa from late May to mid-September. The project was supervised and managed by the Geological Survey of Denmark and Greenland (GEUS).

The field operation was based at Qaarsut airport as was the magnetic base station utilised for correction of magnetic diurnal variations. Details of the survey operation and equipment can be found in a report by Sander Geophysics Ltd (2002).

Products

The survey was carried out by flying along a gently draped surface 300 m above the ground and sea level. Survey lines were aligned in a N–S direction with a separation of 500 m. Orthogonal tie-lines were flown with a separation of 5000 m. Total magnetic field data were recorded with a sampling rate of 0.1 sec which corresponds to a sampling distance of 7 m. The magnetic field at the base station was recorded with a 0.5 sec sampling rate. Aircraft positional data from GPS (Global Positioning System) measurements were recorded with a 1 sec sampling rate, and aircraft altitude measurements obtained from barometric altimeter and radar were recorded with a sampling rate of 0.25 sec. A continuous video-tape record of the terrain passing below the aircraft was made.

In addition to the line data obtained from the measurements, maps at scales 1:250 000 and 1:50 000 have been produced by interpolation and gridding of the measured data. Vertical gradient data of the magnetic total field were calculated from the gridded magnetic total field data. Altogether five new maps (magnetic total field intensity, associated vertical gradient, shadow of the total magnetic intensity, combined shadow and colour of magnetic total field intensity and topography) at scale 1:250 000 of the entire survey area and three sets of maps (colour and contours of magnetic total

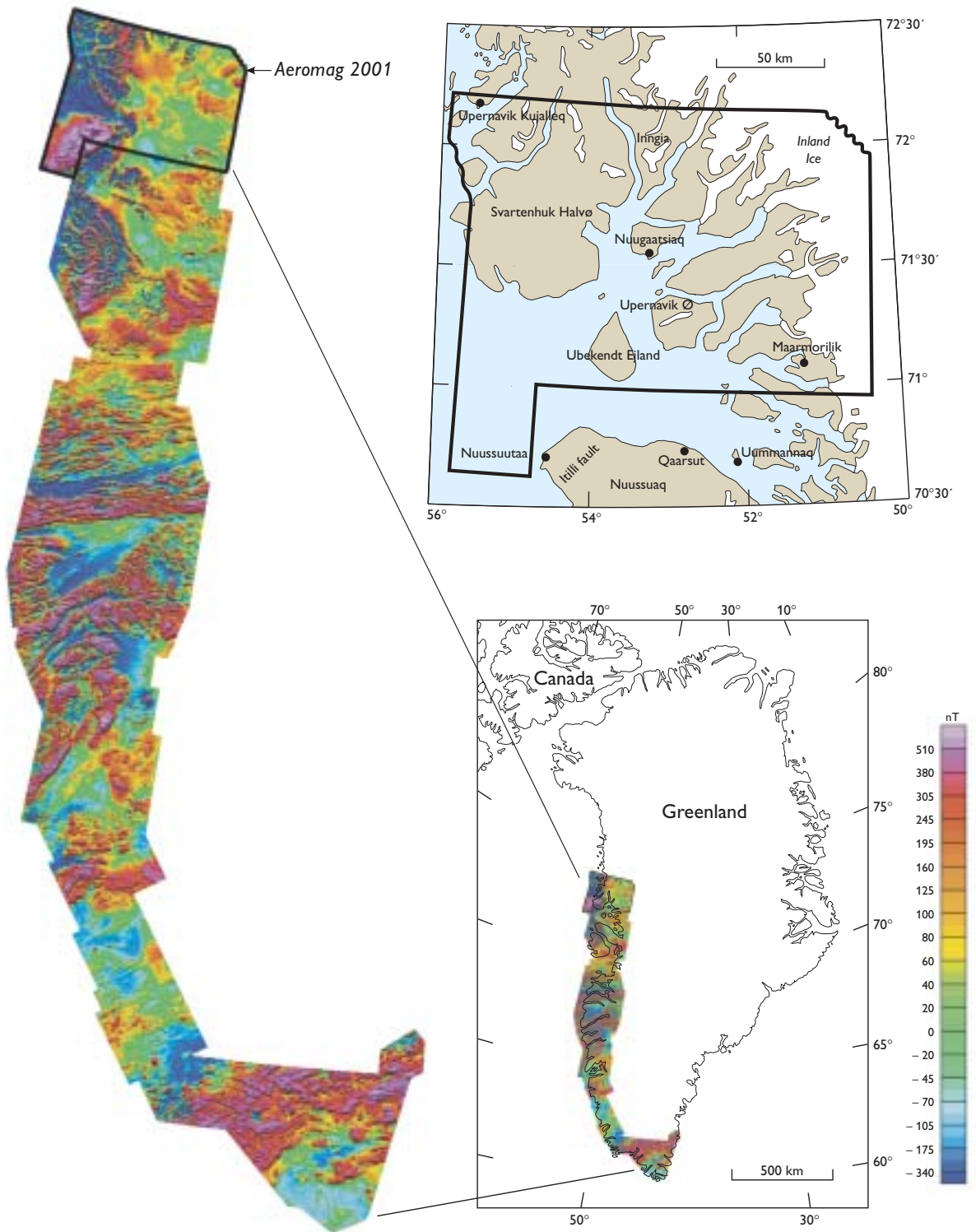


Fig. 1. Coverage of government-financed aeromagnetic surveys in western Greenland during the period 1992–2001. The location of the aeromagnetic survey in 2001 is circumscribed by a **black line**.

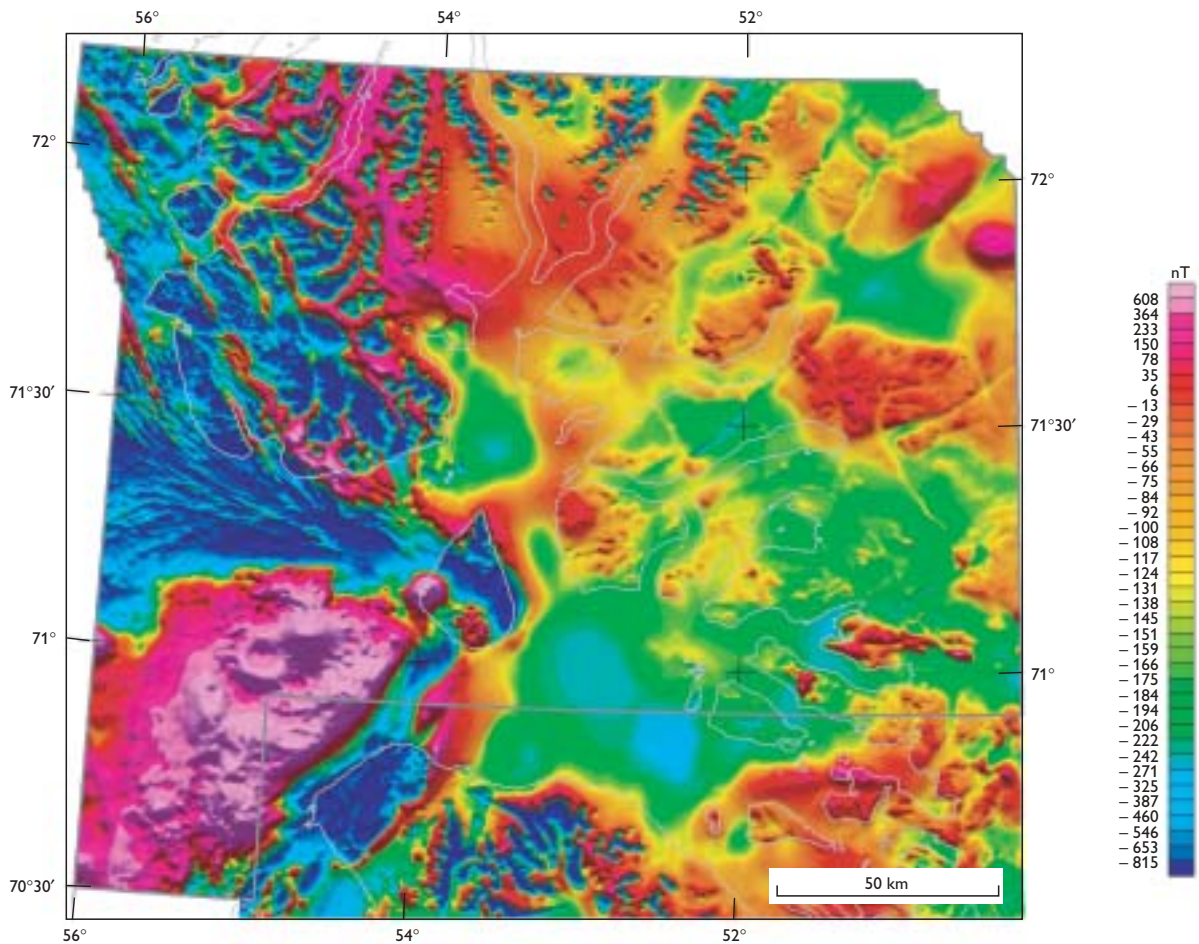


Fig. 2. Magnetic total field intensity with shaded relief for the area in central West Greenland covered by project *Aeromag 2001*. The location of the aeromagnetic survey in 2001 is circumscribed by a **grey line** and the new data have been merged with data from project *Aeromag 1997*.

field intensity and flight path) each comprising 32 sheets at scale 1:50 000 are included in the map series.

The gridded magnetic total field data from *Aeromag 2001* are shown in Fig. 2. The data have been merged with those from the *Aeromag 1997* project. The International Geomagnetic Reference Field corresponding to the date of measurement has been subtracted from the data. Shaded relief data, superimposed on the magnetic total field data, have been modelled by using a light-source illumination from north with an inclination of 45°. The magnetic anomalies are in the range from -2500 to 2000 nT. The calculated vertical gradient of the magnetic total field is shown in Fig. 3 for the merged data set. Some implications of the new geophysical data for the interpretation of the geology are given below after a short introduction to the geology.

Geology of the surveyed area

Five geological maps at scale 1:100 000 have been published of the surveyed area by the Survey; a descriptive text for three of the map sheets is given by Henderson & Pulvertaft (1987). The surveyed area between Uummanaq and Upernavik Kujalleq/Søndre Upernavik comprises Archaean crystalline basement rocks overlain by a several kilometres thick succession of Palaeoproterozoic supracrustal rocks; they are intruded by a Palaeoproterozoic granitic complex. Minor units of down-faulted Cretaceous sediments occur, and Palaeogene plateau basalts are prominent onshore and offshore. The Precambrian rocks have been correlated with similar rocks on Baffin Island in Canada, and were folded and metamorphosed during the Hudsonian

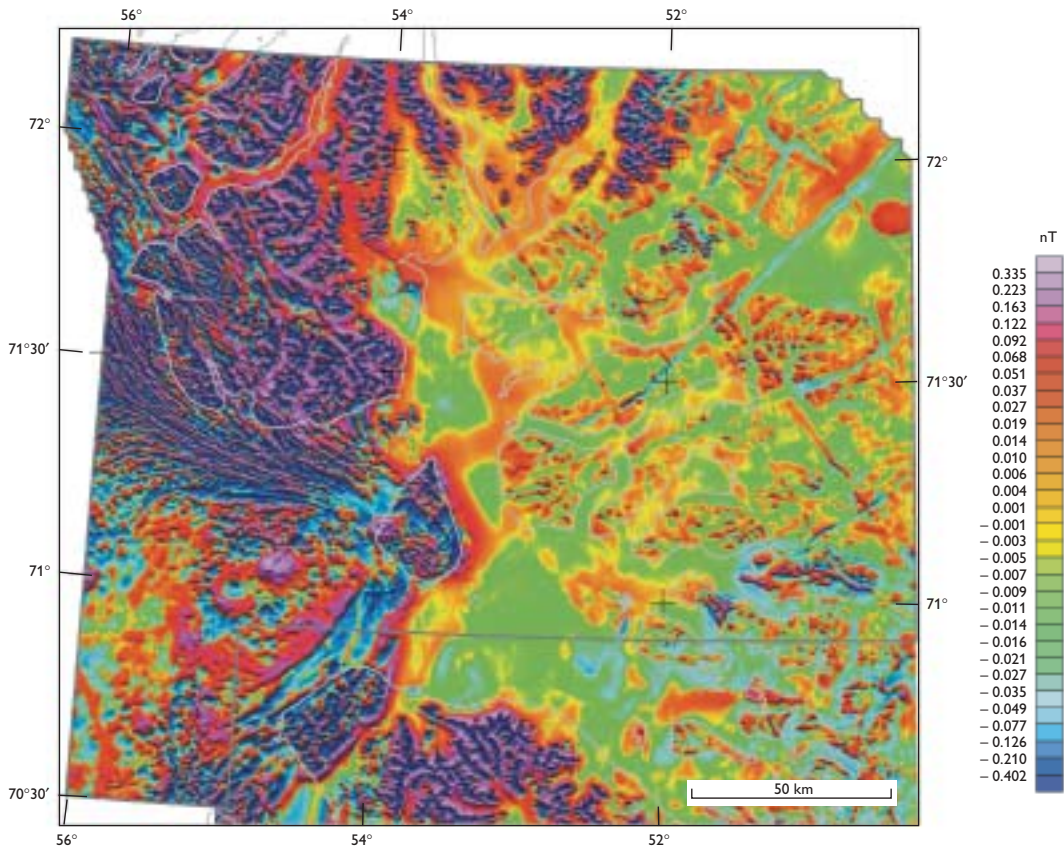


Fig. 3. Calculated vertical gradient of the total magnetic field intensity with shaded relief for the area in central West Greenland covered by project *Aeromag 2001*. The location of the aeromagnetic survey in 2001 is circumscribed by a **grey line** and the new data have been merged with data from project *Aeromag 1997*.

orogeny at around 1.85 Ga, and intruded by a 1.65 Ga old swarm of dolerite dykes.

The Palaeoproterozoic metasediments (the Karrat Group) host the now exhausted Black Angel Pb-Zn ore bodies (13.5 mill. tonnes ore at 4.0% Pb and 12.3% Zn) which were mined from 1973–1990. Similar marble-hosted lead-zinc occurrences at other localities indicate an additional potential for this type of mineralisation. The clastic facies of the Karrat Group include extensive sulphide facies iron formation and vein-type base and precious metals mineralisation, and offer a potential for shale-hosted massive sulphides and turbidite-hosted gold-bearing veins and shear zones (Thomassen 1992).

The Karrat Group crops out within the Rinkian Belt of central West Greenland, a region that is characterised by gneiss domes and fold nappes with sheath-like geometry and flat-lying axial surfaces that affect both Archaean basement gneisses and the Palaeoproterozoic Karrat Group. Grocott & Pulvertaft (1990) identified seven

phases in the tectonic evolution of the region, of which three involve extension and four compression.

The southern and south-western part of the surveyed region preserves extensive areas of Palaeogene volcanic rocks, related to the plate break-up between Greenland and Baffin Island. These volcanic rocks represent, together with similar volcanic rocks on the Canadian side of Davis Strait and on the east coast of Greenland, the results of mantle plume activity along the track of the present Iceland mantle plume (Storey *et al.* 1998). In the surveyed area volcanic activity started in mid-Paleocene time with deposition of the Vaigat Formation. The earliest volcanics were extruded below sea level as hyaloclastite breccias, while most later volcanism was subaerial. The Vaigat Formation is dominated by picritic and other olivine-rich tholeiitic basalts; it is between 0 and 3 km thick on Svartenhuk Halvø and more than 5 km thick on Ubekendt Ejland (Hald & Pedersen 1975). In the northern part of the basalt-

covered area, the Vaigat Formation was followed by deposition of about 50 m of fluvio-lacustrine sediments and hyaloclastite breccias. The succeeding volcanic rocks of the Svartenhuk Formation are characterised by plagioclase-porphyratic and aphyric basalts, and have a minimum thickness of 2.8 km. Determinations of the magnetic palaeodirection and palaeointensity from samples of the Vaigat Formation at Nuussuutaa on Nuussuaq have been presented by Riisager & Abrahamsen (1999) and Riisager *et al.* (1999). The lower part of the Vaigat Formation (the Anaanaa Member and part of the Naujánguit Member) has normal magnetisation (C27N), whereas the upper part of the Vaigat Formation is reversely magnetised. Palaeomagnetic data for the Maligât Formation on Nuussuaq, a stratigraphic equivalent to the Svartenhuk Formation, yielded reverse magnetisation directions; a detailed chronostratigraphy has not yet been established. The Palaeogene volcanics are characterised by units of strongly reduced lavas with native iron, indicating a potential for Norilsk-type nickel-copper-PGM in the plateau basalt areas.

Magnetic anomaly maps and geological implications

The geophysical data illustrated in Figs 2 and 3 are considerably simplified representations of the original data sets, but major anomalies can be discerned. Onshore, six sub-parallel linear anomalies striking NNW–SSE cross the entire survey area. Some of these coincide with the locations of mapped Mesoproterozoic mafic dykes of the Melville Bugt dyke swarm (Nielsen 1987). The dolerite dykes and thin layers of hornblende schist and amphibolite at many inland locations (Henderson & Pulvertaft 1987) are seen very clearly in the magnetic response.

Elongated anomalies with variable strikes between 40–65° and with distinct minimum magnetic total field values are visible in the eastern half of Figs 2 and 3. These structures, many in areas covered by ice, appear not to have been deformed, which implies that they are younger than the Rinkian orogeny. Of the five anomalies of this type, the most prominent is a NE–SW feature with its south-western termination at Upernivik Ø. This anomaly may be an extension of the Itilli fault that crosses the westernmost part of Nuussuaq, and is marked by a sharp transition between positive and negative magnetic total field anomaly values. However, none of these anomalies have so far been correlated with any confidence with known geological structures. The amplitudes of the anomalies are in the order of –150 nT and

may have a magnetisation direction opposite to the present geomagnetic field direction.

The Palaeogene basalts dominate the magnetic response in the coastal region and the offshore part of the survey. Differences in polarities of the basalts are clearly defined by the low magnetic field values on Svartenhuk Halvø and the positive values west of Nuussuaq. On Ubekendt Ejland both the acid tuff/ignimbrite mapped on the western part of the island and the granite intrusion on the southern part are associated with positive magnetic anomalies.

A distinct pattern of elongated, arcuate anomalies is dominated by low magnetic values. A similar anomaly pattern is not visible in the area with high magnetic field values. Comparison with mapped faults and dykes on Svartenhuk Halvø (Larsen & Pulvertaft 2000) shows an excellent correlation between the magnetic lineaments and geologically mapped structures, e.g. dykes and presumed non-exposed dykes associated with faults. However, basalt with normal magnetisation at depth in conjunction with vertical displacement along faults may also contribute to the anomalies. Topographic effects clearly contribute to the anomaly pattern, but are not sufficient to explain the anomalies. The distinct differences in anomaly pattern between areas with positive and negative magnetic anomaly values may be a result of difference in: (1) rheology due to difference in thermal state and pressure at the time of magmatic activity; (2) crustal composition; (3) volcanic source type. Firstly, the time span between the eruption of two different magma types may have been sufficiently long that the thermal state and pressure in the crust may have changed, leading to a difference in eruption style and in the amount of dyke intrusion. Secondly, the initial composition of the crust at the location of the magnetic high may have been unfavourable for the creation of faults and intrusion of dykes. Thirdly, the basalt region with reverse magnetisation may be an amalgamation of lavas from numerous eruptions with limited flow distances whereas the basalt with normal magnetisation may represent episodes with flows of a much larger extent. The magnetic data alone are not conclusive with respect to which of the three interpretations are correct. Establishment of age relationships between the two types of basalts is essential for a reliable interpretation. In particular, if the basalt of the area with high magnetic field values was extruded after the basalt causing low magnetic values, a mechanism must be found that explains why none of the elongated anomalies within the area of low magnetic intensity are truncated by basalts with normal magnetisation.

Conclusions

The aeromagnetic survey has revealed a number of regional anomalies that must be accounted for when interpreting the geology of the region. Some of the major structures seen on the map of the magnetic total field intensity do not correlate with geologically mapped structures, and further geological and geophysical mapping, offshore as well as onshore, is necessary in order to gain more insights into the structural development of the area.

This paper has focused mainly on anomalies of regional extent. Many local anomalies can be identified, but interpretation requires a thorough modelling of topographic effects. A discussion of these anomalies and their implications for mineral prospecting in the region will be presented elsewhere.

Acknowledgements

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