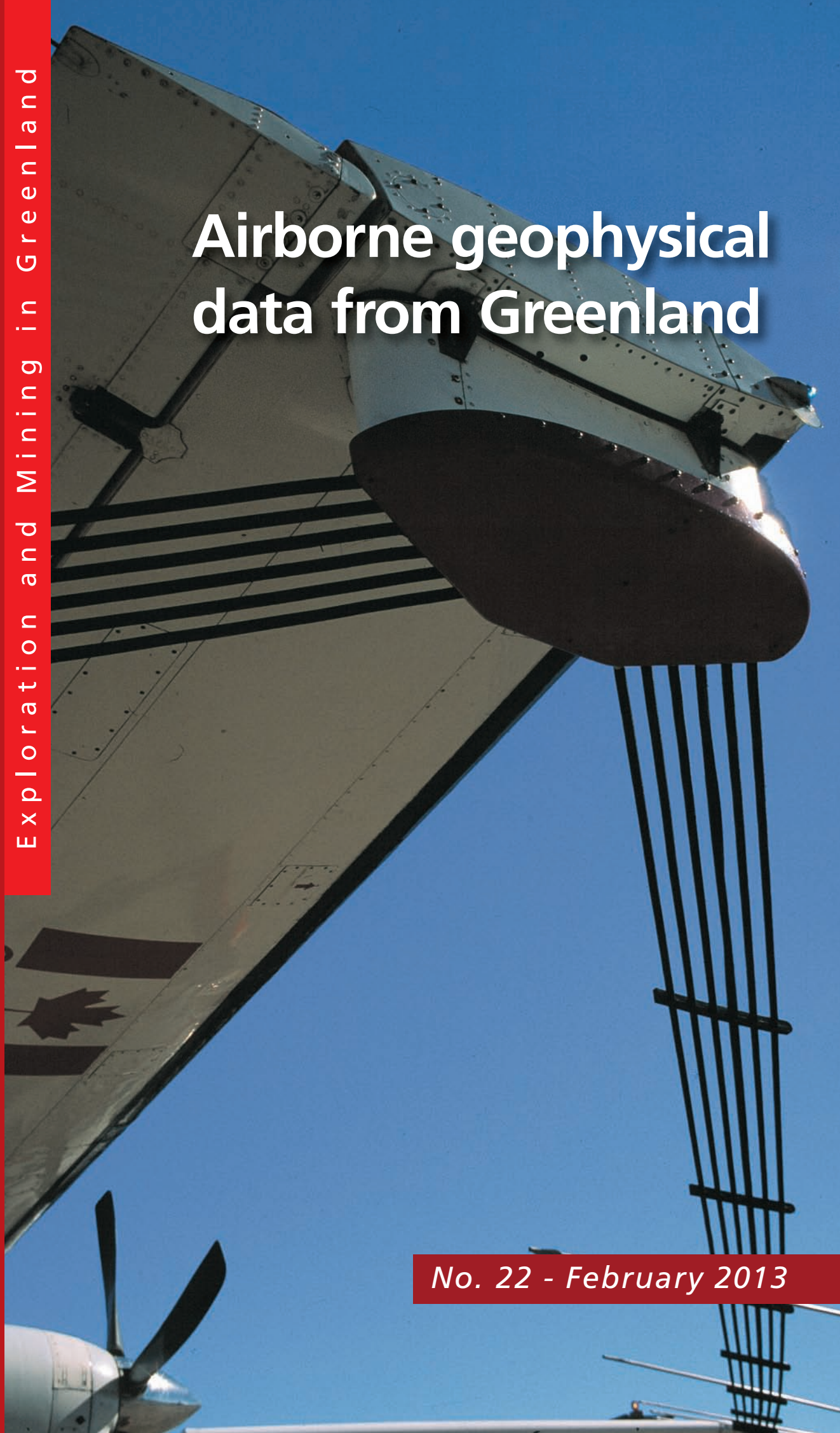
GEOLOGY AND ORE

Exploration and Mining in Greenland

Airborne geophysical data from Greenland



No. 22 - February 2013

Airborne geophysical data from Greenland

This issue of Geology and Ore provides a 2013 update on the airborne geophysical surveys from Greenland, previously presented in Geology and Ore no. 3 in 2003.

Geophysical data constitute a major source of information on the structure and composition of Earth. New technological achievements with respect to both data acquisition and data interpretation place geophysics as an important key to improved mapping and understanding of Earth structures. Airborne geophysical surveying is a particular efficient tool for systematic investigations of large areas as is the case in Greenland.

For these reasons large efforts have been invested in geophysical surveying, and, consequently both the quantity and quality of Greenland geophysical data have grown significantly over recent times. Easy accessibility to geophysical data from Greenland is recognised as being of utmost importance and several efforts have been made to provide potential users with an overview of publicly available data and access to data and reports. In particular, web-based solutions play a significant role in fulfilling the demand for easy data access to both newly acquired data as well as data from older surveys.

Introduction

In Greenland, compared to the rest of North America and Europe, the use of airborne geophysical surveys as a basic tool in mineral exploration came fairly late. During the early 1970s the first publicly financed airborne surveys were carried out in East Greenland, followed in the mid 1970s in West and South Greenland. As for most surveys at the time, the earliest data, magnetic and radiometric, were acquired in digital form but positioned visually by tracking photography. In the eighties, experimental surveys with very wide spacing of lines (10–12 km) were carried out over the southern part of the Inland Ice. Since 1992, systematic airborne geophysical programmes have been conducted in many parts of Greenland, now taking advantage of modern GPS techniques. Substantial parts of Greenland have now been covered by magnetic, electromagnetic and radiometric surveys using a methodology practical for exploration companies. Airborne hyperspectral scanning have been introduced and used in selected areas.

Air Greenland A/S helicopter AS 350 during take-off from Grønnedal in South-West Greenland with its geophysical instrumentation from Aerodat Inc. The lower bird contains the electromagnetic equipment and the upper bird is the magnetometer. During survey the electromagnetic equipment is carried 30 m above the ground.

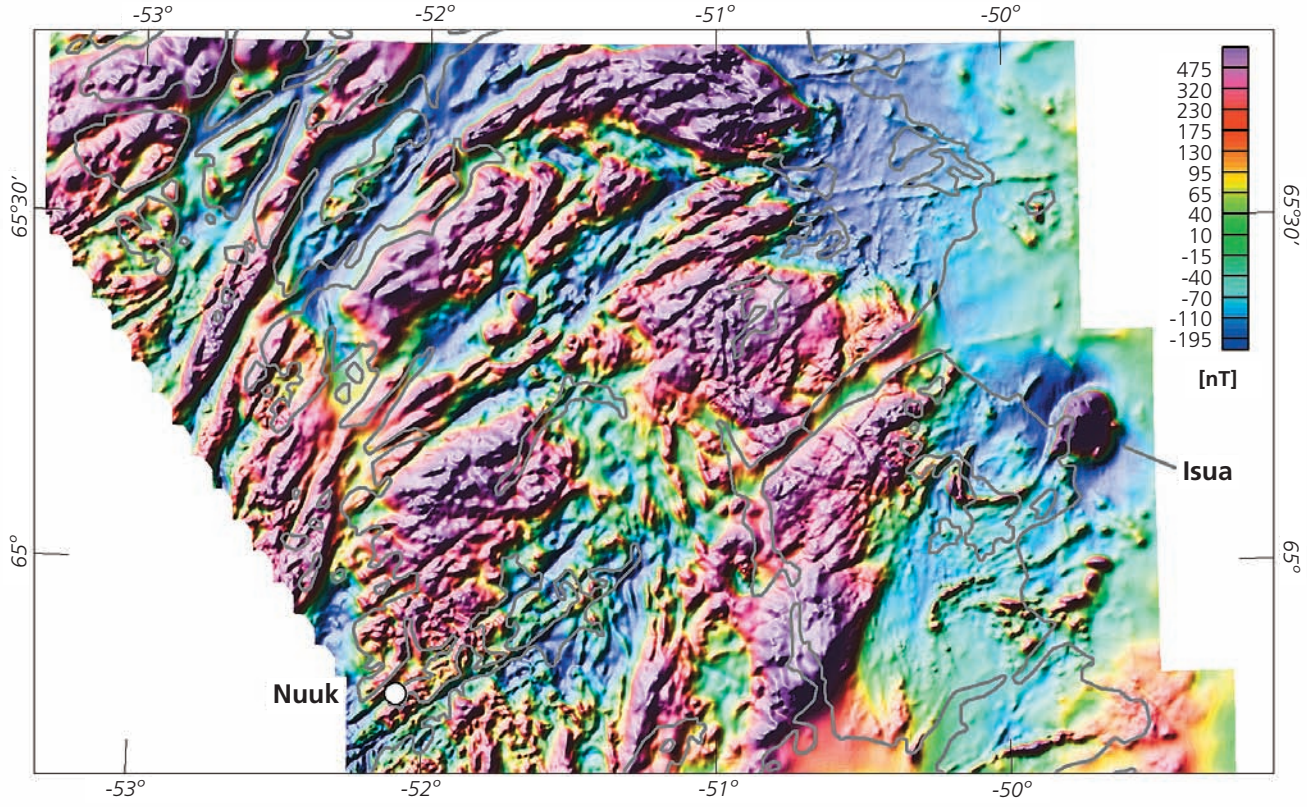
In addition to the short-term objective of stimulating mineral exploration, another purpose of the government-funded programmes is to provide a lasting database of high-quality geophysical data that adds a new dimension to the understanding of the geology of Greenland.

History of modern airborne geophysical surveying

In the early nineties the Government of Greenland was seeking new ways to stimulate mineral exploration in Greenland. Among other initiatives, a five-year programme, AEM Greenland 1994–1998, of airborne combined electromagnetic and magnetic surveying was proposed. The

Piper Navajo PA-31 aircraft during take-off from Narsarsuaq Airport, 2012.

The electromagnetic (GEOTEM) transmitter loop fixed at the nose of the Geoterrex Ltd. Aircraft (Casa), Constable Pynt, 1997.



In West Greenland the spectacular 20 000 nT anomaly of the Isua banded iron formation measured at a survey altitude of 300 m can easily be located on the aeromagnetic total field anomaly map (right part) from project Aeromag 1998.

survey areas were chosen on the basis of potential for the discovery of economic mineral deposits and to demonstrate the general applicability of airborne methods in the various terrains in Greenland. Simultaneously with the AEM programme with detailed surveying of selected areas, another airborne project, Aeromag, was soon after started and financed by the authorities, producing a regional coverage of high-quality aeromagnetic data. The total coverage of the various airborne methods is shown in a number of index maps. Management of the publicly funded airborne programme and the handling and interpretation of the data were performed by Geological Survey of Denmark and Greenland – GEUS, while the surveys were flown by commercial geophysical contractors after international tender.

Major airborne geophysical surveys conducted in Greenland cover the following four major geophysical data types:

- Magnetics
- Electromagnetics
- Hyperspectral mesurements
- Radiometry

Aircraft (Casa) outfitted for geophysical surveying. The electromagnetic transmitter loop is fixed to the wing tips, tail and nose, Constable Pynt, 1997.

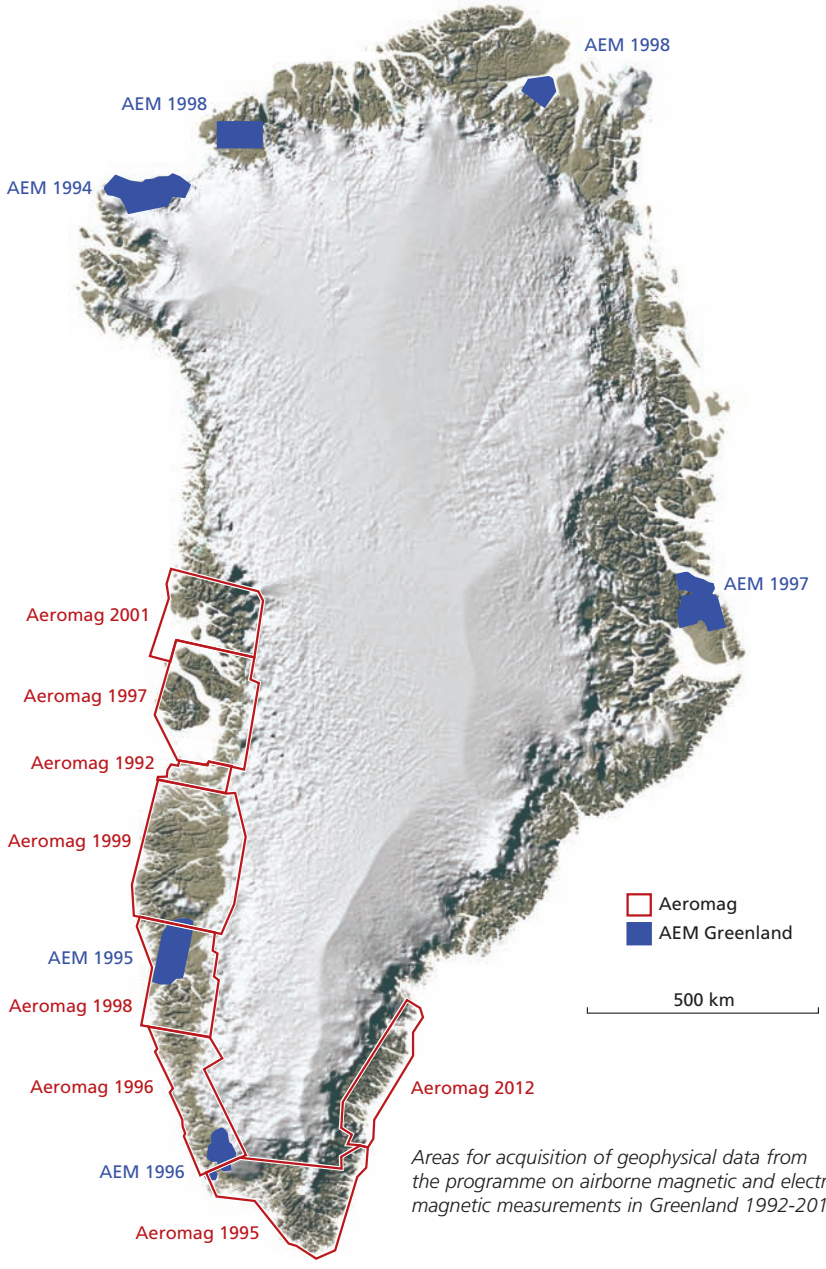
The Dornier 228-101 research aircraft used in the HyperEast 2012 hyperspectral and LiDAR survey in Central East Greenland.

Prospecting companies have also utilised airborne geophysical surveying in their search for mineralisations in Greenland. Parts of these detailed surveys are made publicly available from GEUS. The locations of these surveys are shown on the index map on page 6.

The regional Aeromag surveys

The Aeromag projects encompass high-resolution magnetic surveys conducted in 1992 and each of the years from 1995 to 1999, in 2001 and 2012, producing a total of nearly 570 000 line kilometres. The term 'high-resolution' applies here to dense sampling along flight lines. Initial measurements were carried out in West Greenland 1975–1976, producing around 50 000 line kilometres, but these data should now be considered to be superseded by the more modern Aeromag data.

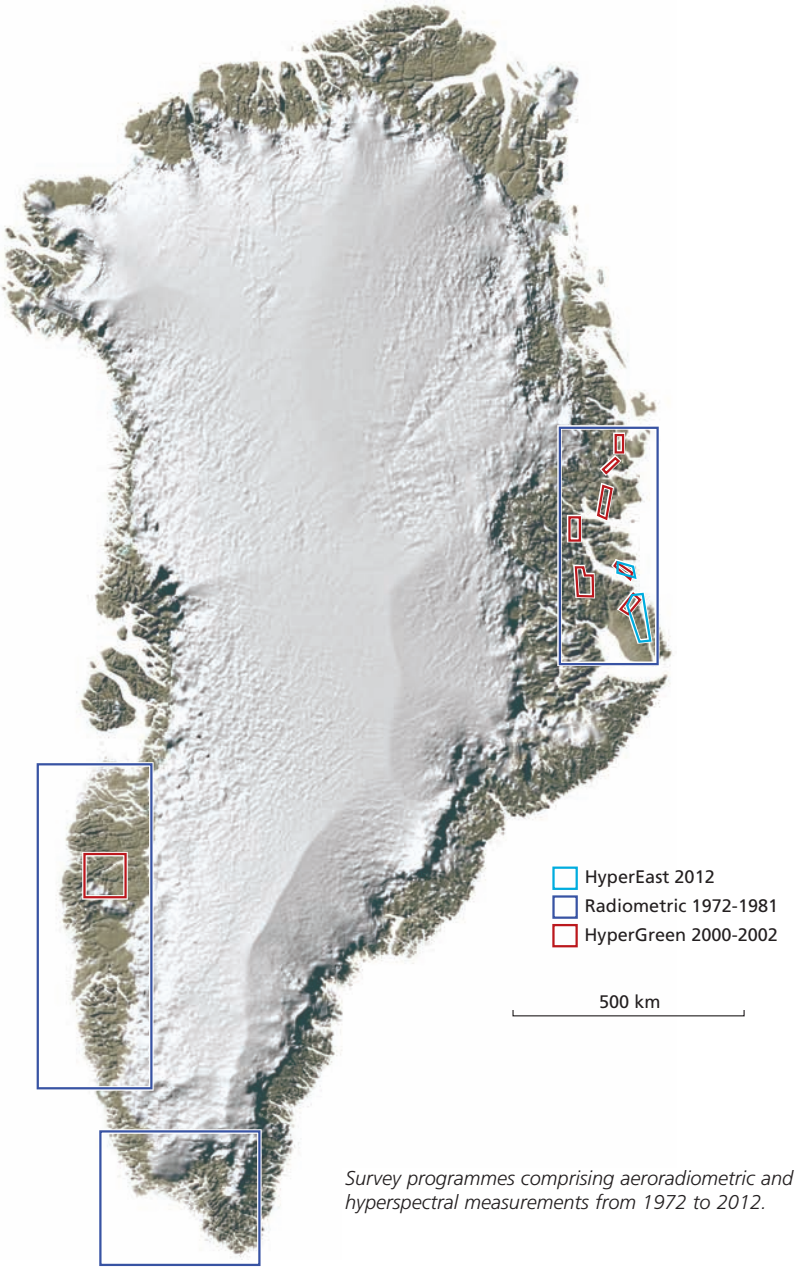
The Aeromag surveys now provides high-quality, high-resolution magnetic data for the total ice-free area of West and South Greenland from the southern tip of Greenland to Svartenhuk Peninsula, covering an area of approximately 300 000 km² along the west coast of Greenland. The 2012 Aeromag survey covered an area in South-East Greenland. A continuation northward in east Greenland is planned for 2013. Most of the surveys have mainly covered onshore areas. The survey in 2001 north of Nuussuaq and the survey in 1997 in the Disko Bay region also included significant offshore areas. Approximately one third of the 2001 survey region is offshore, and includes an area well known for its importance in relation to the understanding of the offshore hydrocarbon potential.



Areas for acquisition of geophysical data from the programme on airborne magnetic and electromagnetic measurements in Greenland 1992-2012.

Government funded Aeromag surveys

	Aeromag *1975–76*	Aeromag *1992*	Aeromag *1995–99*	Aeromag *2001*	Aeromag *2012*
Region	*Central West Greenland*	*Central West Greenland*	*South-West Greenland*	*West Greenland*	*South-East Greenland*
Size of area km²	60 000	8 600	210 000	31 400	23 000
Line km	52 000	10 100	440 000	70 000	48 493



Survey programmes comprising aeroradiometric and hyperspectral measurements from 1972 to 2012.

Generally, the Aeromag surveys are carried out by flying with fixed-wing aircraft along a gently draped surface 300 m above the ground and sea level. Rough topography in many areas places some limitations with respect to satisfying a general wish to minimise terrain clearance. Survey lines are with a separation of 500–1000 m. Orthogonal tie-lines are flown with a separation of 5000 m. Total magnetic field data are recorded with a sampling rate of 0.1 sec which corresponds to a sampling distance of 7 m. Aircraft positional data from simultaneous GPS measurements, as well as aircraft altitude measurements obtained from barometric altimeter and radar are recorded.

The AEM Greenland 1994–1998 surveys

The AEM Greenland 1994–1998 detailed surveys with combined electromagnetic and magnetic measurements were carried out in six selected areas of expected high mineral potential. In total, 75 000 line km covering an area of 23 000 km^2 were measured in the project.

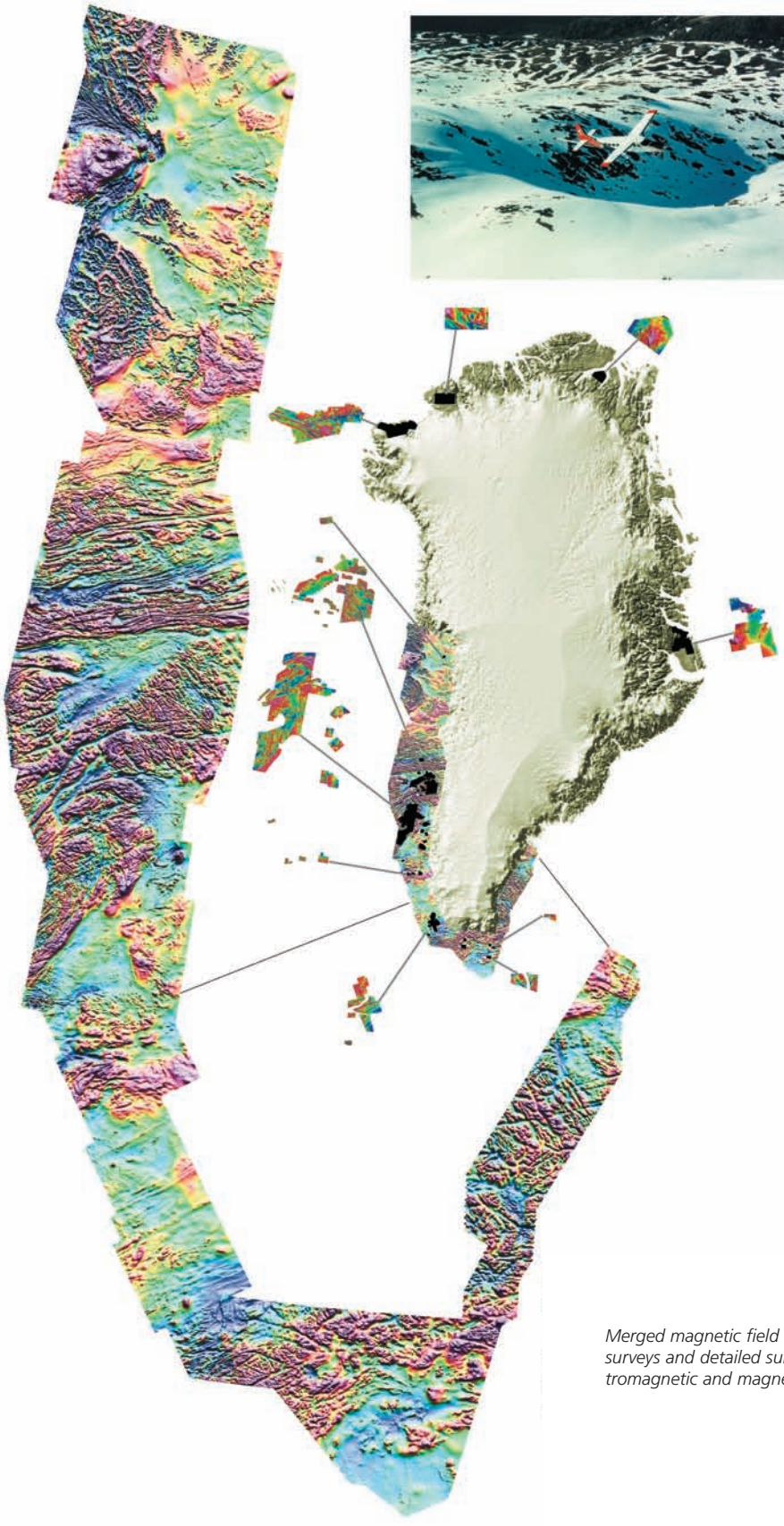
The AEM surveys include transient electromagnetic data (GEOTEM) and combined multi-coil frequency domain data, radiometric and VLF-data. Magnetic total field measurements are available from all surveyed areas.

Various geological terrains have been covered, including Inglefield Land in North-West Greenland, the Maniitsoq–Nuuk region in southern West Greenland, the Grønnedal region in South-West Greenland, Jameson

Government funded airborne electromagnetic surveys

AEM	1994	1995–1996	1997	1998
Region	*North-West Greenland*	*South-West Greenland*	*Central East Greenland*	*North Greenland*
Size of area km²	6 500	6 800	5 200	4 900
Line km	17 400	29 200	14 000	4 500

Regional and detailed airborne surveys



Merged magnetic field data from regional aeromagnetic surveys and detailed surveys mostly with combined electromagnetic and magnetic data acquisition.

Land in central East Greenland, Washington Land and Daugaard-Jensen Land in western North Greenland and J.C. Christensen Land in eastern North Greenland. Additional reconnaissance lines were measured adjacent to some of the main survey areas.

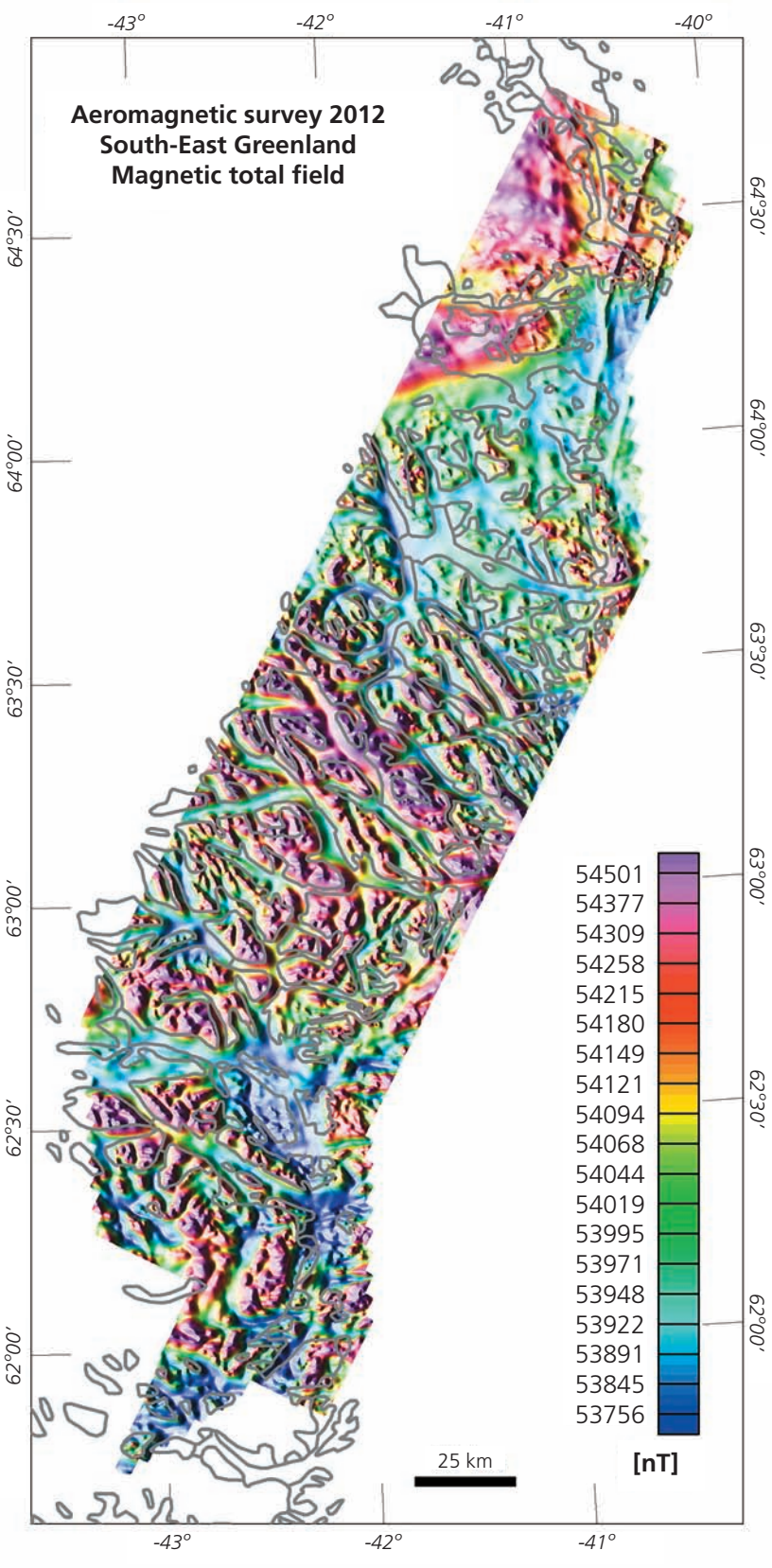
The project was initiated and designed to encourage mineral exploration. Thus, at the start of the project all holders of prospecting and exploration licences in Greenland were contacted to solicit views on possible target areas for the five-year period. The selection of areas was primarily guided by the knowledge of mineral occurrences but also to some extent by a wish to cover different types of geological settings. In addition to the government-financed surveys, several companies undertook surveys of a similar type, often in adjacent areas to the government-organised activities, exploiting an option in the contract between the Survey and the geophysical contractor whereby the mobilisation costs to and from Greenland could be disregarded for the prospecting company.

The activities sparked a considerable interest from the prospecting companies after the yearly release of data from the 1994–1998 surveys, and it has been confirmed that modern high-resolution geophysical data are of paramount importance in the search for mineral deposits.

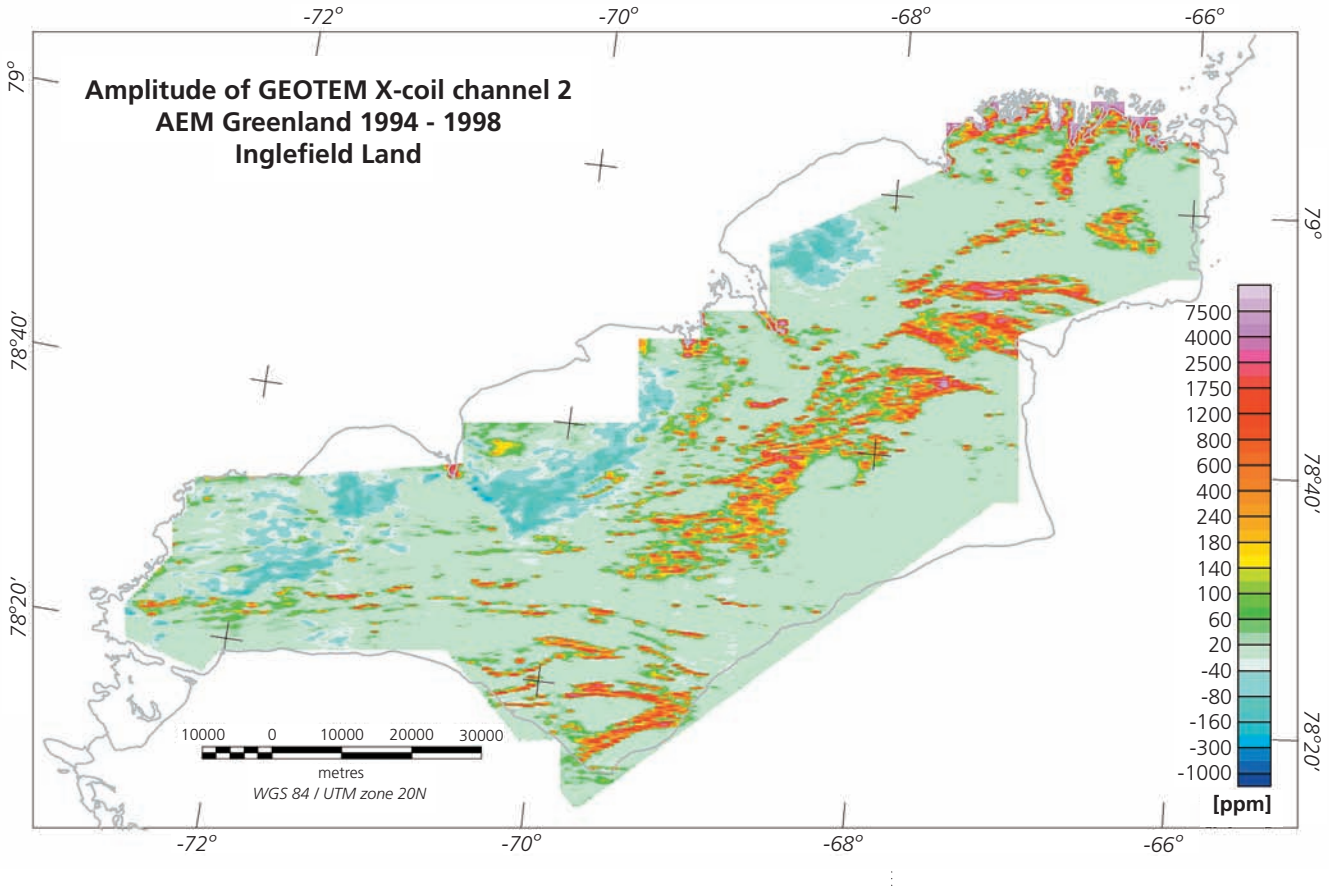
The hyperspectral surveys

Airborne remote sensing provides an efficient method for the rapid collection of data to assist geological mapping and mineral exploration. Depending on the spatial and spectral resolution, hyperspectral surveys offer mapping opportunities from a reconnaissance to a detailed level of study.

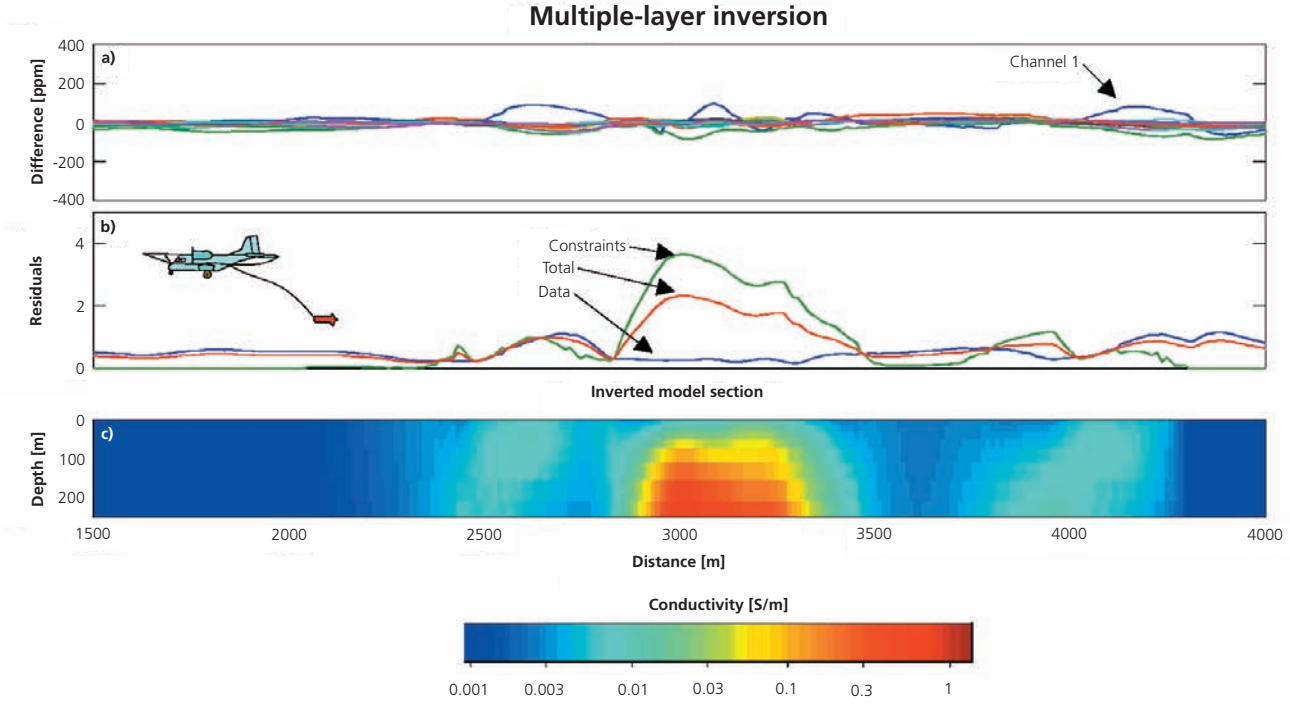
Airborne imaging spectrometer data were acquired for the first time over Greenland during hyperspectral surveys in 2000 and 2002. Data acquisition were based on the HyMap™ hyperspectral imaging spectrometer, which collects data from 126 bands across the reflective solar wavelength region of 450–2500 nm with bandwidths between



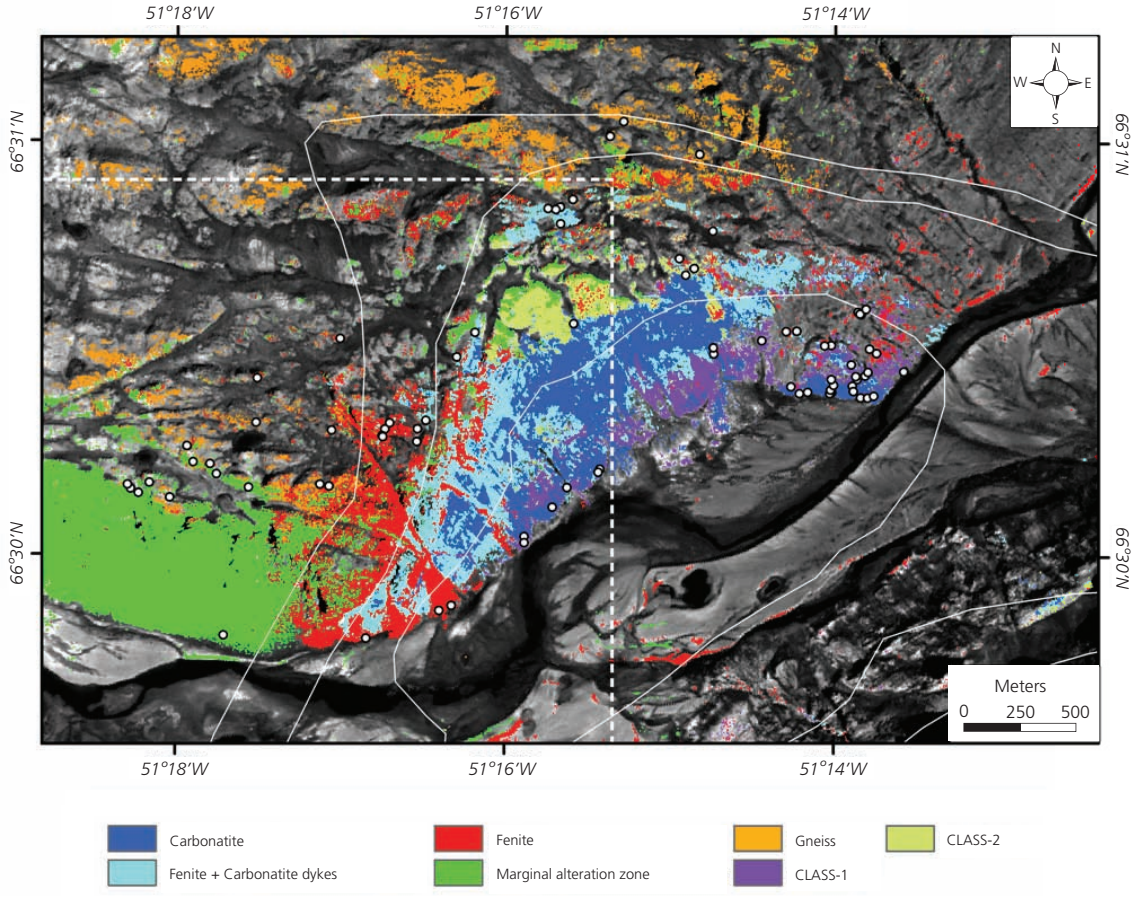
Magnetic total field data from the regional aeromagnetic survey in 2012 of the southern part of the North Atlantic craton in South-East Greenland.



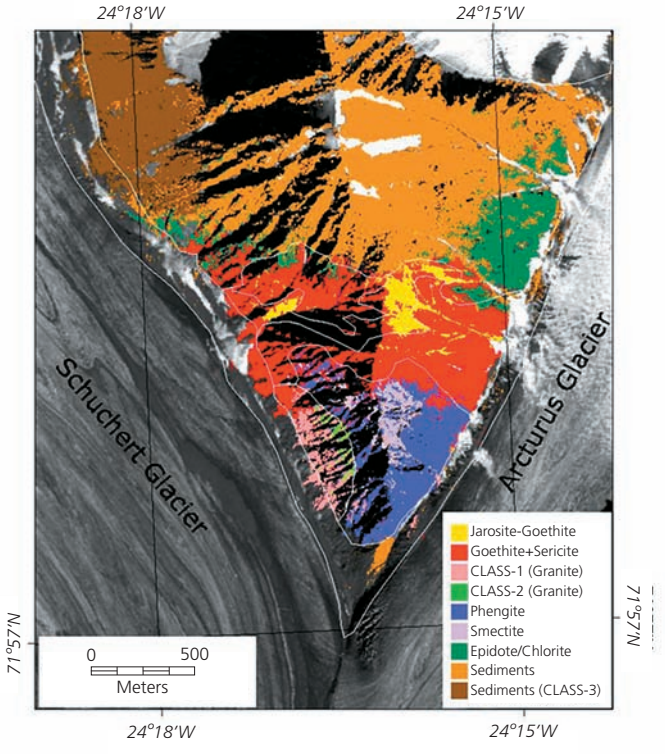
Amplitude of GEOTEM X-coil receiver at 560 microseconds turn-off time of transmitter signal for the AEM Greenland 1994 survey in Inglefield Land, North-West Greenland.



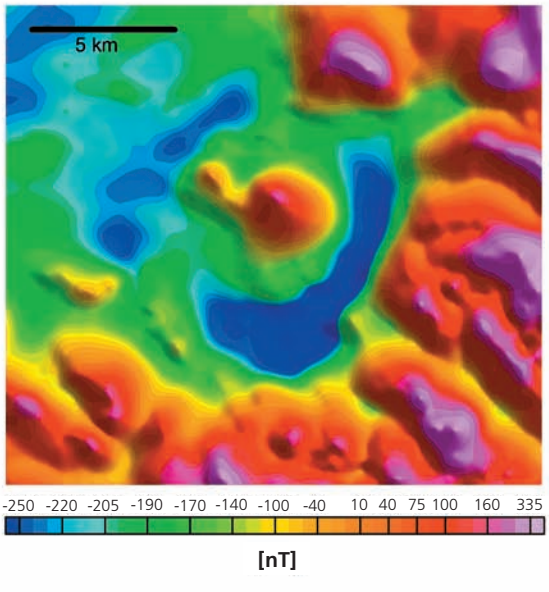
Results of multiple-layer inversion of data from the AEM Greenland 1994 survey in Inglefield Land, North-West Greenland.



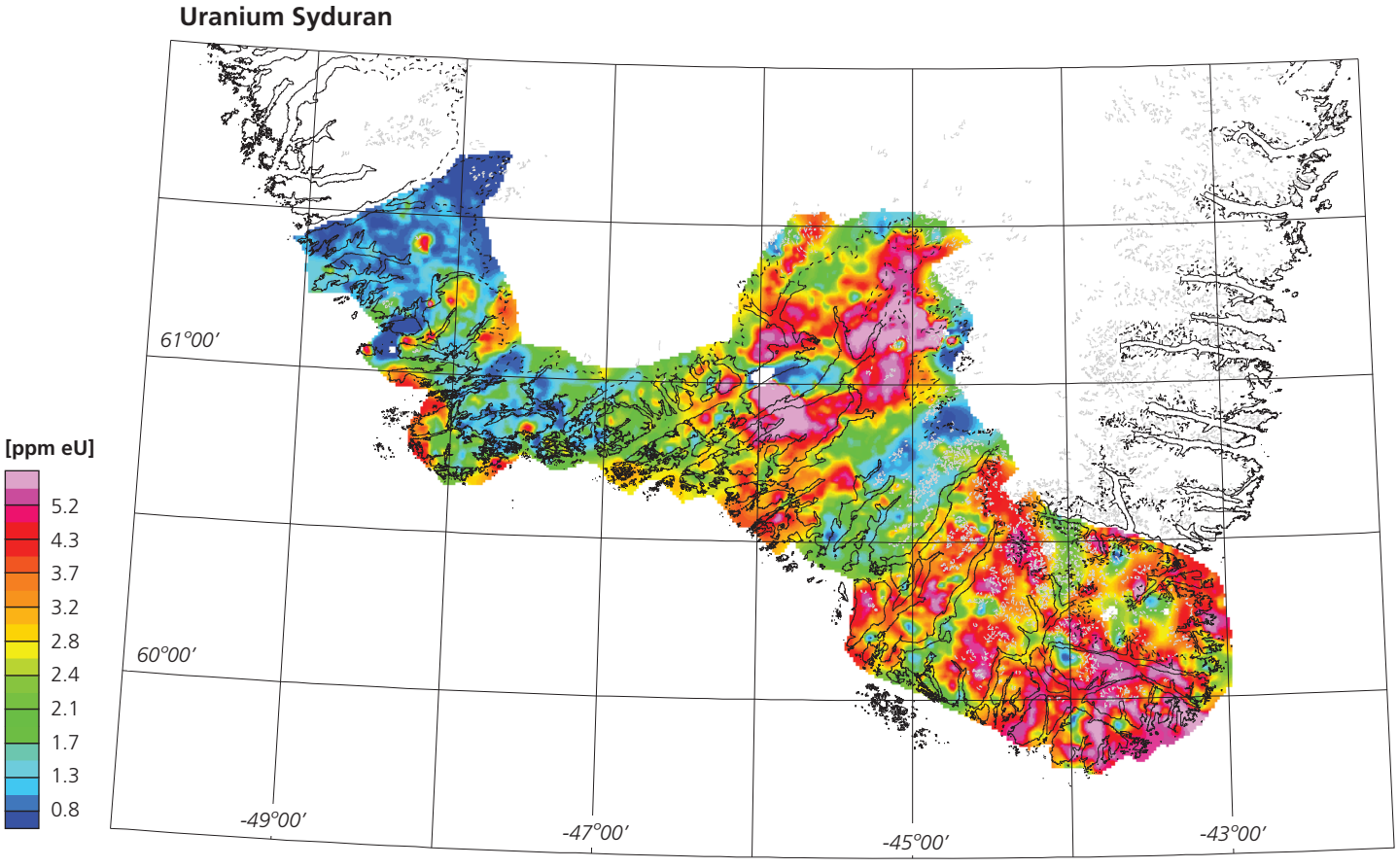
Thematic hard classification of the hyperspectral data for the main lithologies of the Sarfartoq carbonatite complex, southern West Greenland (Bedini, 2009).



Self-Organized Map classification of hyperspectral data from the Malmbjerg molybdenum deposit in the Werner Bjerge Complex, central East Greenland (Bedini, 2012).



Close-up on the type of magnetic anomaly from the Sarfartoq carbonatite complex, southern West Greenland. The centre of the complex is marked by a high magnetic field caused by the presence of magnetite. Aeromag 1999.



Equivalent uranium (eU) in South Greenland, based on gamma-spectrometric measurements during the airborne campaign 1980-81.

15–20 nm, and a signal-to-noise ratio better than 500:1. The first campaign in 2000 was carried out in East Greenland focussing on environmental aspects of the former Blyklippen lead-zinc mine at Mestersvig, and known mineral occurrences at various locations in the region. The hyperspectral survey in 2002 also involved mapping of kimberlites and mineral occurrences associated with hydrothermal alterations in West Greenland.

In the summer of 2012 a survey (HyperEast 2012) was flown by NERC Airborne Research & Survey Facility over central East Greenland using a Dornier 228-101 research aircraft equipped with both Specim AISA Eagle and Hawk sensors, a Leica ALS50-II LiDAR and a Leica RCD105 39 mega-pixel camera. The hyperspectral data from AISA Eagle and Hawk have 2 metre spatial resolution and cover 486 spectral bands from 400 up to 2500 nm, with bandwidths of 3 and 6 nm, respectively.

The aeroradiometric survey

Aeroradiometric data (acquired as gamma-ray measurements) have been used to quantify and describe the radioactivity of rocks in Greenland since the early 1970s. The major part of the gamma-ray signal originates in

The hyperspectral survey

HyperGreen	2000–2001	2002	**HyperEast**	2012	2012
Region	*Central East Greenland*	*Central West Greenland*	**Region**	*Central East Greenland Kap Simpson*	*Central East Greenland Carlsberg Fjord*
Size of area km²	2 500	8 000	**Size of area km²**	664	2 620
Line km	2 000	6 000	**Line km**	1 310	4 426

Government funded aeroradiometric survey

Gammaspec	1972–1974	1975–1976	1979–1981	1996
Region	*Central East Greenland*	*Central West Greenland*	*South Greenland*	*South-West Greenland*
Size of area km²	50 000	100 000	35 000	1 600
Line km	10 000	30 000	1 500	9 000

the upper 20–25 cm of surficial rock materials, and therefore the method is a good tool for geological mapping. The gamma-spectrometer is mounted in an aircraft that is flown over an area at low altitude, in the range 30–150 m. The size of the total gamma exposure is estimated by combining the data from the uranium, thorium and potassium data channels. Different types of contour maps of the measurements or ratios of combinations of channels are produced and used for the interpretation of geological features.

A large part of the data gathered from Greenland areas (1972–1976), however, are in an analogue form and with irregular tracking lines along terrain contours and thus not suitable for up-to-date map presentation.

The correlation of early airborne radiometric measurements with the geology has been done visually and typically based on the studying of anomalies from the different channels. Results from that type of comparison have led to recognition of several geological structures and rock associations of relevance to mineral exploration. As examples, some of the promising targets of the present day exploration, e.g. the Sarfartoq carbonatite complex and the Motzfeldt alkaline centre in West and South-West Greenland, were recognised this way.

Online access to airborne geophysical data from Greenland

Information concerning the airborne geophysical surveys in Greenland is available online through the Greenland Mineral Resources Portal: *www.greenmin.gl*. The portal includes an interactive map functionality that shows the geographical extent of the geophysical surveys carried out in Greenland. It is also possible to query the interactive map and download survey metadata.

Closing remarks

The series of publicly funded geophysical surveys in Greenland are intended to provide the industry and the geoscientific community with data relevant for the exploration for mineral resources. The modern survey programme has added more than 600 000 line kilometres of high-quality measurements to the existing database of airborne geophysical data from Greenland. The data are used extensively by the exploration industry and will continue to be useful for many years to come. High-resolution geophysical data are certainly an investment for the future.

Access to modern high-quality geophysical data is an essential tool if exploration is to be effective. The airborne geophysical measurements carried out in Greenland represent data acquisitions up to international best practice, comparable with data furnished for regional exploration and mapping by other national geological surveys. The data collected in Greenland since 1992 form an important contribution to the development of mineral exploration.

Maps, digital data on CD-ROMs and accompanying reports are sold from GEUS.

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Cessna Grand Caravan from Sander Geophysics Ltd. with tail mounted magnetometer traverses snow-covered terrain at the Nuussuaq peninsula in central West Greenland, Aeromag 1997.

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Front cover photograph
Close up of the electromagnetic transmitter loop fixed to the wings of the Geoterrrex Ltd. Casa aircraft. Thule Airbase 1994. Photo: Jakob Lautrup, GEUS.

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