Aeromagnetic survey in southern West Greenland: project Aeromag 1999

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The acquisition of public airborne geophysical data from Greenland that commenced in 1992 continued in 1999 with project *Aeromag 1999*, an aeromagnetic survey of part of southern West Greenland. This paper presents results of the aeromagnetic survey and discusses the correlation of the measured data with the previously mapped surface geology.

The project was financed by the Government of Greenland and managed by the Geological Survey of Denmark and Greenland. Sander Geophysics Ltd., Ottawa, Canada, was selected in April 1999 as the contractor for the project through a European Union open-tender procedure.

With the completion of the *Aeromag 1999* project, a total of approximately 445 000 line km of regional high-resolution magnetic data and approximately 75 000 line km of detailed multiparameter data (electromagnetic, magnetic and partly radiometric data) are now available from government-financed projects. Figure 1 shows the location of the surveyed areas with various types of high-resolution geophysical data. Information on the previous surveys (in 1992 and 1994–1998) can be found in Thorning (1993), Stemp & Thorning (1995), Thorning & Stemp (1996, 1998), Stemp (1997) and Rasmussen & Thorning (1999).

The 1999 survey block is between latitudes 65°40´N and 68°20´N covering the entire ice-free land from the Inland Ice to the outer coast. The survey covers an area with Archaean and Proterozoic crystalline rocks, including the southern part of the Nagssugtoqidian orogen and its southern foreland. The initial plan for the survey included approximately 75 000 line km between latitudes 65°40´N and 67°15´N. In August 1999 during flying operations, it was decided to extend the survey to the north so that the entire region between the 1992 and 1998 survey areas was covered (Fig. 1). In total, 141 000 line km were flown corresponding to a 46% increase of regional high-resolution magnetic data from Greenland.

Details of the 1999 survey

Sander Geophysics Ltd. flew the survey between 17 May and 6 September 1999, using two geophysically

Fig. 1. Location of government-financed high-resolution airborne geophysical surveys in the period 1992–1999. Aeromagnetic surveys (Aeromag) are outlined in **red** and combined electromagnetic and magnetic surveys (AEM Greenland) are outlined in **green**. Slightly modified from Rasmussen & Thorning (1999).

equipped Cessna Grand Caravan aircraft operating out of the airport at Kangerlussuaq (Fig. 1). The magnetic base station utilised for correction of magnetic diurnal variations was also at Kangerlussuaq. Details on the survey operation and equipment can be found in a report by Sander Geophysics Ltd. (1999).

The measurements were carried out by flying along a gently draped surface 300 m above the ground. The survey lines were aligned in a N–S direction with a separation of 500 m while 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 differential GPS 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 is available.

In order to facilitate merging of the 1999 data set with data from the adjacent survey blocks, there is an overlap at the southern and northern boundaries over a distance corresponding to five minutes of an arc. The southern part overlaps the areas covered in projects *Aeromag 1998* and *AEM Greenland 1995*; the northern part overlaps the area surveyed in project *Aeromag 1992* (Fig. 1). In addition to this overlap, two N–S-oriented lines and one intersecting E–W line were flown over the area covered in the 1992 survey. The purpose of these additional lines is to further help in data integration with the 1992 survey, which was flown at an altitude 500 m above ground and with a 1000 m line spacing. Like the rest of the 1999 flying these additional lines were flown at an altitude of 300 m above ground.

Results and products

In addition to the line data obtained from the measurements, map sheets at scales 1:250 000 and 1:50 000 have been produced from interpolation and gridding of the measured data. Vertical gradient data of the magnetic total field have been calculated from the gridded magnetic total field data. For each of the two sheets at 1:250 000, five maps are available showing the following parameters: magnetic total field intensity, associated vertical gradient, shadow of the total magnetic intensity, combined shadow and colour of magnetic total field intensity and topography, while three maps showing colour, contours of magnetic total field intensity and flight path are available for each of the 60 sheets at 1:50 000.

Figure 2 shows the gridded magnetic total field data that were obtained from the 1999 survey. The International Geomagnetic Reference Field corresponding to the date of measuring 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 inclination of 45 degrees and a declination from the north-west direction. The magnetic anomalies are in the range from –1000 nT to 2000 nT.

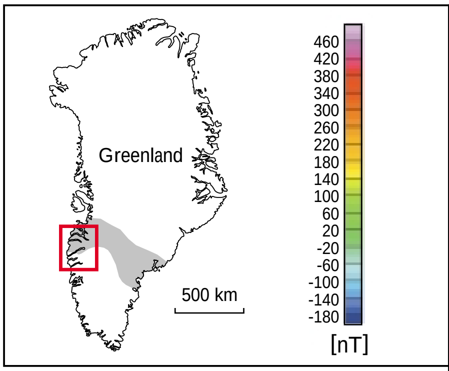
Release of data

Completion of the *Aeromag 1999* project was marked by the release of data on 1 March 2000. The data are included in the Survey's geoscientific databases for public use; digital data and maps may be purchased from the Survey.

Correlation with surface geology

The aeromagnetic data in Fig. 2 closely correlate with the surface geology of the surveyed region as shown on the schematic geological map in Fig. 3. The 1999 survey covers most of the Nagssugtoqidian orogen and part of its southern foreland. The Nagssugtoqidian orogen consists predominantly of reworked Archaean gneisses with minor supracrustal rocks and Palaeoproterozoic intrusives. All rocks of the orogen were metamorphosed under upper amphibolite to granulite facies conditions, while the Archaean gneisses in the southern foreland escaped the Nagssugtoqidian metamorphic overprint and have preserved their Archaean granulite facies mineralogy. Prior to Nagssugtoqidian orogenesis, the foreland and the southern segment of the orogen were invaded by mafic dykes of the NE–SW-trending Kangâmiut dyke swarm. The subdivision of the orogen, as defined by Marker *et al.* (1995), into northern, central and southern segments (NNO, CNO and SNO, respectively; see Fig. 3) and a southern foreland is clearly reflected in the magnetic anomalies. The different domains within these segments and different boundary features are also evident.

The *Northern Nagssugtoqidian orogen* (NNO) is characterised by a rather irregular pattern of magnetic anomalies containing short segments with a predominant E–W linear trend. The *Nordre Strømfjord steep belt* (van Gool *et al.* 1996; Hanmer *et al.* 1997) – previously the *Nordre*



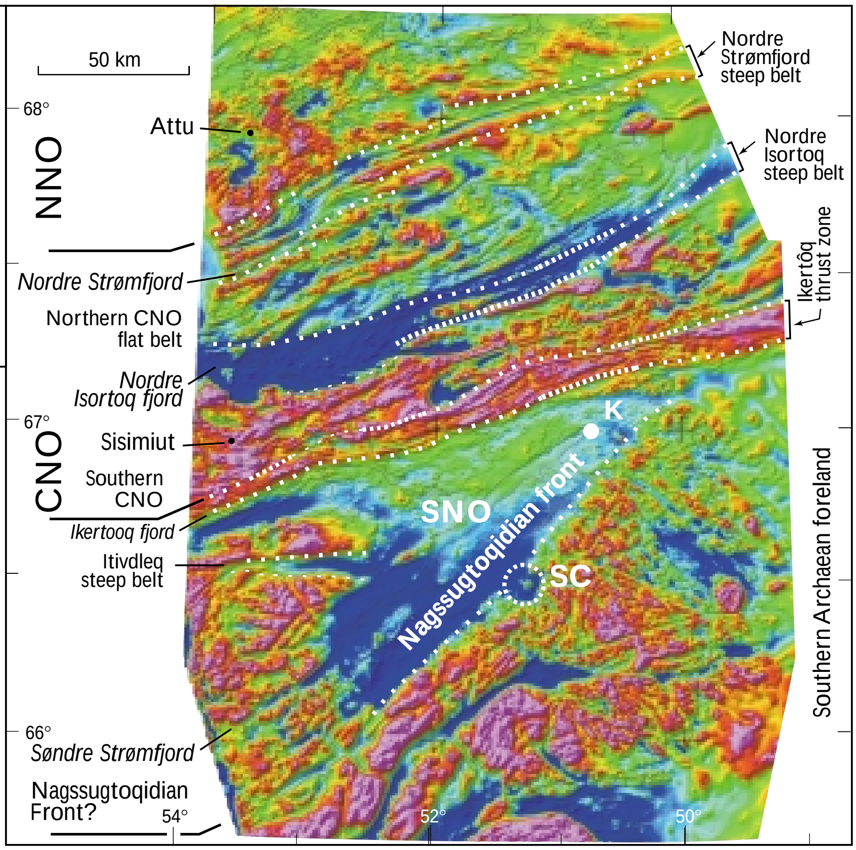
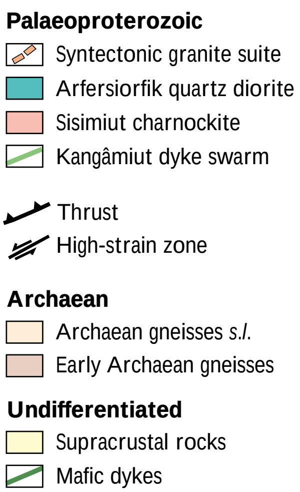


Fig. 2. Magnetic total-field intensity with shaded relief for the region covered by project *Aeromag 1999*. Obtained magnetic anomalies are in the range –1000 nT to 2000 nT. **Dotted lines**: boundaries of the segments and belts of the Nagssugtoqidian orogen as discussed in the text, **closely spaced dots** indicate boundaries mapped in the field, **wider-spaced dots** indicate extrapolations based on the aeromagnetic data. For explanation of **NNO**, **CNO** and **SNO** see Fig. 3. **SC**: Sarfartoq carbonatite; **K**: Kangerlussuaq airport. **Shading** on the inset map shows the regional extent of the Nagssugtoqidian orogen.



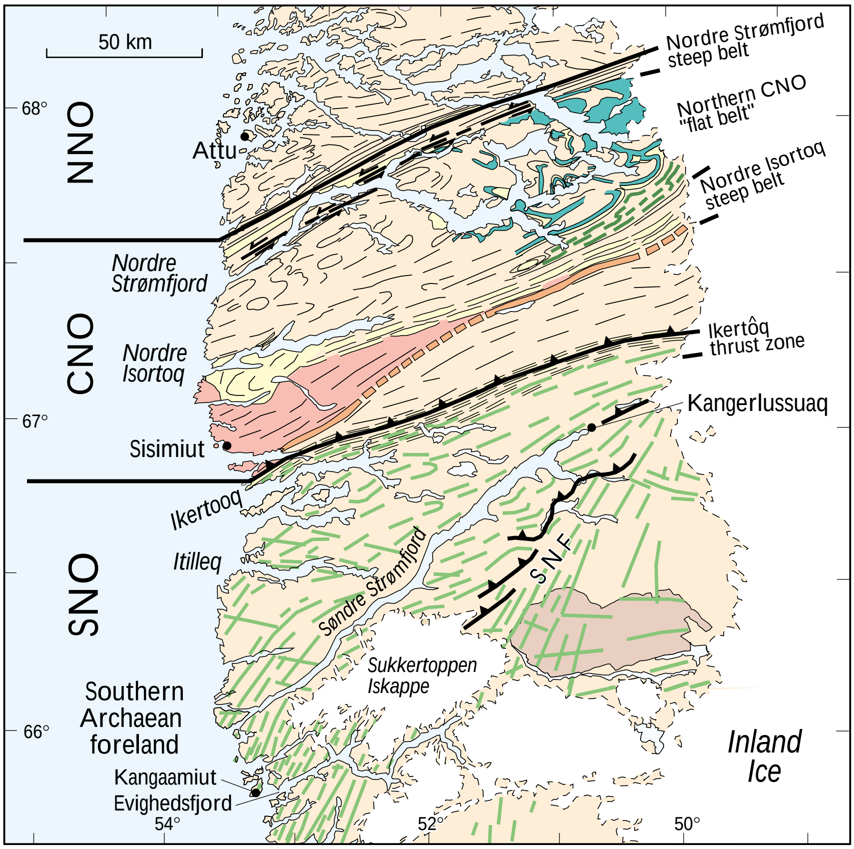


Fig. 3. Lithotectonic sketch map of the Nagssugtoqidian orogen and its southern foreland, modified from Mengel *et al.* (1998). **NNO**, **CNO** and **SNO**: northern, central and southern Nagssugtoqidian orogen, respectively (as in Fig. 2). **SNF**: southern Nagssugtoqidian front. For location and regional extent of the Naqssugtoqidian orogen, see inset map of Fig. 2.

Strømfjord shear zone of Bak *et al.* (1975) and Sørensen (1983) – forms the southern boundary of the NNO. This belt stands out as a set of sharp, ENE–WSW lineaments along which structures entering the belt from both the south and the north are transposed into the strike of the belt, conforming with a sinistral strike-slip motion. The magnetic data also show that the steep belt consists of several discontinuous, sinistrally side-stepping lineaments, each representing a zone of higher strain (Hanmer *et al.* 1997). The similarity of the patterns north and south of the Nordre Strømfjord steep belt supports previous conclusions that the structure does not form a fundamental tectonic break in the orogen (Hanmer *et al.* 1997; van Gool *et al.* 1998; Connelly *et al.* in press).

The *Central Nagssugtoqidian orogen* (CNO) contains three ENE–WSW-trending domains, each with a very distinct character, and which from north to south have been named the *northern CNO flat belt*, *Nordre Isortoq steep belt*, and *southern CNO* (van Gool *et al.* 1996). Large-scale, open and upright folds dominate the northern CNO flat belt and are obvious in both magnetic and geological maps. The Nordre Isortoq steep belt is a zone of steeply dipping and tightly folded gneisses consisting of interleaved orthogneisses and pelitic to quartzitic paragneisses, which define an area with low magnetic values. This zone forms a rather strong lineament along most of its length, but ends in a fold-dominated coastal region near the mouth of Nordre Isortoq fjord. The southern CNO consists of rather homogeneous, granulite-grade Archaean granitoid gneisses in the east and is dominated by the Palaeoproterozoic Sisimiut charnockite suite in the west. The dominant ENE–WSW trend is clearly visible and some large fold structures are reflected by the magnetic data.

The boundary between the CNO and SNO named the *Ikertôq thrust zone* (after Korstgård *et al.* 1987) is in Fig. 2 recognised as a 5 to 10 km wide strongly lineated zone with a high magnetic anomaly. It is formed by a metamorphic fold and thrust belt, the western end of which was described in detail by Grocott (1977; see also van Gool *et al.* 1996). It consists of tightly folded and imbricated panels of Archaean gneisses and Palaeoproterozoic pelitic to psammitic metasediments as well as highly deformed mafic dykes of the Kangâmiut dyke swarm. In the eastern half, the northern boundary is a very sharp lineament, both in the field and in the magnetic map, which truncates structural trends to the north. In the central part of the zone, the boundary is more diffuse. At the coast, the northern boundary is again marked by a distinct lineament, but there is no strong contrast between the magnetic signature north and south of the boundary. The southern boundary to the thrust zone is marked by a consistent sharp and strong magnetic gradient along its length, but which is rather irregular in shape.

The *southern Nagssugtoqidian orogen* (SNO) and the southern Archaean foreland are lithologically very similar, but the magnetic signature of the SNO is very distinct from both the remainder of the orogen and the Archaean foreland. The rocks in the SNO are the equivalents of the Archaean granulite gneisses in the foreland, but reworked at amphibolite facies. To the west are some rather abrupt transitions to large areas that escaped intense reworking and have preserved a signature that strongly resembles that of the foreland. A number of E–W-trending zones characterised by intense retrograde shearing and reworking separate these blocks (see Korstgård 1979 and references therein) and are marked by magnetic lows. The two main zones are along Ikertooq and Itilleq fjords.

East of Sukkertoppen Iskappe (ice cap) the *southern Nagssugtoqidian front* appears as a sharp boundary on both maps, which in surface geology is expressed as a stepped series of shear zones that form the southernmost boundary to distributed, penetrative deformation and metamorphism. In Fig. 2 the front separates two areas with sharp contrasting patterns, and truncates the north-western trend of the Archaean gneisses in the eastern part of the foreland. However, that boundary stops abruptly underneath the ice, near the western edge of the ice cap. Along the coast, the transition from foreland to SNO is marked in surface geology by a progressive change in orientation of the Kangâmiut dykes as a result of a progressive strain gradient. Historically, the orogenic front has been drawn through Itilleq fjord, but that solution is unlikely in the light of the new aeromagnetic data presented here. It is more likely that the sharp thrust front from the inland area continues, but as a much less significant structure, in the unnamed fjord north of the mouth of Evighedsfjorden (Fig. 3). An additional interesting feature is that towards the north-east, close to Kangerlussuaq airport at the head of Søndre Strømfjord, the front appears to be truncated by the eastern extension of Ikertôq thrust zone.

The *southern foreland* is marked by major fold structures in the extreme south, and a fairly straight NW–SE-trending fabric in the south-eastern corner of the map, both of which are truncated by the Nagssugtoqidian front. The Sarfartoq carbonatite (Secher & Larsen 1980), which is just south of the Nagssugtoqidian front, stands out in Fig. 2 by the wide alteration zone that surrounds it, forming a magnetic low.

Conclusions

The new data presented here are a substantial aid in the geological interpretation of the region and in the revision of the geological map, particularly since large stretches of land are difficult to reach and therefore are only known from aerial photograph interpretation. Some inconsistencies between the magnetic features and the geological map (e.g. the eastern end of the Nordre Isortoq steep belt) clearly indicate that some of the inferred elements on the map need to be adjusted. The data also shed new light on the nature and trace of the southern Nagssugtoqidian front. Furthermore, the magnetic map can guide future workers to key areas and the data can be used for modelling the 3D geometry of rocks in the subsurface.

Acknowledgements

Funding of the project was provided by the Government of Greenland, Bureau of Minerals and Petroleum, Nuuk. Thanks are due to Sander Geophysics Ltd. for fulfilling all aspects of their contracts in a professional and timely manner.

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