DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/92

# The mineral resource assessment project of the Nuuk region 2004-2007: Summary and DVD

Mineral resource assessment of the Archaean Craton (66° to 63°30'N) SW Greenland Contribution no. 12

Leif Thorning, Henrik Stendal & Frands Schjøth

(1 DVD included)

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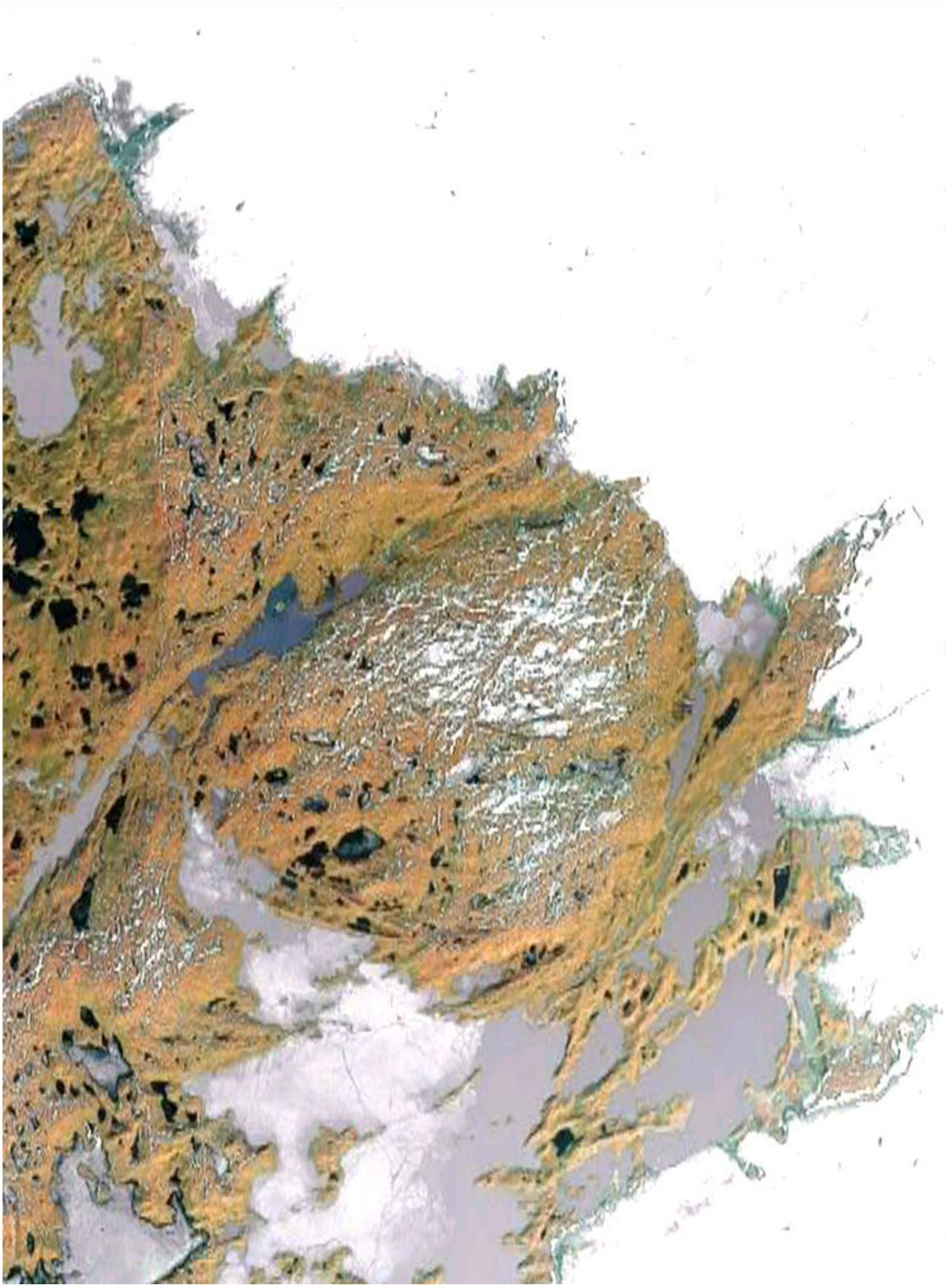
G E U S



***Frontispiece*.**

Isua - one of the well-known and probably most publicised geological features in the Nuuk region. Rocks from the oldest times and potential for exploitation of iron and gold (Map from Google Earth).

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# Abstract

This report summarises the activities and results of the four-year mineral resource assessment activities focussed on the Nuuk region. Preparations for the project were carried out in 2003, resulting in a compilation of all existing knowledge of the area published on a DVD. During the next four years, 2004 – 2007, field work was carried out from base camps in Nuuk (2004) and Storø (2005 to 2007). The results of the different projects have been reported in GEUS reports and articles. This report give a summary of the activities and results and include a DVD with data and maps in an ArcGIS environment.

# Introduction

Beginning in the early 90-ties, GGU/GEUS began a series of regional compilations of all types of geodata from selected regions judged to be of special interest for the exploration industry.

From 2004 to 2007, GEUS studied aspects of the geology of supracrustal belts in the Nuuk region, in particular focussing on aspects of the primary geological environments and their mineral occurrences, geological setting, and alteration patterns. Detailed mapping of key areas in 2004–2007 and targeted geochemistry and geochronology has identified Meso-Neoarchaean belts. Contemporaneously with the regional Nuuk project, a mapping project (2004-2007) of the 1:100,000 Kapisillit map sheet was carried out and diamond exploration was carried out by GEUS north of Nuuk in the Maniitsoq area (2004–2006) and south of Nuuk in the area east of Fiskenæsset and Buksefjorden (2005–2007). The regional Nuuk activities were co-financed between Bureau of Mines and Petroleum (BMP), Government of Greenland, and GEUS. The Kapisillit mapping project was financed by GEUS. Logistics in 2004 were based on two people stationed in Nuuk but the helicopter programme was managed from the field by the expedition leader in direct contact with Greenland Air. From 2005–2007, GEUS joined the Nunaminerals A/S base camp on Storø. Greenland Resources A/S (GRAS), Air Greenland, Nunaminerals A/S assisted GEUS with all the practical matters on Storø and in Nuuk during the field campaigns. During the field seasons 2005–2007, Nunaminerals had chartered an AS350 helicopter from Greenland Air and based it on Storø.  GEUS had guaranteed Nunaminerals A/S to use a certain amount of helicopter hours for logistical operations. The logistical co-operation between GEUS and Nunaminerals A/S worked to GEUS" full satisfaction during all the years in the Nuuk region.

# The Nuuk project

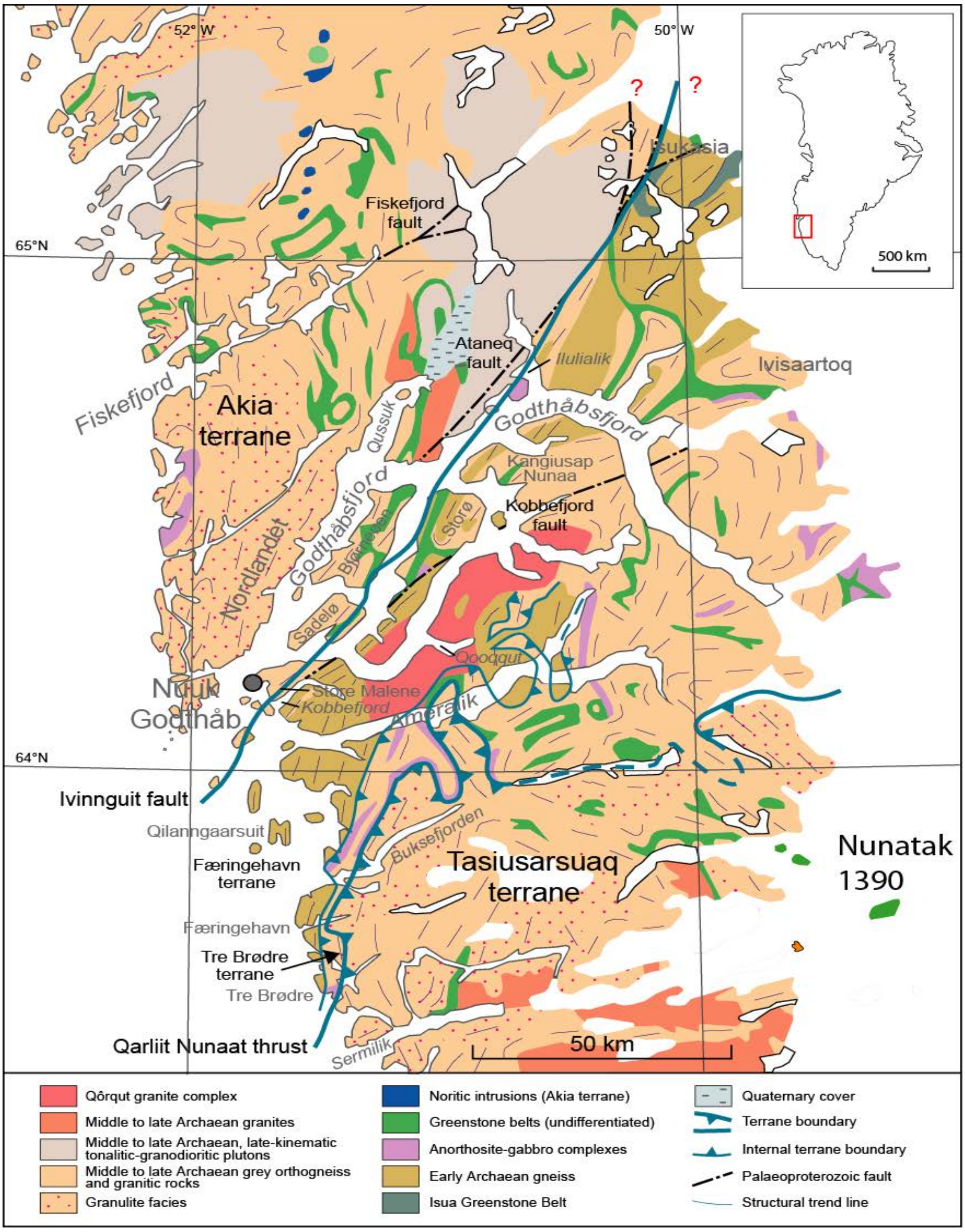


**Figure 1.** *Geological map of the Nuuk region modified after Escher & Pulvertaft (1995), reflecting the view of the geology of the area in 2007.*

## The inception phase 2003

The inception phase was initiated by the Bureau of Minerals and Petroleum (BMP) in Nuuk and carried out by GEUS staff from the Department of Economic Geology and Department of Geological Mapping at the Geological Survey of Denmark and Greenland (GEUS) and comprised a compilation of all existing data from the area, reported in (Appel *et al.* 2003). The compilation was carried out during the second half of 2003 with the aim to compile existing knowledge of the general geology, the known mineral occurrences of the greenstone belts, available geochemical and geophysical data from the Nuuk region. The resultant inception report outlined all known mineral occurrences and suggested, which lines of investigation should be followed in order to assess, whether the Nuuk region can be seen as a gold province, or whether the gold only occurs in small showings irregularly distributed throughout the region. The subsequent mineral resource assessment fieldwork 2004 – 2007 of the Nuuk region comprised the region between 66°N and 63°30‟N.

The report (2003/94) contains a compilation of existing data from the Nuuk region with emphasis on the greenstone belts, mostly acquired by geologists from the Geological Survey of Denmark and Greenland (GEUS), formerly The Geological Survey of Greenland (GGU). Some airborne geophysical data acquired by exploration companies have been included. A DVD is enclosed in the report, containing a digital version of this as well as numerous figures showing the geochemical trends in rock samples, stream sediments and heavy mineral concentrates from stream sediments of the Nuuk region.

## Campaign 2004

The aim of the field work was to investigate the geological setting and evolution of important greenstone belts with respect to their mineral potential especially for precious metals. The fieldwork was split between two groups. One group investigated the kilometre-thick units of supracrustal rocks in the central Godthåbsfjord region, especially at Qussuk, Bjørneøen, and Storø greenstone belts (Hollis *et al.* 2004). The second group focussed on detailed investigations of mineral occurrences in the greenstone belts. The study and sampling was focussed both around known gold-bearing mineral occurrences (Storø and Bjørneøen) and unknown areas with respect to gold occurrences such as Fiskefjord region, Qussuk peninsula, Sermitsiaq, the inner part of Godthåbsfjord and Ameralik on Aappalaartoq and Qingaaq mountains on central Storø, where gold showings were discovered in the 1990‟s (Appel *et al.* 2005). Furthermore, regional investigations were carried out in the Fiskefjord area for PGE and for base metals in the Qooqqut and Ameralik areas. Limited work on Ivisaartoq was carried out for research on the tungsten with respect to the genesis of these occurrences (Appel *et al.* 2005).

## Campaign 2005

Four projects were in focus during the 2005 campaign:

- Geochronology of the 2004 field data (Hollis 2005);

- Tectonothermal evolution of supracrustal belts in the inner Godthåbsfjord region (Hollis *et al.* 2006b, c);
- Potential for precious metals in hydrothermal systems within the wider Godthåbsfjord region (Hollis *et al.* 2006a, b; Eilu *et al.* 2006).
- The discovery of the Tikiusaaq carbonatite (Steenfelt *et al.* 2006, 2007a, 2010).

## Geochronology

The research yielded extensive new geochronology and geochemistry data, petrographic studies, and new digital geological map data for the Nuuk region. The analytical data were obtained for samples collected during the 2004 GEUS field mapping. More than 850 zircon grains in 41 samples were analysed for U-Pb isotopes via secondary ion and laser ablation mass spectrometry. The zircon age data indicate two distinct age groups of supracrustal rocks. The tectonically dismembered Qussuk–Bjørneøen greenstone belt (in the Akia terrane) is ≤ 3070 Ma and occurs on Store Malene, Sermitsiaq, Bjørneøen, part of Storø, and the Qussuk peninsula. This was affected by amphibolite facies metamorphism at c. 2980–2970 Ma – correlated with previously reported granulite facies metamorphism farther northwest in this terrane. The Archaean Storø belt is also tectonically dismembered, cropping out on Storø, the Nuuk peninsula, Sermitsiaq, and Bjørneøen. Sedimentary rocks in this belt were deposited at c. 2800 Ma, mainly from a c. 2880 Ma source. An important volcanic component of the Storø belt was dated at c. 2830 Ma. Metamorphic and pegmatitic zircon age data indicate more than one episode, or a prolonged period, of thermal activity from 2700–2600 Ma. Amphibolite facies metamorphism of the Storø greenstone belt at c. 520–620°C and c. 4.5–6 kbar, was dated at c. 2700 and c. 2630 Ma. Abundant pegmatite emplacement happened during crustal–scale thrusting in the Storø shear zone around 2630 Ma.

## Tectonothermal evolution of supracrustal belts

In the Ujarassuit area, detailed 2005 field mapping has identified several previously unrecognised amphibolite belts. The largest amphibolite belt on Ujarassuit Nunaat is thought to correlate with the Mesoarchaean Ivisaartoq belt. The supposed Proterozoic Ataneq fault is shown to have a complex history of multiple reactivations of its shear zone system under greenschist facies conditions.

## Potential for precious metals in hydrothermal systems within the wider Godthåbsfjord region

Several sub-projects were operating under this heading.

- Preliminary geochemical results confirm and add evidence for a strata-bound gold mineralisation discovered in 2004 on the Qussuk peninsula.

- A magmatic complex at Fiskefjord comprises ultramafic rocks, noritic and layered amphibolites. Magnetite and chromite were identified in the ultramafic units and iron-sulphides in norites and amphibolites together with significant PGE and gold anomalies.
- The hydrothermal system associated with the Ataneq fault was found to be barren with respect to gold, whereas copper and barium were moderately enriched. Along the fault zone ultramafic rocks are hydrothermally altered to soapstone for a length of at least one km.
- The Qooqqut Lake area shows signs of copper and zinc mineralisation. For the first time a pillowed mafic sequence, similar to that described at Ivisaartoq, was found.
- The Ameralik area shows evidence of significant hydrothermal alteration, particularly along fault zones.
- Anomalous gold and arsenic were identified in mafic sequences and exhalites in the Tasiuarsuaq terrane southeast of Kangerdluarssenguup taserssua. This is the only locality found outside Storø with an arsenic-gold association.

### The discovery of the Tikiusaaq carbonatite

The Tikiusaaq complex comprises massive carbonatite veins and ultramafic lamprophyre dykes. The complex covers an area of 14 x 14 km, while the area with exposure of massive carbonatite sheets is 2 x 3 km in size.

## Campaign 2006

The 2006 campaign was focussed on three major geological environments. These are:

1) island arc (Garde 2007 a, b, 2008; Garde *et al.* 2007),
2) magmatic complexes (Frei & Konnerup-Madsen 2007; Solgevik *et al.* 2007), and
3) oceanic environments (Stendal & Scherstén 2007 a, b; Scherstén & Stendal 2008).

All the environments are Mesoarchaean in age but have probably Neo-archaean metamorphic overprint. The geochemical signatures of mafic metavolcanic rocks show both ocean floor and island-arc affinities. Understanding the primary geological environments of these supracrustal rocks and the alteration patterns is important for the understanding of the formation of mineral occurrences. However, the issue is complicated by 1) the rarity of preserved primary structures due to hydrothermal alteration, metamorphism, and multiple deformation events; and 2) the recognition of tectonic imbrications of rocks of widely different ages, possibly formed in very different geological environments. To throw more light on some of these issues, field work was carried out in three different regions, each with its own specific geological environment.

## Campaign 2007

The 2007 campaign was focussed within the Kapisillit 1:100 000 geological map sheet project and observations along the boundaries of the map sheet. Field investigations focussed on the geological environments and their mineral occurrences. The main target areas were the eastern Nunataarsuk, north-eastern part of Qarliit Nunaat and the Ameralik region, which was briefly visited by (Kolb & Stendal 2007).

## Data compilation and bibliography

The mapping, mineral occurrence, structural, geochemical, and geochronological data obtained in 2004–2007 add to an already large amount of contributions to the geological dataset for the Nuuk region. The high volume of quality data needed considerable efforts on data compilation and interpretation before it allowed us to interpret and use the data for a mineral assessment of the region. This assessment rests on a compilation of all field data as well as lab data. The data is presented on a DVD and most presentations are in ArcGIS format. The bibliography is presented as three EndNote files split into articles, theses and company reports, respectively.

The contribution of published GEUS reports include the following volumes concerning studies in the Nuuk region: Appel *et al.* (2003/94), Hollis *et al.* (2004/110), Nielsen *et al.* (2004/121), Appel *et al.* (2005/27), Nielsen & Jensen (2005/43), Hollis (2005/42), Polat (2005/42), Hollis *et al.* (2006c/7), Stensgaard *et al.* (2006a/27), Eilu *et al.* (2006/30), Hollis *et al.* (2006b/45), Frei & Konnerup-Madsen (2007/20), Garde (2007a/20), Stendal (2007/20), Stendal & Kolb (2007/58), Steenfelt *et al.* (2007a/2), Steenfelt *et al.* (2007b/64), Sand *et al.* (2007/77), Østergaard & van Gool (2007/78), Andreasen (2007/79), Solgevik *et al.* (2008/3), Garde (2008/4), Stensgaard (2008/8 ), Scherstén & Stendal (2008/15), Stendal *et al.*(2011/57), and this report.

Recent publications in GEUS Bulletins, which are relevant contributions for the Nuuk project: Garde *et al.* (2007), Knudsen *et al.* (2007), Hollis *et al.* (2005, 2006a), Nielsen *et al.* (2006), Steenfelt *et al.* (2006), Stendal & Scherstén (2007b) and Stensgaard *et al.* (2006b).

Recent relevant publications in international journals/abstracts related to the Nuuk projects are: Friend & Nutman (2005), Garde *et al.* (2006), Garde (2007b), Heijlen *et al.* (2006), Juul-Pedersen *et al.* (2007), Nutman *et al.* (2007), Polat *et al.* (2007, 2008), Stendal *et al.* (2007) and Stensgaard *et al.* (2006c) and Thøgersen *et al.* (2006).

The diamond project contributes with data to the target area especially from the Maniitsoq region with GEUS reports Jensen *et al.* (2003/21), Jensen *et al.* (2004/117) and a GEUS Bulletin (Jensen & Secher 2004).

Within the Nuuk project several Master of Science projects have been carried out (Andreasen 2007; Juul-Pedersen 2005; Kristensen 2006; Marcussen 2006; Persson 2007; Thøgersen 2006; Vognsen 2007).

# Highlights in the Nuuk project

Several highlights are worth mentioning as important outcomes of the Nuuk project:

- Disvovery of a subduction related island arc in a collision zone between an ocean floor plate and a continent. In the same island arc system, gold-copper were discovered as a potential for gold deposits (Andreasen 2007; Garde 2007a, b, 2008; Garde *et al.* 2007; Hollis *et al.* 2006b).
- Identification of an ulramafic-mafic complex in the Fiskefjord area (Amikoq) with the potential for PGE occurrences (Kristensen 2006; Appel *et al.* 2005; Hollis *et al.* 2006a).
- Many new zircon age determinations produced during the Nuuk project constrain the geological evolution much better than has hitherto been possible (Hollis 2005; Hollis *et al.* 2006).
- The Storø gold deposit has been studied in co-operation with Nunaminerals A/S and has been debated intensely concerning geological setting and age constraints (Eilu *et al.* 2006; Juul-Pedersen *et al.* 2007; Knudsen *et al.* 2007; Nutman *et al.* 2007).
- Discovery of a new carbonatite (158 Ma±2), the Tikiusaq deposit (Steenfelt *et al.* 2006).
- Discovery of new kimberlite blocks in an hitherto unknown kimberlite area on Nunatak 1390 (Sand *et al.* 2007; Stendal & Scherstén 2007a).
- Confirmation of the diamond potential of the Maniitsoq region and an suggested promising analogy to South Africa (Nielsen *et al.* 2006).
- Updating of many existing sites with signs of mineralisations and addition of new sites; all are now available for user inspection in the Greenland Mineral Occurrence (Thorning *et al*. 2011) Map on the web (www.geus/GMOM)
- The development and presentation of a new statistical method to elucidate a classification of the area in terms of favourability for gold mineralisation was presented (Steensgaard 2006a, b). The methods was succesfully followed-up in the field; the results are reported in (Stensgaard 2008).

Many of the ideas and the understanding of the geology develop during the Nuuk project were further developed during the mineral assessment activities in South-West Greenland 2008 to 2010. Final reporting from these took place in 2010 and 2011; in 2010, the focus of the mineral resource assessment activities in Greenland shifted to South-East Greenland.

## Commodity potential

A general description of the commodity potential of the Godthåbsfjord region is given in Stendal *et al.* (2011), quoted in brief here:

- The precious metals such as gold, platinum and palladium are a promising target. The gold potential on Storø is in an advanced exploration drilling stage. The Fiskefjord platinum-palladium project (Amikoq) are planning further drilling targets.
- The base metals are not the most obvious target in the region. Copper are known by several occurrences but only as small occurrences. The best copper potential is at Qussuk within the gold-copper prospect. Zinc and lead are sporadic known but not of any economic interest.
- The iron and ferroalloy group is represented by the world class BIF deposit, Isua, which might be commercial one day. Ferroalloy such as nickel and tungsten are present but need more exploration such as the nickel-bearing Norite Belt and the tungsten in the Godthåbsfjord tract with the best potential at Ivisaartoq.
- The speciality metals such as rare earth elements, niobium and tantalum are known from the Qaqqarsuk carbonatite but a lot more exploration to judge the potential for these elements.
- The fissionable metals such as uranium and thorium are known from pegmatites in the Godhåbsfjord tract and in relation to the Qorqut granite but with the present knowledge not of any economic interest.
- Gemstones are especially known from the Maniitsoq area with diamond, lazurite and ruby. Rubies are also found in the Nuuk region. Beryllium are known from Ivisaartoq and at other localities within pegmatites.
- Industrial minerals are well represented in the region by the olivine mine, Seqi, which are producing a nearly pure forsterite. Another industrial mineral, which can be of economic interest is the appatite content of the Qaqqarsuk carbonatite.

A more detailed discussion of the geology and economic potential of the area are given in (Stensgaard *et al* 2011), where also descriptions representing 220 mineral occurrence sites from www.geus.dk/GMOM are included.

# The Nuuk DVD

As is usual for GEUS" regional compilations of data, the compiled material for the Godthåbsfjord region have been collected on a DVD, enclosed with this report. The use of the DVD is straight forward for anyone with a reasonable knowledge of GIS. The DVD directory structure is shown in Figure 2 below.

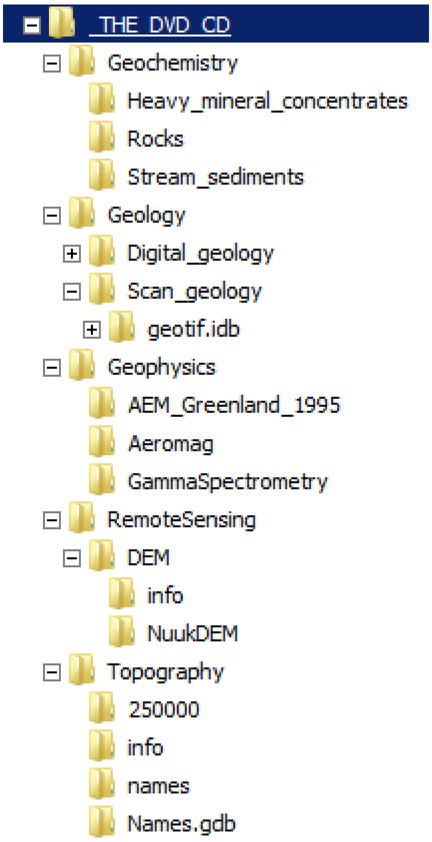


**Figure 2.** *The data directory structure for the Nuuk DVD.*

For the ArcGIS project “NuukRegion.mxd” and the 3D-scene project “NuukRegion3D.sxd” you need at least ArcGIS version 9.3 installed on your computer.

Further information on the sources and compilation processes for the various data types can be found in appendix A. Note the conditions for use printed at the inside of the cover.

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# Appendix: notes on data compilation for the DVD

In this appendix, notes concerning the data have been compiled by the researchers responsible for the data and the inclusion thereof in the DVD.

## Geochemistry

**Agnete Steenfelt & Else Moberg**

Chemical data have been obtained for a large number of samples within the assessment region. GEUS data comprise analyses of systematically collected stream sediment samples and of rock samples collected during geological mapping and mineral exploration by GEUS and co-workers.

### Regional stream sediment surveys (fine fraction)

The view displays a contoured grid image (a georeferenced TIF file) for each of the elements. Additional themes are sample location, geographic grid, and outlines of the land areas between the coast and the Inland Ice. Analytical data are not available on the DVD; they can be acquired from GEUS at cost.

#### Sampling (sample location)

The low-density coverage with stream sediment samples has been accomplished during several sampling campaigns; see Steenfelt (1999).

Suitable sample sites with an even distribution have been selected by stereoscopic inspection of aerial photographs prior to the fieldwork. Second or third order streams with catchment areas less than 20 $km^2$ are preferred. The actual sampling was undertaken by two-man crews supported by helicopter. When visited, the selected site may have been inaccessible or unsuitable in other way, and an alternative site has been sought in the same or neighbouring drainage system. In certain low-relief landscapes, proper streams were absent, and samples have been collected from sediment on the shores of small lakes instead.

At each sampling site, c. 500 g of stream sediment was collected in a paper bag, the gamma-radiation was measured and a short site description made. The stream sediment sample was composed of subsamples from three to fifteen sediment deposits along 10 to 50 m of the stream course. Samples were preferably collected among stones and gravel on the streambed, with the consideration that the resultant sample should contain a sufficient amount of fine material. Deficiency of suitable stream sediment has been met in streams with high water flow or streams in low-relief, vegetated terrain. In such places, a sample was collected from sediment trapped in moss or other vegetation between stones or along the banks.

Until 1992, the sample locations were noted on aerial photographs, transferred to topographic maps at 1:250 000 scale, and then digitised. From 1992 onwards, the Global Positioning System (GPS) was used. The DVD uses a new topographic base at scale 1:500 000 (see the section on Topography), in which streams and lakes are variably offset from their location in the old topographic base. All stream sediment sample sites have been adjusted to the new topographic base by manually moving the sample location to the proper new stream position.

**Sample preparation and analysis**

Sample bags were provisionally dried in the field before they were wrapped, packed and shipped to GEUS, Copenhagen. Samples were then oven-dried at 60°C and dry-sieved using two polyethylene screens. The fraction above 1 mm grain size was discarded, the 0.1 to 1 mm size fraction stored, and the < 0.1 mm size fraction was submitted for analysis.

The record of analytical treatment of samples throughout the long period of surveying is given in Steenfelt (1999). This report also gives a short description of each of the laboratories and analytical methods employed. In summary, all samples were analysed for major elements by X-ray fluorescence spectrometry (XRF) at either the Rock Geochemical Laboratory, GGU until 1995, now GEUS, or by Activation Laboratories Ltd. (Actlabs), Ontario, Canada. Almost all samples have been analysed for trace elements by Instrumental Neutron Activation method at either Bondar-Clegg and Company Ltd. or at Actlabs. By contrast, trace element analysis by other methods including XRF and Inductively coupled plasma emission spectrometry (ICP), have not been carried out for all samples.

**Quality control**

The low-density stream sediment data presented here are extracted from the quality-controlled and calibrated data used to produce a geochemical atlas of West and South Greenland (Steenfelt 2001). Steenfelt (1999) describes the methods used for selection of valid data and correction of analytical bias.

**Map presentation**

Data from a total of 1090 samples have been analysed for a maximum of 43 elements. A number of 28 of these are included in the GIS presentation. Main statistical parameters for the analytical data are presented in Table 1. Because of differences in analytical treatment among sample batches, all elements are not determined in all samples. All element concentrations below the lower limit of detection for the analytical method have been set to zero for simplicity, and in accordance with their registration in the GEUS database. Major element oxide concentrations have been recalculated as volatile-free concentrations to compensate for the effect of variable contents of organic matter and carbonate.

**Table 1.** *Statistical parameters for stream sediment data from southern West Greenland.*

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % |
| *Number* | *1047* | *1047* | *1047* | *1047* | *1047* | *1047* | *1047* | *1047* | *1047* | *1047* |
| Minimum | 35.83 | 0.16 | 7.63 | 0.74 | 0.03 | 0.77 | 2.28 | 0.12 | 0.34 | 0.02 |
| 10th pct | 60.09 | 0.39 | 13.96 | 3.63 | 0.06 | 1.64 | 3.89 | 3.15 | 1.14 | 0.10 |
| 20th pct | 62.36 | 0.43 | 14.31 | 4.10 | 0.07 | 1.91 | 4.09 | 3.38 | 1.27 | 0.13 |
| 30th pct | 64.01 | 0.46 | 14.54 | 4.45 | 0.07 | 2.14 | 4.26 | 3.52 | 1.37 | 0.14 |
| 40th pct | 65.02 | 0.49 | 14.68 | 4.78 | 0.08 | 2.34 | 4.37 | 3.62 | 1.45 | 0.17 |
| 50th pct | 65.97 | 0.54 | 14.87 | 5.25 | 0.09 | 2.55 | 4.54 | 3.71 | 1.53 | 0.19 |
| 60th pct | 66.71 | 0.58 | 15.03 | 5.72 | 0.09 | 2.77 | 4.72 | 3.79 | 1.60 | 0.21 |
| 70th pct | 67.40 | 0.64 | 15.24 | 6.36 | 0.11 | 3.08 | 4.90 | 3.87 | 1.69 | 0.24 |
| 80th pct | 68.11 | 0.73 | 15.47 | 7.21 | 0.12 | 3.50 | 5.20 | 3.95 | 1.79 | 0.28 |
| 90th pct | 68.94 | 0.90 | 15.85 | 8.64 | 0.14 | 4.18 | 5.58 | 4.08 | 1.96 | 0.35 |
| 95th pct | 69.88 | 1.07 | 16.33 | 9.81 | 0.16 | 5.01 | 6.07 | 4.20 | 2.18 | 0.43 |
| 98th pct | 70.52 | 1.29 | 16.90 | 11.34 | 0.19 | 6.48 | 6.78 | 4.30 | 2.52 | 0.52 |
| 99th pct | 71.15 | 1.46 | 17.50 | 12.53 | 0.21 | 8.68 | 7.26 | 4.38 | 2.78 | 0.75 |
| Maximum | 74.70 | 3.04 | 18.64 | 17.39 | 0.93 | 26.34 | 16.09 | 5.62 | 3.96 | 5.29 |

| | As | Au | Ba | Ce | Co | Cr | Cs | Cu | Nb | Ni |
|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | ppb | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm |
| *Number* | *716* | *716* | *1017* | *716* | *716* | *1017* | *716* | *869* | *1017* | *1017* |
| Minimum | 0 | 0 | 23 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10th pct | 0 | 0 | 359 | 39 | 11 | 66 | 0 | 11 | 1 | 25 |
| 20th pct | 0 | 0 | 406 | 46 | 13 | 84 | 0 | 15 | 3 | 31 |
| 30th pct | 0 | 0 | 454 | 53 | 15 | 100 | 0 | 17 | 4 | 36 |
| 40th pct | 0 | 0 | 486 | 58 | 16 | 115 | 0 | 22 | 5 | 42 |
| 50th pct | 0 | 0 | 523 | 63 | 18 | 130 | 0 | 26 | 6 | 48 |
| 60th pct | 0 | 0 | 558 | 70 | 20 | 147 | 0 | 30 | 6 | 55 |
| 70th pct | 0 | 0 | 599 | 79 | 24 | 167 | 0 | 37 | 7 | 68 |
| 80th pct | 0 | 4.0 | 640 | 90 | 28 | 200 | 2.0 | 46 | 9 | 84 |
| 90th pct | 2.0 | 8.0 | 698 | 110 | 34 | 263 | 3.0 | 63 | 11 | 114 |
| 95th pct | 3.0 | 9.3 | 800 | 140 | 40 | 350 | 4.0 | 83 | 13 | 158 |
| 98th pct | 4.0 | 12.0 | 931 | 170 | 48 | 546 | 4.0 | 113 | 16 | 230 |
| 99th pct | 5.0 | 18.0 | 1031 | 230 | 51 | 724 | 5.0 | 135 | 23 | 298 |
| Maximum | 44 | 511 | 2736 | 630 | 75 | 24770 | 10 | 302 | 412 | 1504 |

| | Rb | Sr | Th | U | V | Yb | Zn | Zr |
|---|---|---|---|---|---|---|---|---|
| | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm |
| *Number* | *1017* | *1017* | *716* | *926* | *1017* | *716* | *1017* | *1017* |
| Minimum | 0 | 43 | 0 | 0 | 42 | 0 | 0 | 4 |
| 10th pct | 21 | 225 | 3 | 0 | 62 | 1.3 | 34 | 190 |
| 20th pct | 25 | 255 | 4 | 1.1 | 68 | 1.5 | 40 | 228 |
| 30th pct | 29 | 278 | 5 | 1.5 | 73 | 1.7 | 44 | 258 |
| 40th pct | 32 | 295 | 5 | 1.8 | 76 | 1.8 | 49 | 288 |
| 50th pct | 35 | 309 | 6 | 2.1 | 82 | 2.0 | 55 | 322 |
| 60th pct | 39 | 324 | 7 | 2.8 | 87 | 2.1 | 62 | 365 |
| 70th pct | 43 | 342 | 8 | 3.8 | 94 | 2.3 | 70 | 411 |
| 80th pct | 49 | 371 | 9 | 5.4 | 107 | 2.6 | 80 | 485 |
| 90th pct | 61 | 420 | 13 | 10.6 | 135 | 3.1 | 98 | 609 |
| 95th pct | 74 | 460 | 17 | 17.0 | 169 | 3.7 | 113 | 706 |
| 98th pct | 98 | 521 | 24 | 31.5 | 205 | 6.1 | 136 | 943 |
| 99th pct | 124 | 586 | 30 | 44.6 | 235 | 7.8 | 148 | 1127 |
| Maximum | 301 | 1744 | 130 | 160 | 308 | 11.0 | 455 | 2358 |

Element distributions are illustrated by coloured grid maps using commercial software (Oasis Montaj, Geosoft Inc). The gridding was performed with the minimum curvature method, a grid cell size of 5x5 km and a blanking distance of 5 km. The square outline of individual grid cells is seen at the margin of the grid image only. The software has a default interpolation procedure for smoothing boundaries between differently coloured cells similar to contouring. The colour scale giving class intervals for grid colours is constructed individually for each element and is guided by percentiles of the frequency distribution. A rigorous use of percentiles as class intervals is not always desirable, and there are occasional deviations from this practice (compare scales with Table 1).

A map of gamma-radiation measured at the stream sampling sites is presented in view 3.4 „Regional gamma-spectrometric survey".

## Geology

**Bo M. Stensgaard**

The geology view comprises the geological maps available in scale 1:100 000 to 1:500 000 in both digital vector format and raster image format (scanned geo-referenced TIFF files of geological maps).

Table 2 summaries the content of the Geology view. Vector formats of the geological maps exist only for the central part of the Nuuk region. The vectorised maps are placed on top of scanned geological maps. Scanned geological maps include all published 1:100 000 and 1:500 000 geological maps. The legends (as pop-up pdf files) of the geological maps in raster image format is accessible by clicking within the frame of the different geological maps with the ArcMap hyperlink tool activated (activate the „lightning‟ symbol before clicking).

**Table 2.** *Overview of geological maps included in the Geology view*

| Map name | Coverage, scale | Format | Reference |
|---|---|---|---|
| Frederikshåb Isblink – Søndre Strømfjord, Sheet 2 | 62°30‟–66°45‟N;<br>49°00‟–54°00'W<br>1:500 000 | Scanned | Allaart, J.H. 1982: Geological map of Greenland, 1:500 000, Frederikshåb Isblink – Søndre Strømfjord, sheet 2. Copenhagen: Geological Survey of Greenland |
| Isukasia, 65 V.2 Syd | 65°00‟–65°30‟N;<br>49°45‟–51°27'W<br>1:100 000 | Scanned | Garde, A.A. 1987: Geological map of Greenland, 1:100 000, Isukasia, 65 V.2 Syd. Copenhagen: Geological Survey of Greenland |
| Ivisârtoq, 64 V.2 Nord | 64°30‟–65°00‟N;<br>49°21‟–50°54'W<br>1:100 000 | Scanned | Chadwick, B. & Coe, K. 1988: Geological map of Greenland, 1:100 000, Ivisârtoq, 64 V.2 Nord. Copenhagen: Geological Survey of Greenland |
| Fiskefjord, 64 V.1 Nord | 64°30‟–65°00‟N;<br>50°54‟–52°30'W<br>1:100 000 | Scanned | Garde, A.A. 1989: Geological map of Greenland, 1:100 000, Fiskefjord, 64 V.1 Nord. Copenhagen: Geological Survey of Greenland |
| Qôrqut, 64 V.1 Syd | 64°00‟–64°30‟N;<br>50°45‟–52°30'W<br>1:100 000 | Scanned | McGregor, V.R. 1984: Geological map of Greenland, 1:100 000, Qôrqut, 64 V.1 Syd. Copenhagen: Geological Survey of Greenland |
| Kangiata nuna, 63 V.2 Nord | 63°30‟–64°00‟N;<br>49°00‟–50°42'W<br>1:100 000 | Scanned | Escher, J.C. 1981: Geological map of Greenland, 1:100 000, Kangiata nuna, 63 V.2 Nord. Copenhagen: Geological Survey of Greenland |
| Buksefjorden, 63 V.1 Nord | 63°30‟–64°00‟N;<br>50°42‟–52°15'W<br>1:100 000 | Scanned | Chadwick, B. & Coe, K. 1983:: Geological map of Greenland, 1:100 000, Buksefjorden, 63 V.1 Nord. Copenhagen: Geological Survey of Greenland |
| Central Nuuk region – digital compiled map with part of the 1:100 000 scale Fiskefjorden, Qôrqut, Ivisârtoq map sheets. | 63°30‟–64°00‟N;<br>50°45‟–52°30'W+<br>64°30‟–65°00‟N;<br>49°05‟–51°15'W<br>1:100 000 | Vectorised, digital | The following three 1:100 000 scale maps form the basis geological data source for the integrated digital geological dataset:<br>• McGregor, V.R. 1984: Geological map of Greenland, 1:100 000, Qôrqut, sheet 64 V.1 Syd. Copenhagen: Geological Survey of Greenland.<br>• Chadwick, B. and Coe, K. 1988: Geological map of Greenland, 1:100 000, Ivisârtoq, sheet 64 V.2 Nord. Copenhagen: Geological Survey of Greenland.<br>• Garde, A. A. 1989: Geological map of Greenland, 1:100 000, Fiskefjord, sheet 64 V.1 Nord. Copenhagen: Geological Survey of Greenland. |

The Nordlandet area (Qôrqut map sheet) have been supplemented with data from:

- McGregor, V. R., 1993: Qôrqut 74 V.1 Syd, Descriptive Text, Fig. 5. Geological map of Greenland 1:100 000. Copenhagen: Geological Survey of Greenland.

The northern part of Storø incorporates data from:

- Steven Grimes, 2004: Preliminary bedrock geology map, north Storø, 1:20 000 (Hollis, J.A., van Gool, J.A.M., Steenfelt, A. & Garde, A.A. 2004: Greenstone belts in the central Godthåbsfjord region, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2004/110, 110 pp., 1 DVD).

# Geophysics

**Thorkild M. Rasmussen & Bo M. Stensgaard**

The geophysical information from the Nuuk region comprises magnetic, gravity, electromagnetic, radiometric and seismic data. The magnetic, electromagnetic and radiometric data are mainly obtained from airborne surveys, the gravity data are from airborne, shipborne and ground-based surveys. The data are described below with reference to either the specific survey from where the data are obtained or to previous compilations and interpretations of data.

## Radiometric data from a reconnaissance airborne radiometric survey

The radiometric data were collected in airborne surveys in 1975 and 1976 by using a contour flying technique at a nominal altitude of approximately 100 m above ground. Mean flight line separation is in the order of 5–10 km and the data are represented as concentrations of potassium [%], uranium [eU ppm] and thorium [eTh ppm]. The ratio of uranium and thorium is displayed as (U/Th+ε) with a value of ε=0.1 ppm introduced to avoid division by zero and for noise suppression. Total count values are also provided. All data are shown as colour-range symbol for each sample location.

Details about the data and acquisition techniques can be found in Tukiainen et al. (2003) and references therein.

## Magnetic data from regional aeromagnetic surveys – projects Aeromag 1996 and Aeromag 1998

The area south of latitude 63°30‟ were measured in 1996 by Geoterrex Ltd., whereas the area to the north was measured in 1998 by Sander Geophysics Ltd. Both projects were financed by the Bureau of Minerals and Petroleum.

The magnetic data originates from sampling of the total magnetic field along 500 m spaced and E-W oriented flight lines. Nominal survey altitude was 300 above ground. The data from each survey were levelled based on 5000 m separated tie-lines. Grids with cell size of 100 m from interpolated line data from the two surveys were merged into a single grid.

## Magnetic and electromagnetic data from an airborne combined magnetic and time-domain electromagnetic survey- project AEM Greenland 1995

A combined GEOTEM electromagnetic and magnetic survey was flown in the Maniitsoq-Nuuk area of southern West Greenland in 1995. Geoterrex Ltd. did the data acquisition and processing. Detailed information on the equipment and processing can be found in a report by Geoterrex Ltd. (1996). The data are presented and discussed in Stemp (1996a, 1996b) and Rasmussen et al. (2001).

Nominal flight line spacing was 400 m for the northern and southern part and 200 m for the central part of the survey area. Flight lines are oriented WSW-ENE. Orthogonal control lines were correspondingly spaced at four km and two km intervals. A total of 20 446 line km were flown. Nominal flight altitude was 120 m over terrain with the total field magnetic sensor and the electromagnetic sensor 73 m and 64 m above ground, respectively. The size of the survey area is 5235 $km^2$. Reconnaissance lines were flown south and east of the main area.

## Compilation of gravity data from various sources

The gravity data consist of merged satellite, airborne and surface gravity measurements collected by several agencies. The data are extracted as grids from the gravity database maintained by Kort & Matrikelstyrelsen (KMS; the National Survey and Cadastre Denmark) and refer to the IGSN71 datum. The different types of measurements and surveys included imply variable station spacing. Areas covered by the Inland Ice are only sparsely covered compared to onshore ice-free and offshore areas; however, great differences exist also for these areas. Problems with inconsistency at long and medium wavelengths when merging different types of gravity data (satellite, airborne and surface measurements) are minimised by use of a least squares collocation draping technique where data of high quality are used as reference for correcting data of lower quality (Strykowski and Forsberg, 1998). For oceanic parts, the Free Air anomaly is available whereas also the Bouguer anomaly is available for continental parts. A merging of three gravity grids produced the grid used for this presentation. The grids are: a gravity grid produced under the Arctic Gravity Project for the polar region north of 64°N (Kenyon and Forsberg, 2000), a similar gravity grid for South

Greenland and adjacent areas (59° – 64°N) and a gravity grid for the region between 58° – 59°N (Andersen et al., 2001).

The Bouguer anomaly correction-procedure uses the sea level as reference datum and a reduction density of 2670 kg $m^{-3}$ for areas not covered by ice. For measurements carried out on the surface of the Inland Ice or above (airborne measurements), the thickness and the density of the ice sheet are taken into account in the construction of the Bouguer gravity anomaly. Thus, a density lower than 2670 kg/$m^3$ is used. Airborne gravity data are downward continued from a nominal measuring height of 4.1 km to terrain level (Forsberg, 2002) and then the normal Bouguer anomaly correction is applied. For measurements directly on rock exposures, a correction where the topographical deviations from a Bouguer slab are taken into account is used.

## Mineral occurrences

**Bo M. Stensgaard**

The mineral occurrences are not on the DVD but can be found in GMOM on the web.

A total of 220 mineral occurrences are registered from the assessment region. Data on these occurrences have been compiled and reviewed. Many of the occurrences have also been visited by the Survey, either during recent or fieldwork prior to 2004. Subsequently, the occurrences have been registered, described and classified in a systematic way and archived in the Greenland Mineral Occurrence Map Database (abbreviated GMOM-DB; Thorning *et al.* 2004). For other examples of the systematic descriptions and further information on the used classifications, see Stendal *et al.* 2004.

A mineral occurrence in the context of this work denotes a concentration of ore mineral and includes industrial mineral, diamondiferous rocks and gemstones. Each mineral occurrence has been given a unique identification number (id. no). Closely situated occurrences of the same type have been groups and one occurrence within each group has been chosen as representative for the group. This occurrence is termed „type locality". Fifty-two type localities and associated groups (with one or more occurrences) have been identified. Each of the 52 type localities is described using a standardised form with in GMOM-DB, in which occurrences are categorised according to commodity, economical significance, occurrence type, geological setting, mineralogy, etc.

An extract of the compiled information on each type locality occurrence – a mineral occurrence description sheet – is available in Stendal *et al.* (2008) together with a summary of the geological settings and mineralisation patterns within different parts of the Nuuk region.

Some of the main references dealing with the mineral occurrences in the Nuuk region are: Andreasen 2007; Appel 1979, 1990a, 1990b, 1991, 1994, Appel et al. 2002, 2005; Garde et al. 2007, Garde 2008; Jensen & Secher 2004; Jensen et al. 2004; Juul-Pedersen et al. 2007; Knudsen 1991; Kolb & Stendal, 2007; Kristensen 2006; Larsen 1991; Olsen 1986; Østergaard & van Gool 2007; Secher 1980, 2001; Steenfelt et al. 2006, 2007; Stendal 2007; Stensgaard 2008).

## Remote sensing

**Tapani Tukiainen**

The satellite image data at the spatial resolution of 30 meters or better is available from the entire area described in this report. The image data from following sensors were used:

**ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)**

VNIR (resolution 15 m)

Band1: 0.5560 µm
Band2: 0.6610 µm
Band3N: 0.8070 µm
Band3B: 0.8040 µm

SWIR (resolution 30 m)

Band4: 1.6560 µm
Band5: 2.1670 µm
Band6: 2.2090 µm
Band7: 2.2620 µm
Band8: 2.3360 µm
Band9: 2.4000 µm

TIR (resolution 90 m)

Band10: 8.2910 µm
Band11: 8.6340 µm
Band12: 9.0750 µm
Band13: 10.6570 µm
Band14: 11.3180 µm

The following geocoded (UTM Zone 22, WGS 84) mosaics of ASTER data are included:

- Colour composite based on the ASTER VNIR data (Red: band3 Green: band 2 Blue: band 1). Spatial resolution 15 m.
- Colour composite based on the ASTER VNIR data (Red: band3 Green: band 2 Blue: band 1). Spatial resolution 30 m.
- Digital elevation model extracted from the ASTER VNIR data. Spatial resolution 30 m.

**Landsat 7 (ETM+ Landsat Enhanced Thematic Mapper)**

VNIR-SWIR (resolution 30 m)

TM Band1: 0.4950 µm
TM Band2: 0.5600 µm
TM Band3: 0.6600 µm
TM Band4: 0.8300 µm
TM Band5: 1.6500 µm
TM Band7: 2.2150 µm

The Landsat 7 data were used to map the areas of ferric oxides and gossanous alteration using Crosta-technique (Crosta & Moore, 1989).

## Topography

**Frands Schjøth & Mette S. Jørgensen**

The base map used for the geoscience data is based on the G250 Vector digital topographical map in scale 1 : 250 000, produced jointly by National Survey & Cadastre / Kort- og Matrikelstyrelsen (KMS) and GEUS in a project financed by the Bureau of Minerals and Petroleum (Minerals Office 1997). The vectorised map data are based on the printed maps as published by KMS, or where possible, on newer photogrammetric maps in scale 1 : 100 000. The original maps are in a Lambert conformal conic projection. The scanning and digitisation process therefore involved a fitting of the data to the modern standard Universal Transverse Mercator projection (UTM) for this region of Greenland by 'warping' the scanned and digitised map data to fit triangulated geodetic control points. In general, such a process is not accurate, but produces a digital map in UTM, which though on average better than the original map, still contains significant errors in the position of individual features of the map. Also, the process does not correct the position of features erroneously located on the original map.

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