DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2004/16

Mineral resources of the Precambrian shield of central West Greenland (66° to 70°15'N)

Part 1. Compilation of geoscience data

Edited by Frands Schjøth and Agnete Steenfelt

(1 DVD included)

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MINISTRY OF THE ENVIRONMENT

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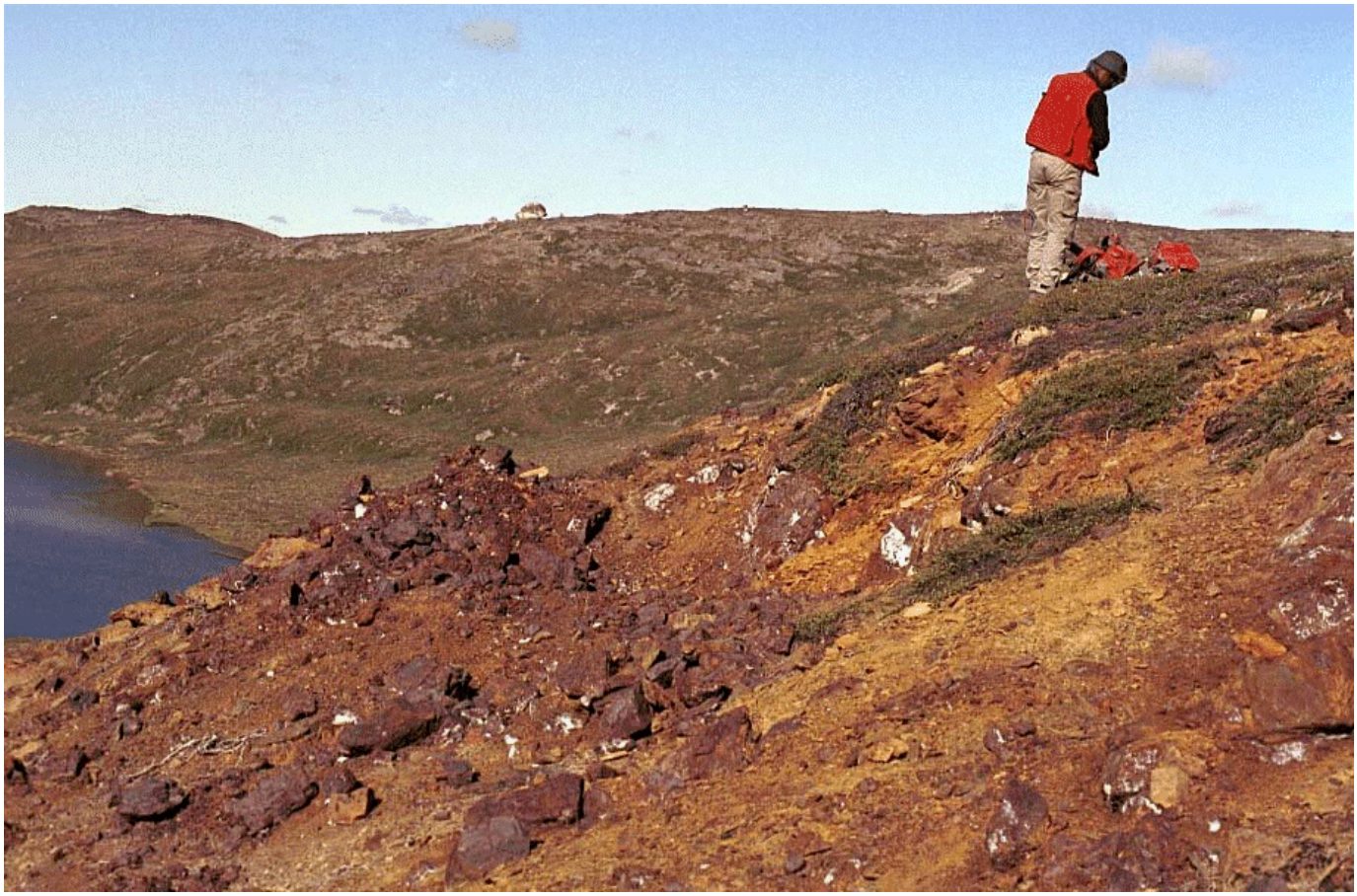

Rusty outcrops of massive pyrrhotite hosted in metasediments of the supracrustal belt at Naternaq, south-east of the town Aasiaat.

Contents

Abstract

The Geological Survey of Denmark and Greenland has conducted a four-year project with the objective of assessing the mineral resource potential of the Precambrian shield of central West Greenland. This involved geological mapping, field studies of mineral occurrences, compilation of available digital topographical, geological, geophysical, geochemical maps and data as well as publication of reports and journal articles.

The DVD of this report presents digital maps and data in an ArcView GIS project file with accessory data files, and additional text files in PDF format. The latter include this report, a report on mineral occurrences, a bibliography, a list of company reports and a list of publications related to the assessment. The text of this report provides a description of the contents of the DVD, instructions for the use of the ArcView GIS project, and documentation of the acquisition, processing and presentation of each kind of data sets included on the DVD.

The investigated region of West Greenland is underlain by an Archaean basement of tonalitic orthogneisses with intercalated supracrustal belts representing both continental and volcanic arc environments. The basement has been variably reworked during the Palaeoproterozoic Nagssugtoqidian collisional orogen and has been intruded by minor volumes of arc-related magmas in the core zone of the orogen

The investigations performed during the assessment project have contributed much to the geological understanding of this previously poorly known region of West Greenland, and has enabled the recognition of environments favourable to the formation of economic ore deposits.

The compilation of the many kinds of geoscience data in a geographical information system provides an unprecedented and inescapable base for further work in this part of Greenland, not only in geology and mineral exploration, but also in environmental science and land use planning.

Introduction

The Geological Survey of Denmark and Greenland has conducted a four-year programme on the mineral resource potential of central West Greenland (Fig. 1) in 2000–2003. The programme involved compilation of all available digital geoscience data in a Geographical Information System, compilation of literature and company reports dealing with the region, description of known mineral occurrences and an assessment of the compiled information with regard to mineral resource potential. The programme also comprised geological mapping and investigations of mineral occurrences in the field. The results obtained are published in GEUS reports, journal articles, abstracts and workshop proceedings (see Appendix). Four geological map sheets at 1:100 000 scale are underway to being prepared for publication by GEUS.

The study region largely consists of Archaean and Palaeoproterozoic orthogneisses and supracrustal rocks. The Archaean basement comprises remnants of supracrustal successions hosting iron-formations and syn- and epigenetic gold occurrences. The supracrustal strata probably represent continental shelf as well as back-arc and volcanic arc depositional environments. The Archaean basement together with Palaeoproterozoic cover rocks has been variably affected by the Palaeoproterozoic Nagssugtoqidian orogeny. The core zone of the orogen, situated in the central part of the study region, comprises volcanic, sedimentary and plutonic rocks generated in a volcanic arc environment. Abundant minor occurrences of semi-massive sulphides and two major graphite occurrences are associated with the supracrustal rocks. The Archaean basement south of the orogen hosts a swarm of Phanerozoic diamond bearing kimberlite dykes and a carbonatite complex with a significant Nb-Ta occurrence.

The present report includes a DVD with the compiled digital information from central West Greenland together with a separate GEUS report on mineral occurrences, lists of compiled literature references and company reports, and a list of publications related to the project. The report is mainly aimed at professionals in mining and mineral exploration, but many data sets may also be useful for geo-scientists in general as well as for environmental scientists.

The user of the compiled data is reminded of the constraints for their use as specified in the colophon of the report.

The map data are presented as an ArcView GIS project file with accompanying accessory files, the remaining information as PDF files. The first section of this report explains how the data are organised and used, and the following sections provide information on the acquisition and processing of each kind of data. Some of the geophysical and geochemical maps are only presented as images in the project file. The original data behind such maps can be obtained at cost from GEUS.

The presentation of these data follows the tradition of a range of previously published data on CD-ROM/DVD (see Schjøth & Thorning 1998; Pedersen 1999; Schjøth *et al.* 2000; Steenfelt 2001; Rasmussen *et al.* 2001; Appel *et al.* 2003; Jensen *et al.* 2003).

The digital information represents an extract from the information system GimmeX (Geoscience information management for mineral exploration) developed and operated by the Department of Economic Geology. This is a combination of databases, programs and work procedures, which are used in the Survey's research activities in Greenland.

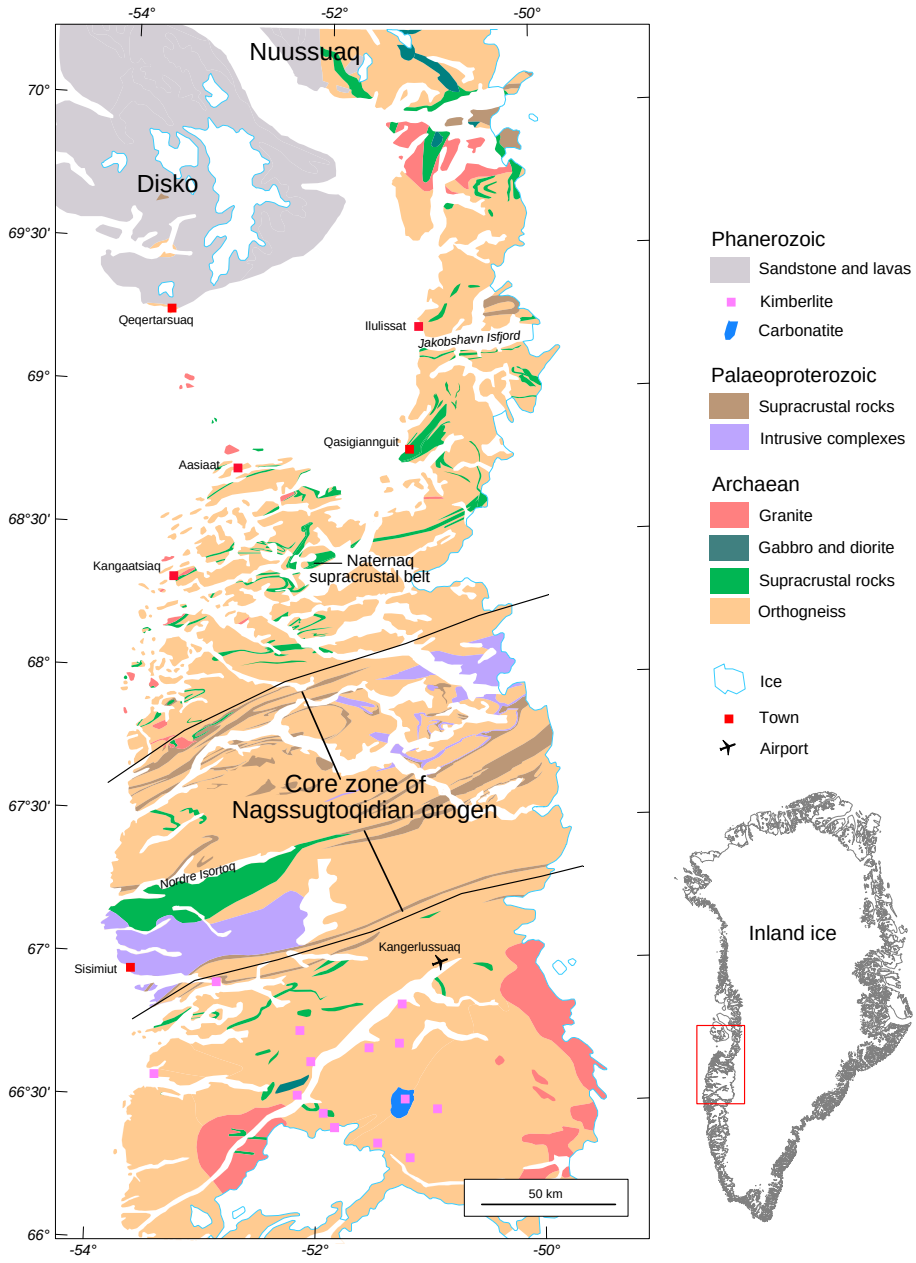

Figure 1. *Location (red frame) and simplified geology of central West Greenland. Data from the Phanerozoic strata on Disko and Nuussuaq are not included in the compilation. The basis for the map is given in the section 'Geological maps', View 2.1, of this report.*

The DVD

The DVD accompanying this report contains the hitherto most comprehensive digital geoscience data from central West Greenland. In agreement with the stated strategy of the Greenland Home Rule Government, the DVD has been compiled with the basic philosophy in mind that quality controlled digital data should be released for general use in order to promote their use in mineral exploration.

General information

In the subsequent sections of this report, each type of data is dealt with separately. Firstly, general information on the use of the DVD is presented. The user is expected to have a fair knowledge of ArcView GIS and its use, and basic functions of ArcView GIS are not explained.

The ArcView Project File has been constructed using ArcView GIS version 3.3 and makes full use of many of the facilities in this version of the programme. The project has been designed and tested in Windows 2000 and NT 4.0. The screen layout of views etc. has been designed to be optimal for a 17” screen size.

Some information is provided as PDF-files for use in the Adobe Acrobat Reader program. A free installation kit for Acrobat Reader, version 5.1, is included on the DVD for those users who do not already have access to this program.

Directory structure of the DVD

The directory structure of the DVD is visualised in Figs 2 and 3, showing the top level and sub levels, respectively. The central West Greenland Project File itself is the *CWGMineralResources.apr* in the root directory.

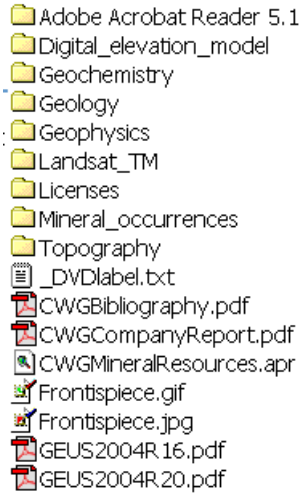

Figure 2. *Top level directory of the DVD. The 'CWGMineralResources.apr' file is the ArcView GIS Project File.*

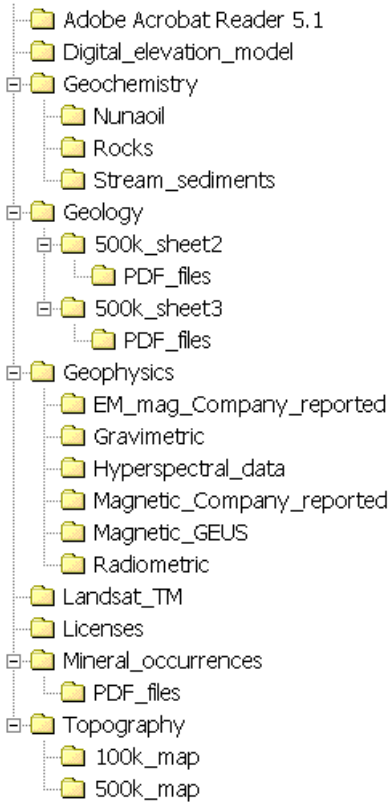

Figure 3. *Directory structure of the DVD including main and sub levels.*

Use of the DVD

1. Place the DVD in the slot.
2. Start ArcView GIS 3.3 on your computer.
3. Open the ‘CWGMineralResources.apr’; it will probably take some time to load.
4. The Project file will open on a view (1.0), which contains the location of the study region in Greenland. When this is closed, a list of views will become visible/appear. Choose the desired view and start exploring the data.

If desired, the entire directory structure of the DVD with all the files can be copied to your hard disk as long as the same structure is maintained.

The most common file extensions of the many different data types on the DVD are

ArcView GIS shapefiles as .SHP
Textfiles as .TXT
Images as .GIF, .TIF, .JPG and .BMP
Adobe as .PDF

In order to extend the functionality of the ArcView GIS project file some customised Avenue scripts (ArcView GIS internal macro language) has been added to the project. The Avenue scripts have been well tested and they work as long as the data on the DVD keeps the same relation to each other.

The customised Avenue script for linking to PDF-files uses the location of the file ‘Frontis-piece.jpg’ which is read from the first view (‘0.1 Frontispiece’) in the ArcView GIS project file. If the user saves a version of ArcView GIS project file it should be noticed that if the linking to the PDF-files should still work then keep the ArcView GIS view ‘0.1 Frontispiece’ in the ArcView GIS project file.

In Adobe Acrobat Reader it is recommended to open cross-document links in a separate window. This is done as follows in Adobe Acrobat Reader:

Adobe Acrobat Reader 5.0 and 5.1:

Edit > Preference > Options
uncheck ‘Open Cross-Document Links in Same Window’

Adobe Reader 6.0 :

Edit > Preference > General
uncheck ‘Open cross-document links in same window’

Added buttons in ArcView GIS project file

The two blue tool buttons marked ‘1024’ and ‘1280’ serve two purposes:

1. In the Project window, press one of the buttons to resize the project window to fit a screen with 1024 × 768 or 1280 × 1024 pixels, respectively

2. In any View, press one of the buttons to select and make active one from a list of Views. Selecting a View also resizes it to a screen with 1024 × 768 or 1280 × 1024 pixels, respectively

In the ArcView GIS view, the button marked ‘R16’ opens the PDF file ‘GEUS2004R16.pdf’ (the present report).

In the ArcView GIS view, the button marked ‘R20’ opens the PDF file ‘GEUS2004R20.pdf’ (the report on mineral occurrences).

In the ArcView GIS view, the button marked ‘Bib’ opens the PDF file ‘CWGBibliography.pdf’’ (the bibliography for central West Greenland).

In the ArcView GIS view, the button marked ‘Com’ opens the PDF file ‘CWGCompanyReport.pdf’ (the company report for central West Greenland).

The ‘hot-link’ button is clear (not dimmed) when a GIS theme has links. This facility is computed in the view ‘5.1 Mineral occurrences’.

Data presentation and acquisition

The geoscience data are presented in a number of views in the ArcView GIS project file (*CWGMineralResources.apr*). Wherever possible the maps have been adjusted for presentation in 1:500 000 scale, using the topographic base at this scale.

The projection parameters of the base map and for all spatial data described in the following sub-sections, are:

Geodetic reference:	WGS84
UTM-zone:	22 (*i.e.* the central meridian is 51° West)
False Easting:	500 000

The copyright for topographic base data in scales 1:100 000 and 1:500 000 belongs to GEUS and shall be notified as follow:

Topographic base: copyright GEUS 2003

The copyright for the topographic base for the geological map in scale 1:2 500 000 belongs to Kort & Matrikelstyrelsen (National Survey of Cadastre, KMS) and GEUS and shall be notified as follow:

Topographic base: G/2.5 M Vector, copyright KMS/GEUS 1997

Topography

View 1.0 Index map

Location of the region studied in the programme 'Mineral resources of the Precambrian shield of central West Greenland (66° to 70°15'N)' on a map of Greenland.

Digital topographic map **(Hans F. Jepsen & Willy L. Weng)**

History

The history of the topographic mapping of West Greenland is described in Nielsen *et al.* (1995). Prior to 1974, the Danish Geodetic Institute (now part of the National Survey and Cadastre, KMS) compiled maps covering the project area at scale 1:250 000. From the middle 1970's new techniques were available: 1) Satellite based geodetic ground control;

2) High altitude super-wide angle photography; 3) Computation of large least squares bundle adjustment; 4) Digital registration from photogrammetric stereo plotters. These techniques were not used by KMS to compile new maps in the project area. However, at the same time the Geological Survey of Greenland (GGU) needed modern topographic maps for compiling geological data at map scale 1:100 000 and 1:500 000. In 1977 GGU established a Laboratory for Geological Applied Photogrammetry using the new methods for producing high precision digital geological and topographic data from the study of aerial photographs of Greenland (Hougaard *et al.* 1991).

In 1995, the Geological Survey of Greenland (GGU) and the Geological Survey of Denmark (DGU) merged to become the Geological Survey of Denmark and Greenland (GEUS), and GEUS has continued the high precision mapping of areas in Greenland where geological mapping was undertaken.

Coverage, origin and description of data

The present project area covers West Greenland from 66°00' N to 70°15' N and comprises c. 51 000 km^2 ice-free land area (Fig. 1). The GGU/GEUS laboratory produced digital topographic data covering the area during the period from 1986 to 2001.

The topographic data have been grouped into subsets reflecting that the quality of the ground control of the photogrammetric methods have improved over the years (Fig. 4). Aerial photography from *c.* 14 km altitude with super-wide-angle 9-inch photogrammetric cameras (giving a nominal scale of 1:150 000) was carried out by KMS in 1985 and 1987 and is the basis for all map productions.

Ground control was also established by KMS. From 1976 the TRANSIT satellites and Doppler measurements and later GPS measurements were used at a number of geodetic control points to strengthen the traditional trigonometric network. The network was tied to the reference frame WGS84.

A large part of the area is aerotriangulated by KMS. In each aerial photograph 10+ points are measured, each of which are measured in 2 – 4 different overlapping photographs. The location of the geodetic ground control were visually transferred to the photographs and included in the point measurements. The observations were computed in a least squares adjustment (Poder, 1982), with each photo treated as a free bundle of rays. The adjusted xyz-ground coordinates have root mean squared (rms) errors better than 10 m.

The time-consuming measurement of the many photos covering all of Greenland lasted some 25 years. Approximately 50% of the project area was aerotriangulated by the GGU laboratory using photogrammetric model coordinates as computational units. The resulting GGU-generated ground coordinates have xy-rms errors of app. 30 m and z-rms errors of app. 10 m.

Up to 1999, a mechanical-optical 2nd order stereo-restitution instrument of the type KERN PG2 using transparent photographic copies of the aerial photographs produced the topographic data from the GEUS laboratory. Both the hydrographic themes (coastlines, lakes,

rivers, ice margins) and the contour lines were generated manually. In the period up to mid-1988, the PG2 instrument were equipped with a slow prototype xyz-digitiser which time and again would skip one or two vertices when the stereo-operator was drawing with at high speed.

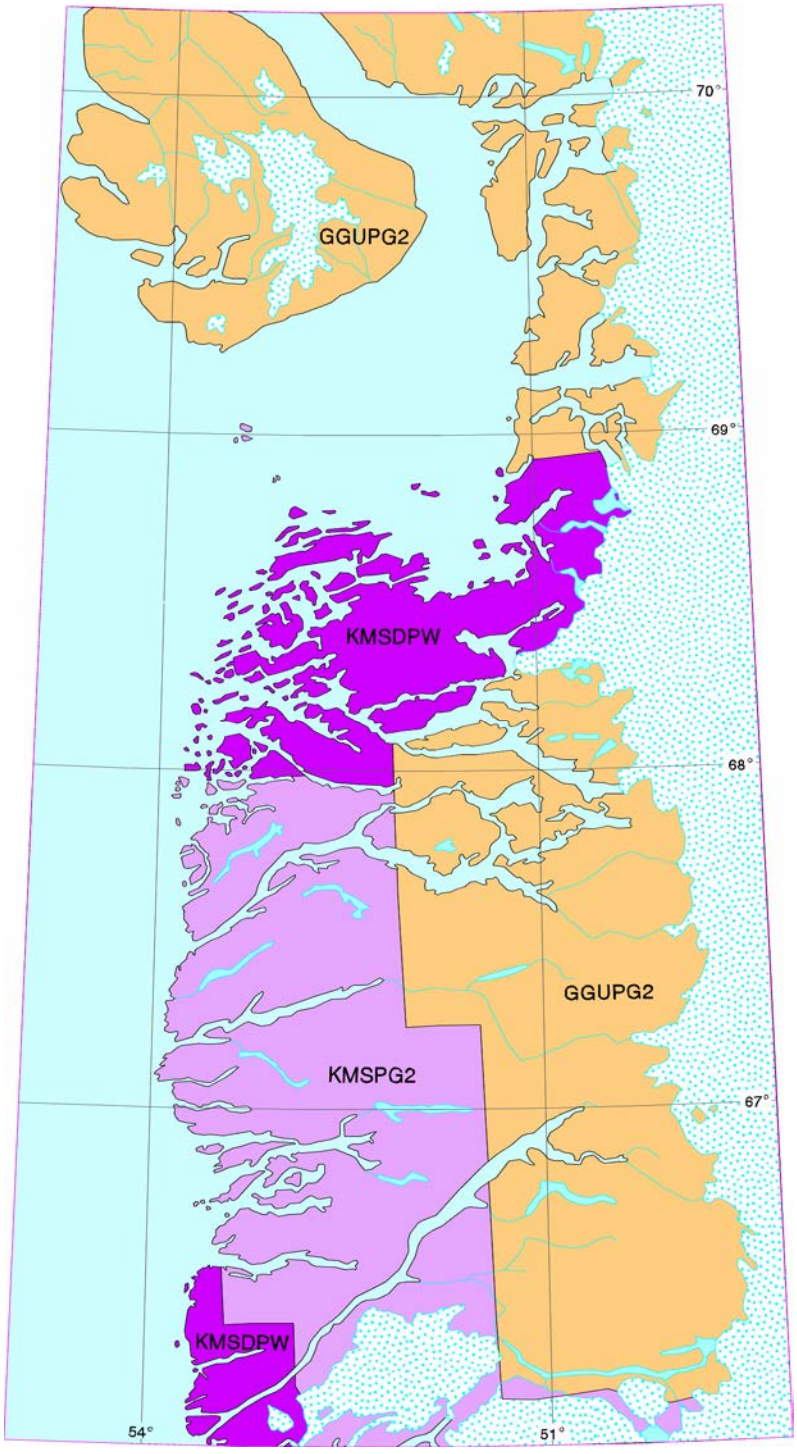

Figure 4. *Index map showing topographic data subsets. GGUPG2 = PG2 data based on GEUS aerotriangulation, KMSPG2 = PG2 data based on KMS aerotriangulation and KMSDPW = DPW data based on KMS aerotriangulation.*

From 2000 and onwards topographic data has been produced by a digital photogrammetric workstation (DPW) from LH-Systems using digital scanned copies of the aerial photographs. The hydrographic themes are still generated manually whereas the contour lines are generated from an automatically extracted digital terrain model (DTM). Breaklines including the hydrographic themes are included during the DTM generation.

GIS vector data set

The raw 3D photogrammetric data (at scale of 1:100 000) are exported to the Esri ArcInfo GIS-platform as 2D data. The topology is validated (i.e. polygons are closed) and attribute data are added. In a semi automatic procedure the 1:100 000 data are generalised to a 1:500 000 version using line smoothing, elimination of small areas and minor rivers. Data at the two target scales are each unified in to seamless data sets. Both data sets are available on the attached DVD.

View 1.1 Digital topographic map 1:500 000 (Mette S. Jørgensen)

This view presents an overview map showing land, sea, ice, major lakes, the latitude-longitude net, and place names as shapefiles. Many of the basic topographical line and polygon features are hidden in the opening map, but they are all contained in the themes 'Line features' and 'Polygon features'. In addition, some of the features are presented separately, i.e. ice, major lakes, small lakes, streams, alluvial deposits, so that they may be copied to other views. 'Line features' include coastline (including outlines of lakes and the margin of ice caps), streams and 200 metre contour lines. The polygon features include land area, ice, sea, lakes, and both the water surface and the alluvial islands and banks in large braided streams.

The location of towns, villages and airstrips is shown. Names of the large island of Disko, the peninsula Nuussuaq and the inland area of Naternaq are given, and (in italic) of major fjords, the large bay of Disko Bugt, the Sarfartoq valley and Sukkertoppen ice cap.

Geographical feature	Name of shapefile	Includes
Geographic net whole degree	Net500	Lines
Placenames	Placenames	Points
200 m contour line	Contours	Lines
Stream	Rivers	Lines
Alluvial deposit	Alluvium	Polygons
Line feature	Coast_l	Lines
Small lake	Minor_lake	Polygons
Major lake	Major_lakeriver	Polygons
Inland ice	Ice	Polygons
Polygon feature	Coast_p	Polygons

Table 1. *Features included as themes in the view. Suitable combinations of these features are also presented in other views.*

View 1.2 Topographic base map 1:100 000 (Mette S. Jørgensen)

The 1:500 000 scale topographic features are appropriate for most of the views presenting regional data. However, 1:100 000 scale features can be useful in views presenting local scale data and sample location as well as for a general appreciation of detailed topographical variation in areas of interest. The latter can be useful for field planning. In this view, only the streams are shown as a separate line-feature theme.

Geographical feature	Name of shapefile	Includes
Geographic net whole degree	Net500	Lines
Geographic net half degree	Net100_30	Lines
Placenames	Placenames	Points
Stream	Rivers	Lines
Line feature	Coast_l	Lines
Polygon feature	Coast_p	Polygons

Table 2. *Features included as themes in the view. A few of these features are presented in other views.*

View 1.3 Digital terrain model (Frands Schjøth)

View 1.3 shows a digital terrain model (DTM) with 50-metre pixel size covering the entire region and a detailed model (16-metre pixel size) covering a small area used in connection with a hyperspectral survey (see View 4.7). Both models are presented as geo-referenced TIF-files.

The regional DTM is made using ArcInfo Workstation TIN-extension (TIN = Triangulated Irregular Network) in command line mode. The data set at 1:100 000 scale, including all valid 100-metre contour lines, is used to create this model. The input lines and polygons are generalised to 50-metre vertex length. The altitude of the lakes is used and the rivers are used as hard break-line. The sea-polygon is added as a hard erase area to improve the visual display of the land area. The TIN-output is then converted to a grid with a cell-size of 50 metres using the ArcView GIS extension Spatial Analyst. A hillshade relief with a simulated light source from 315°N and 45° declination is computed. The grid and the hillshade are then converted to an image using a free ArcView GIS extension.

The 16-metre cell-size DTM is made by GEUS' Laboratory for Geological Applied Photogrammetry.

View 1.4 Landsat TM mosaic (Tapani Tukiainen)

Since the launch of the Landsat 7, Central West Greenland has been well covered by Landsat TM data. The satellite image map presented in this view is based on four nominal Landsat TM scenes (Fig. 5) acquired by the Landsat 7 satellite. Image data were delivered in the form processed to Level 1G from Eros Data Center, USA, which implies that the data were radiometrically and geometrically corrected and georeferenced to UTM projection

(Zone 22, Geodetic reference WGS84). The geometric accuracy of the systematically corrected product should be within 250 metres (1 sigma) for low-relief areas at sea level. The topographic vector data match the geocoded image data well, thus confirming the reported geometric accuracy.

The final image mosaic was prepared by histogram matching of the four scenes. Landsat TM bands 4 (Red), 3 (Green) and 2 (Blue) have been used for the colour composite. The mosaic layout is given in Fig. 5.

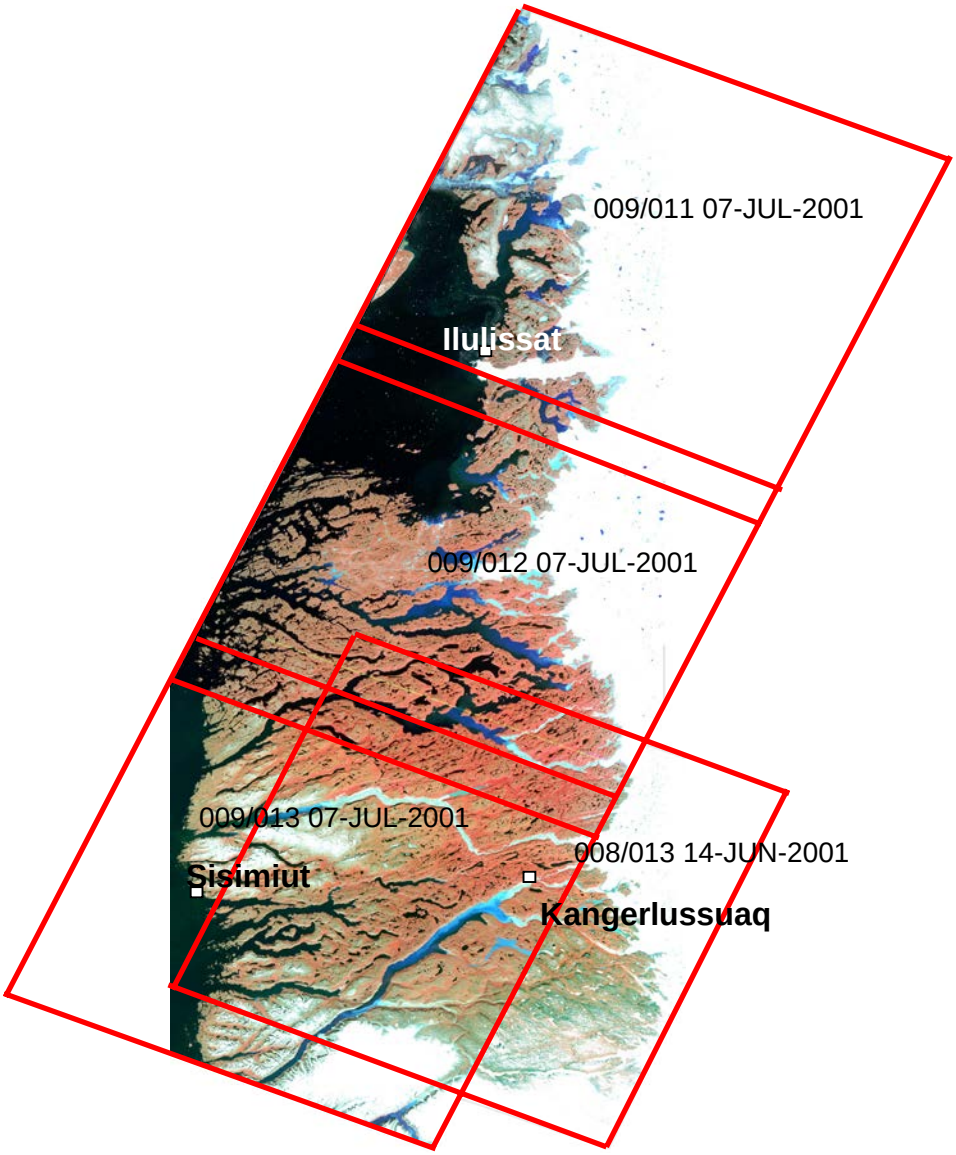

Figure 5. *Landsat TM scenes (Landsat 7 ETM+) used for the production of the satellite mosaic image of West Greenland. For each scene path/row and acquisition date is given.*

The image is of a good quality over most of the area. Due to an acquisition date early in the year, the area covered by the scene 008/013 has more extensive snow cover. There are some major scan line dropouts in the southern part of the scene 009/012. These are in band 3 of the original data. Because of the magnitude of the dropouts (> 15 lines), no cosmetic corrections have been applied to remove these.

To minimise the atmospheric differences between scenes, ´black pixel´ extraction was applied to each scene separately

Geological maps

A digital geological map at scale 1:500 000 is not available for the entire region, but two traditional printed maps at this scale published by the Geological Survey of Greenland (GGU) are included as images. In addition, digital versions of other geological maps are presented.

The main features of the geology of the region are published in Garde and Steenfelt (1999), 69° to 70°30'N, van Gool *et al.* (2002b), 66° to 69°N. The main account of carbonatitic and alkaline ultramafic magmatism in the region is given by Larsen & Rex (1992). The report by Stendal *et al.* (2004), stored on the DVD of this report provides a summary description of the geology and mineral occurrences of the region. Additional literature references may be found in the comprehensive bibliography enclosed as a PDF file on the DVD.

View 2.1 Revised geological map 1:2 500 000 (Adam A. Garde)

Investigations by the Danish Lithosphere Centre, 1994 to 1997 (van Gool *et al.* 2002b), together with geological mapping by GEUS, 2001 to 2003, at 1:100 000 scale (van Gool *et al.* 2002a) in the central part of the assessed region (between latitudes 67° and 69° N) have demonstrated a need for revising the published geological maps.

The view presents a preliminary version of a revised digital map of the study region at 1:2 500 000 scale based on the geological map of Greenland published by Escher & Pulvertaft (1995) and described by Henriksen *et al.* (2000). The outline of the carbonatite complex (see Fig. 1) has been digitised from Secher (1986), and it reflects the outer boundary of the fenitised zone surrounding a core of carbonatite. The revised map only portrays regional scale features as it is intended for presentation in publications, but it reflects the present perception of the regional geology. Notice that the copyright of the topographic base for this map is 'G/2.5 M Vector, copyright KMS/GEUS 1997'. The map in the introduction of this report (Fig. 1) is a simplified version of the map presented in the view.

Kimberlite dykes
This theme illustrates the distribution of the most important of the numerous known kimberlite dykes and sheets in this province. The information is drawn from a report with DVD by

Jensen *et al.* (2003) that compiles a comprehensive amount of data on kimberlite exploration.

View 2.2 Scanned geological maps 1:500 000 (Frands Schjøth)

Most of the assessed region is covered by the map 'Geological map of Greenland 1:500 000, sheet 3' published in 1971 (Escher 1971; Escher 1997), while the southern part can be seen in 'sheet 2' of the same map series (Allaart 1982; Allaart 1998). The two maps are displayed as images in view 2.1. The maps have been produced using an old topographic base so that displayed features on the old maps do not exactly match the corresponding position in the modern, more accurate digital topographic base used elsewhere on the DVD.

It must be pointed out that these maps are meant as reconnaissance maps; geological features and structures in inland areas are largely based on interpretation of aerial photographs, and the maps do not meet today's knowledge and demands. Later mapping and investigations (Garde 1994; maps underway by Jeroen van Gool and Adam Garde, pers. comm. 2004) have found many incorrect features in these maps, particularly in 'sheet 3'. However, the legends of the maps provide useful information on the lithology, mineralogy, metamorphic grade and structure of mapped units.

View 2.3 Local digital geological map 1:500 000
(Mette S. Jørgensen & Agnete Steenfelt)

The view contains a digital version of a geological map of the northernmost part of the assessed region (the Disko Bugt region, originally printed at 1:250 000 scale, Garde 1994). The map presented here has been adjusted to fit the 1:500 000 scale topographical base, and it has been simplified by merging some lithological units and deleting very small lithological features as well as line features such as faults, fold axes and dykes. The map is topographically compatible with the geophysical, geochemical and mineral occurrence maps.

Geophysics

The presentation of geophysical data comprises six views with results of regional scale surveys of the earth's magnetic field, gravity field and gamma radiation, as well as local scale acquisition of electromagnetic (EM), magnetic and hyperspectral data. Regional aeromagnetic surveys with an almost uniform data density have covered the entire region, while detailed measurements of the magnetic field combined with electromagnetic measurements or hyperspectral measurements have been made in small areas for specific purposes. The sampling of the gravity field is non-uniform with large variations in sampling density. The radiometric surveys cover a large part of the area, but have very irregular sampling density.

View 3.1 Regional magnetic surveys (Thorkild M. Rasmussen & Bo M. Nielsen)

This view includes ten images based on data from regional airborne surveys 'Aeromag 1992', 'Aeromag 1997' and 'Aeromag 1999' funded by the Bureau of Minerals and Petroleum, Government of Greenland, and supervised by GEUS (Thorning 1993; Rasmussen & van Gool 2000). Survey specifications are given in Table 3.

Survey parameters	Aeromag 1992	Aeromag 1997	**1. Aeromag 1999**
Area	Lersletten, central West Greenland	Disko-Nuussuaq region, central West Greenland	Southern West Greenland
Measurements	Magnetic total field	Magnetic total field	Magnetic total field
Orientation of regular survey lines	N–S	N–S	N–S
Spacing between regular survey lines	1 km	500 m over land, 1000 m over sea	500 m
Orientation of tie-lines	E–W	E–W	E–W
Spacing between tie-lines	10 km	5 km	5 km
Total line kilometres	10062 km	70630 km	141009 km^2
2. Terrain clearance	515 m	300 m	300 m
Area extent	8610 km^2	46390 km^2	61292 km^2
Contractor	Geoterrex Ltd.	Sander Geophysics Ltd.	Sander Geophysics Ltd.

Table 3. *Information on government-funded regional magnetic surveys*

The original data are stored at GEUS and may be obtained at cost. For the presentation of the maps of this view, the appropriate data from the three surveys have been merged and processed to produce maps displaying variations in the magnetic total field and eight calculated parameters listed below.

The maps represent gridded and interpolated data using a distance between grid-nodes of 100 m and a minimum curvature method for the interpolation, and they appear in the view as colour images (geo-referenced TIFF files). The shaded image has a simulated light source from NW with an inclination of 45 degrees. The Cretaceous-Palaeogene strata on Disko and Nuussuaq were surveyed in Aeromag 97, but this part of the image has been hidden because the mineral resource assessment programme reported here is limited to the Precambrian shield.

The ten map images (ArcView GIS themes) presented in the view are

- Magnetic total field
- Magnetic total field, shaded image
- Vertical gradient of magnetic total field
- Horizontal gradient in N-direction of the magnetic total field
- Horizontal gradient in NE-direction of the magnetic total field
- Horizontal gradient in E-direction of the magnetic total field
- Horizontal gradient in SE-direction of the magnetic total field

- Amplitude of horizontal gradient vector of the magnetic total field
- Amplitude of analytic signal of the magnetic total field
- Pseudo gravity field calculated from the magnetic total field

Details on the calculation and interpretation of the processed data used in this presentation may be found in Nielsen & Rasmussen (2004) and references therein.

View 3.2 Local EM and magnetic surveys
(Thorkild M. Rasmussen & Bo M. Nielsen)

The view contains images produced from data obtained in combined electromagnetic and magnetic helicopterborne surveys financed by commercial companies for mineral exploration purposes. According to the regulations for mineral exploration in Greenland, all data obtained by commercial companies must be delivered in copy to the Bureau of Minerals and Petroleum, Nuuk. GEUS is responsible for the storage and maintenance of such data, which after a period of confidentiality becomes public domain data. All data reported here are now in the public domain and the original data can be obtained at cost from GEUS.

The nominal altitude for the magnetic and EM-sensors is 30 m above ground. Most of the surveys are flown with 200 m line-spacing. The electromagnetic induction measurements utilise artificial sources. Frequency domain data are obtained by either the Dighem^{VRES} system or the five-frequency Aerodat-system. Additional data types have been obtained in some surveys, e.g. digital elevation models. The reader is referred to the company reports cited below for additional details about equipment and data.

Only the magnetic total field data are displayed on the DVD. The data are displayed as geo-referenced coloured map images in tif-format. Shaded images have a simulated light source from NW with an inclination of 45 degrees.

The name of each ArcView GIS theme reflects the GEUS Report File (GRF) number given to the company report that holds the information about the survey and the block number.

Survey for Fjordland Minerals Ltd by Aerodat Inc, 4 blocks (Woolham 1997):
- GRF21604_01_mag
- GRF21604_02_mag
- GRF21604_03_mag
- GRF21604_04_mag

Survey for Monopros Ltd by Aerodat Inc, 3 blocks (Johnson 1997)
- GRF21642_sa1_mag
- GRF21642_sa2_mag
- GRF21642_si3_mag

Survey for Monopros Ltd. by High Science Geophysics Ltd., 7 blocks (Andrews 1998):
- GRF21686_saf1_1_mag
- GRF21686_saf1_2_mag
- GRF21686_saf2_1_mag
- GRF21686_saf2_2_mag

GRF21686_saf3_1_mag
GRF21686_sis3_1_mag
GRF21686_sis3_2_mag

Survey for Dia Met Minerals Ltd by Geoterrex-Dighem Ltd, 3 blocks (Stephens 1999):

GRF21702_a_mag
GRF21702_b_mag
GRF21702_c_mag

Survey for Softrock Petroleums Ltd by Geoterrex-Dighem Ltd, 2 blocks (Chung 1996):

GRF21828_a_mag
GRF21828_b_mag

View 3.3 Local magnetic survey (Thorkild M. Rasmussen)

This view contains a single image of data obtained from an airborne magnetic survey carried out by Sander Geophysics Ltd for Platinova A/S (O'Connor 1999). The data are displayed as a coloured image and included as a geo-referenced file in tif-format. Shading is added to the image by simulating a light source illumination from NW and inclination of 45 degrees.

View 3.4 Regional gravimetric survey (Thorkild M. Rasmussen & Bo M. Nielsen)

This view contains images of gridded gravimetric data compiled by Kort- og Matrikelstyrelsen (Strykowski & Forsberg 1998; Kenyon & Forsberg 2000; Andersen, Knudsen & Trimmer 2001; Forsberg 2002). The original grid has a cell dimension of 5 minutes of an arc.

Free-air gravity values are displayed for offshore areas and both Bouguer gravity anomalies and Free-air anomalies are shown for onshore areas. The calculated vertical gradient of merged Bouguer and Free-Air anomaly data is displayed. Images are presented with and without shading. The shade is created by simulating a light source from NW with an inclination of 45 degrees The ArcView GIS themes are:

- Free-air and Bouguer, shaded: Free-air gravity anomalies for offshore areas and Bouguer anomalies for onshore areas
- Free-air and Bouguer: Free-air gravity anomalies for offshore areas and Bouguer anomalies for onshore areas
- Free-air, shaded: Free-air gravity anomalies
- Free-air: Free-air gravity anomalies
- Vg Free-air and Bouguer, shaded: Calculated vertical gradient of merged free-air anomalies for offshore areas and Bouguer anomalies for onshore areas. Shadow added to the image
- Vg Free-air and Bouguer: Calculated vertical gradient of merged free-air anomalies for offshore areas and Bouguer anomalies for onshore areas

Details of data processing may be found in Nielsen & Rasmussen (2004).

View 3.5 Regional gamma-spectrometric survey
(Agnete Steenfelt & Karsten Secher)

The view contains four themes illustrating the variation in gamma-radiation emitted from radioactive decay products of naturally occurring K, U and Th in surface materials. The data are derived from an airborne survey (Secher 1976) covering the region south of Jakobshavn Isfjord (see location in Fig. 1).

Data acquisition and processing

A four-channel gamma-ray spectrometer with a detector-volume of 11 litres installed in a fixed-wing aircraft was used to measure the gamma-radiation at a height of about 90 m above the ground. Flight lines followed the topographical contours. Further technical details of the survey and data treatment are given in Tukiainen *et al.* (2003). The data were corrected for background radiation, and counts recorded in the K, U and Th channels were corrected for contributions from decay series of the other radioelements (stripping). The measurements have not been corrected for variation in ground clearance, but the altitude data have been screened to include only those obtained within an interval of 75 to 105 m above terrain. Furthermore, all negative values in the data sets have been removed. Negative values result from the stripping in situations where monitoring conditions have not been ideal. The frequency distributions of values for each of the parameters are shown in Fig. 6.

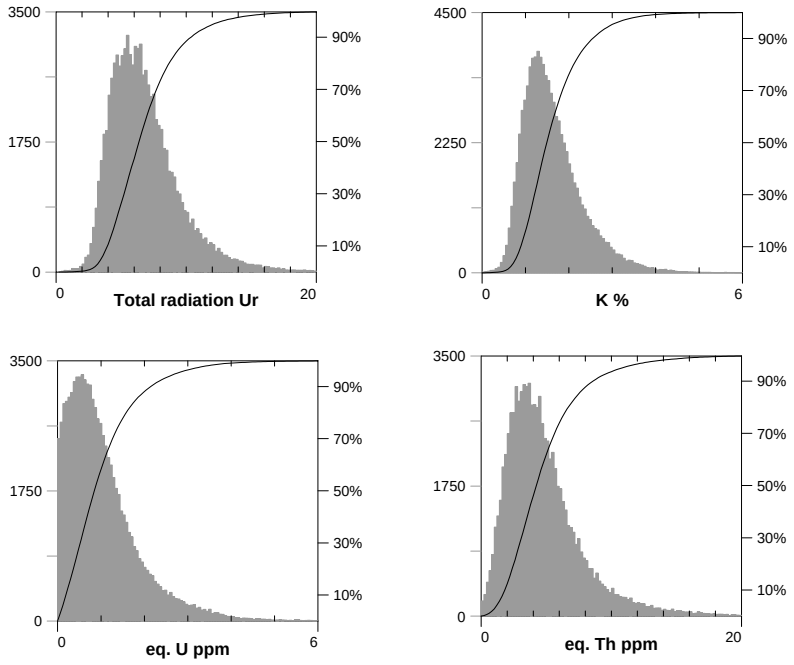

Figure 6. *Frequency distributions of values for four parameters recorded by airborne gamma-spectrometry in central West Greenland. The graphs represent 86283 data records that are plotted in the view.*

Data presentation
The screened data are presented as coloured dot plots along flight lines. The total gamma-radiation is given in the international unit Ur (Unit of radioelement concentration), and the data from the other channels as equivalent concentrations of the overflown ground, K in %, eq. U and eq. Th in ppm. The scaling of the dot colours is based on percentiles relating to the frequency distribution of the measured data, and the intervals are chosen to enhance the highest and lowest values. The nine percentile intervals used are: below 10, 10–25, 25–40, 40–60, 60–75, 75–90, 90–95, 95–98 and above 98. The legends of the themes list the actual values corresponding to the percentile intervals together with the maximum values.

View 3.6 Regional ground gamma radiation (Agnete Steenfelt)

During the systematic stream sediment sampling for geochemical mapping (Steenfelt 2001) the total gamma-radiation from the ground (outcrops and boulders) was measured at each sampling site with a Scintrex SPP2 scintillometer. The measurements were recorded as counts per second. The data represent 2123 site measurements and are presented as a colour-scaled contoured grid image prepared in the same way as the stream sediment grid images (View 4.1).

View 3.7 Local hyperspectral survey (Tapani Tukiainen)

The view presents the coverage of Project HyperGreen2002, an airborne hyperspectral survey performed July – August 2002 over an area south-west of Kangerlussuaq. The project was financed by the Bureau of Minerals and Petroleum, Government of Greenland, and carried out by the Geological Survey of Denmark and Greenland (GEUS) and HyVista Corporation, Australia.

The prime objective of the airborne survey was to assist the mapping of kimberlite occurrences by testing how well the method would work under arctic, high relief conditions. In order to establish the spectral characteristics of the kimberlitic rocks in West Greenland, a ground survey was carried out to measure spectra from selected kimberlite occurrences. Tukiainen *et al.* (2003) describes the results of this work and presents a spectral library of relevant rock types and alteration products.

Data acquisition
The HyMap hyperspectral scanner (Cocks et al. 1998) used in the airborne survey is a state-of-the-art aircraft-mounted commercial hyperspectral sensor developed by Integrated Spectronics, Sydney, Australia and operated by HyVista Corporation, Sydney, Australia. The HyMap system uses a whiskbroom scanner with diffraction gratings and four 32-element detector arrays to provide 126 spectral channels covering the 0.45 – 2.5 μm range over a 512-pixel swath width.

The survey was flown with an instant field of view (IFOV, also termed pixel size) of 5 metres, 20% overlap between lines, and an approximate ground speed of 140 knots (277

km/hour). Aircraft navigation data (X, Y, Z and aircraft attitude) were provided by Differential Global Positioning System (DGPS) and Integrated Inertial Monitoring Unit (IMU).

For the HyMap instrument, the IFOV of 5 metres correspond to the flight altitude of 2500 metres (8200 feet), at which altitude the scanner's swath width is approximately three kilometres. The flight altitude was determined in relation to the local topographic base level.

The airborne hyperspectral survey comprised 54 flight lines totalling approximately 3500 line kilometres, which correspond to ground coverage of approximately 7500 km^2. Highly variable cloud-covers prevented continuous surveying of large areas, and the resulting survey consists of 10 partially overlapping subsets that together provide a reasonably satisfactory data coverage.

Data processing

The contractor delivered the data on 72 DVDs. The following items were delivered:

Item	Format
Flight line radiance cubes & dark current and on-board lamp calibration files	ENVI (BIL)
Flight line spatial data	ASCII
Flight line apparent reflectance data (Image data in units of apparent reflectance where atmospheric correction is implemented using the HyCorr programme	ENVI (BIL)
Geo-referenced files including a 3 band geo-referenced image based on a digital terrain model (50 m resolution) by GEUS	ENVI
Images from the digital camera (RGB colours). The digital images cover only certain parts of the area.	ENVI

In order to fully exploit the possibilities of hyperspectral image data, the radiance data delivered by a hyperspectral scanner system need to be converted to surface reflectance data. Several commercially available programmes have been developed to perform this task, such as Flaash, ATREM, ACORN, and HyCorr. However, these programmes do not use terrain models in the calculation of atmospheric corrections, and they are considered inadequate to perform high-quality corrections of data obtained in mountainous terrain.

The quality of the contractors's apparent reflectance data has proved insufficient. Consequently, a proportion of the data has been re-processed at GEUS making use of a detailed (16 m resolution) digital terrain model (DTM) produced at GEUS' Laboratory for Geological Applied Photogrammetry laboratory. The georeferencing of the image data used a parametric approach based on the detailed DTM and flight line ephemeris (spatial) data. The atmospheric correction was made by means of the advanced modelling method of the ATCOR4 – package (Richter 2003), which also uses the information from the detailed DTM.

So far, new surface reflectance data have been produced this way for the flight lines underlain by the detailed DTM, and they correlate well with obtained spectral ground truth data. The data recorded outside the detailed DTM remain in the form delivered by the contractor. All the hyperspectral data are available at cost from GEUS. A preliminary interpretation of the re-processed hyperspectral data is published by Tukiainen & Krebs (2004).

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 the Danish Lithosphere Centre. In addition, GEUS has acquired analyses of fine and heavy mineral fractions of stream sediment collected within two minor areas from the exploration company NunaMinerals A/S (previously Nunaoil A/S).

View 4.1 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 Table 4, Fig. 7 and reports listed in the reference list.

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.

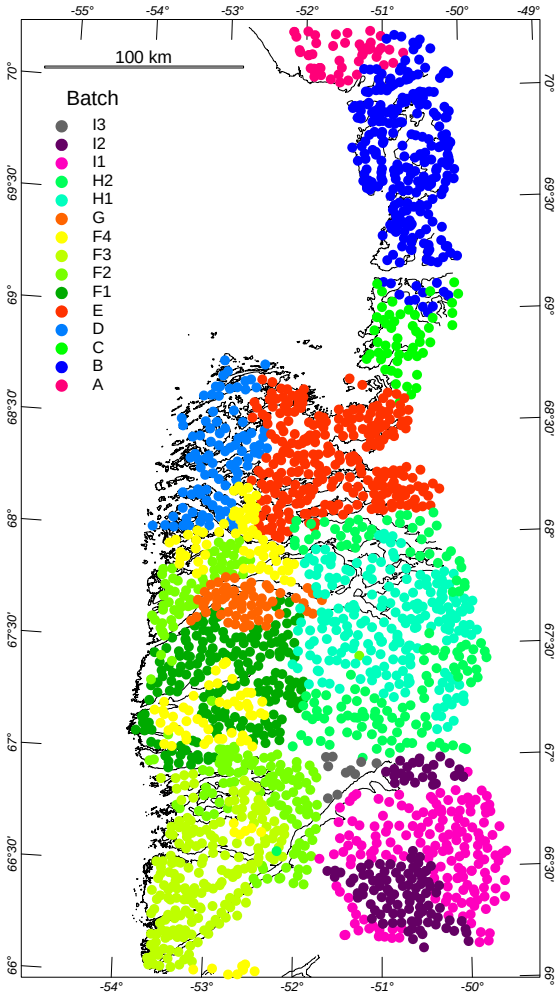

Figure 7. *Stream sediment sample sites of individual surveys within the assessment region.*

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 (1999a). This report also gives a short description of each of the laboratories and analytical methods employed. Table 4 shows the analytical source for each sample batch and element. 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, XRF and Inductively coupled plasma emission spectrometry (ICP), have not been carried out for all samples.

Batch code	Year of sampling	Stream sediment sample series	Major elements	Elements by INA and DNC			Elements by INA	
				As,Au,Br,Cs, Mo,Sb,Ta,W	Nd,Lu	U	Eu,Yb	Ce,Co,Hf,La, Sc,Sm,Th
A	1988	330701-836	GGU*	B-C INA	Act INA (few)	Risø DNC	Act INA (few)	B-C INA*
B	1986	330401-668	GGU*	B-C INA	Act INA (few)	Risø DNC	Act INA (few)	B-C INA*
C	1989	330901-971	GGU	B-C INA	Act INA (few)	B-C INA*	Act INA (few)	B-C INA*
D	1993	381966-382060	GGU	Act INA	Act INA	Act INA	Act INA	Act INA
E	1991	380001-303	GGU	Act INA	Act INA	Act INA	Act INA	Act INA
F	1992	380401-381149	Act	Act INA	Act INA	Act INA	Act INA	Act INA
G	1977	193001-598	Act	Act INA	Act INA	Risø DNC	Act INA	Act INA
H1,H2	1990	368001-367	GGU	Act INA	Act INA	Act INA	Act INA	Act INA
I1	1981	306001-150,306201-251	GGU	Act INA	Act INA	Risø DNC	Act INA	Act INA
I2	1982	306401-548	GGU*	Act INA	Act INA	Risø DNC	Act INA	Act INA
I3	1986	330670-695	GGU*	B-C INA	no data	Risø DNC	no data	B-C INA*

Batch code	Elements mainly by XRF			Elements mainly by XRF				
	Ba,Cr	Ni,Sr	V	Rb,Zn,Zr	Nb	Y	Ga	Cu
A	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF(poor)	GGU XRF(poor)	no data	GGU AAS
B	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF(poor)	GGU XRF	no data	GGU AAS
C	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
D	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	GGU AAS
E	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
F	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
G	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
H1,H2	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I1	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I2	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I3	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF*	GGU XRF(poor)	GGU XRF(poor)	no data	GGU AAS

* analysed without standards

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* B-C *(Bondar-Clegg and Co. Ltd.).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* DNC *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry);* AAS *(Atomic Absorption Spectrometry).*

Table 4. *Sample batches within the assessment region (see Fig. 1) together with analytical laboratories and methods for data used to produce the geochemical atlas of West and South Greenland as well as the grid maps of the present DVD. From Steenfelt (1999a).*

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 (1999a) describes the methods used for selection of valid data and correction of analytical bias.

Map presentation

Data from a total of 2123 samples analysed for a maximum of 43 elements are included in the presentation. Main statistical parameters for the analytical data are presented in Table 3. Because of differences in analytical treatment among batches, not all elements are 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

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
	%	%	%	%	%	%	%	%	%	%
Minimum	38.97	0.18	7.20	0.68	0.02	0.55	1.74	0.51	0.37	0.03
10th perc.	59.13	0.42	13.91	3.65	0.06	1.44	3.26	3.16	1.31	0.13
20th perc.	61.82	0.47	14.21	4.36	0.08	1.78	3.74	3.37	1.43	0.15
30th perc.	63.45	0.51	14.41	4.99	0.09	2.00	4.01	3.47	1.52	0.17
40th perc.	64.46	0.56	14.59	5.50	0.10	2.23	4.22	3.54	1.59	0.18
50th perc.	**65.33**	**0.62**	**14.76**	**6.01**	**0.11**	**2.45**	**4.42**	**3.62**	**1.65**	**0.20**
60th perc.	66.29	0.69	14.97	6.52	0.11	2.63	4.70	3.68	1.73	0.22
70th perc.	67.50	0.77	15.20	7.09	0.12	2.81	4.94	3.75	1.82	0.24
80th perc.	68.86	0.88	15.57	7.84	0.13	3.08	5.19	3.85	1.94	0.29
90th perc.	70.24	1.06	16.08	9.08	0.15	3.68	5.57	3.96	2.14	0.39
95th perc.	71.06	1.22	16.62	10.25	0.17	4.38	6.06	4.05	2.38	0.48
98th perc.	71.99	1.44	17.58	11.73	0.21	5.34	6.70	4.19	2.62	0.63
99th perc.	72.49	1.71	18.15	12.96	0.24	6.09	7.27	4.30	2.77	0.81
Maximum	75.10	9.90	31.00	44.83	0.63	10.61	10.24	5.10	5.32	2.89

	As	Au	Ba	Br	Ce	Co	Cr	Cs	Cu	Eu	Ga
	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum	0	0	0	0	20	0	0	0	0	0.6	9
10th perc.	0	0	433	2	43	11	47	0	9	1.1	16
20th perc.	0	0	462	4	54	14	63	0	12	1.2	16
30th perc.	0	0	486	6	62	16	79	0	17	1.3	17
40th perc.	0	0	506	8	69	17	92	0	21	1.4	18
50th perc.	**0**	**0**	**534**	**10**	**77**	**19**	**104**	**0**	**27**	**1.5**	**18**
60th perc.	0	0	565	13	88	21	116	0	34	1.6	19
70th perc.	0	0	608	18	97	23	129	0	43	1.7	20
80th perc.	0	0	663	27	114	27	148	0	57	1.9	21
90th perc.	3	6	736	43	140	33	188	2	82	2.2	22
95th perc.	4	7	805	61	180	39	239	2	110	2.7	23
98th perc.	8	10	985	88	223	49	323	4	164	3.2	25
99th perc.	13	14	1134	110	260	59	405	4	213	3.8	26
Maximum	717	115	3628	190	1000	130	920	11	825	10.1	32

	Hf	La	Lu	Mo	Nb	Nd	Ni	Rb	Sb	Sc	Sm
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum	0	11	0.05	0	0	7	0	9	0	4.1	1.7
10th perc.	7	26	0.17	0	4	18	20	26	0	11	3.7
20th perc.	9	32	0.21	0	4	22	26	31	0	12	4.3
30th perc.	10	36	0.24	0	5	26	31	34	0	13	4.7
40th perc.	11	40	0.26	0	6	28	37	37	0	14	5.1
50th perc.	**12**	**45**	**0.28**	**0**	**6**	**32**	**42**	**40**	**0**	**15**	**5.5**
60th perc.	14	52	0.31	0	7	36	47	43	0	16	6.0
70th perc.	16	57	0.34	0	8	41	54	47	0	17	6.7
80th perc.	18	68	0.37	0	10	48	65	54	0	19	7.6
90th perc.	23	87	0.43	0	13	62	93	65	0.3	22	9.3
95th perc.	27	120	0.50	0	18	79	121	75	0.4	25	11.0
98th perc.	35	160	0.56	5	29	110	176	93	0.6	29	13.4
99th perc.	41	190	0.64	7	38	140	221	110	0.8	32	15.6
Maximum	99	710	1.20	21	173	390	774	159	36.4	45	46.0

Table continued on next page

	Sr	Ta	Tb	Th	U	V	W	Y	Yb	Zn	Zr
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Minimum	97	0	0	0	0	0	0	0	0.90	0	66
10th perc.	260	0	0	3.0	0	57	0	14	1.40	33	202
20th perc.	303	0	0	3.8	0.4	67	0	16	1.56	40	240
30th perc.	331	0	0	4.6	0.9	76	0	17	1.70	47	276
40th perc.	348	0	0	5.4	1.1	85	0	18	1.80	53	308
50th perc.	**363**	**0**	**0**	**6.2**	**1.4**	**93**	**0**	**19**	**1.95**	**59**	**340**
60th perc.	378	0	0	7.2	1.7	102	0	20	2.10	66	375
70th perc.	393	0	0	8.1	2.2	111	0	21	2.30	74	424
80th perc.	423	0	0.6	9.6	3.0	123	0	23	2.54	84	481
90th perc.	504	1	0.9	12.3	5.1	154	0	26	2.97	103	572
95th perc.	603	1	1.0	16.0	8.3	184	0	29	3.50	121	668
98th perc.	696	2	1.2	21.0	14.9	215	0	36	4.00	144	827
99th perc.	851	2	1.6	25.0	21.5	236	0	41	4.39	159	930
Maximum	2091	5	3.3	40.0	60.0	1030	13	72	9.49	260	1742

Table 5. *Statistical parameters for stream sediment data from central West Greenland.*

Element distributions are illustrated by coloured grid maps using software (Oasis Montaj) provided by Geosoft Inc. The gridding was performed with the kriging method using a power model, 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 5).

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

View 4.2 Local stream sediment surveys (fine fraction and HMC)

This view contains maps illustrating the distribution of element concentrations in fine fraction and heavy mineral concentrates produced from stream sediment samples collected at a density of 1 sample per 3 km^2 within two areas in the northern part of the assessment region. A summary description of the sample treatment is given below. The company report (Sieborg 1992) describes sampling and analytical procedures in more detail and discusses the analytical data. Nunaoil A/S collected a number of stream sediment samples in 1992 as a follow-up within gold anomalous areas (Grahl-Madsen 1993).

The sample sites have been marked on topographic maps (1:100 000) available in 1991. Their position has been adjusted to fit the new topographic base used on the DVD.

Sampling and field preparation

A helicopter- and boat-supported survey was conducted in 1991 in two areas within the assessment region (Fig. 9). In total, 1433 sample sites were visited, and at each site two samples were collected, one 15-20 kg sample of coarse gravel and sand for heavy mineral

recovery, and one *c.* 1 kg of sand and silt. In a few cases where proper streams were missing, substitute samples were collected in soil or scree.

At the base camp, both sample types were wet-screened to < 0.5 mm. The large samples were panned on a vibrating gold screw and the heavy mineral concentrate (HMC) recovered and dried. The smaller and finer grained samples (SS) were dried.

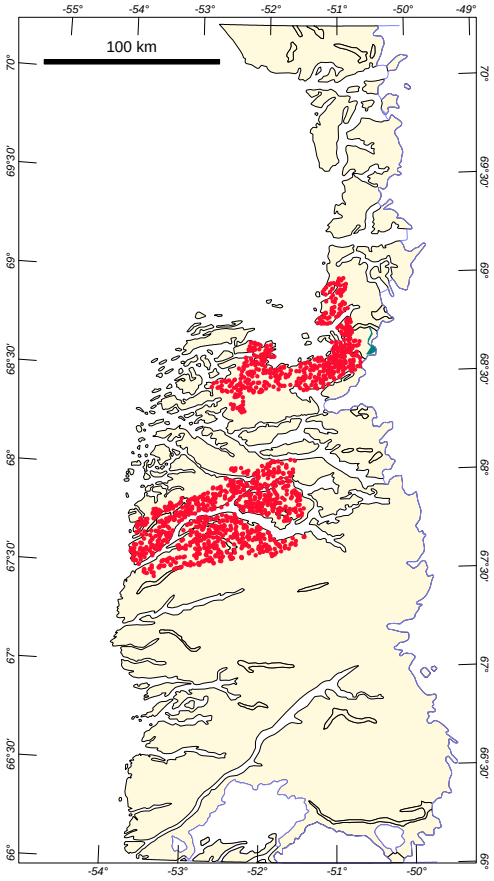

Figure 8. *Location of stream sediment samples provided by NunaMinerals A/S.*

Laboratory preparation and analysis

Both sample types were screened to < 0.25 mm before analysis. The HMC were analysed by Instrumental Neutron Activation analysis (INA) and by Atomic Absorption Spectrometry (AAS) upon digestion with Aqua Regia. The SS were digested in Aqua Regia and analysed by AAS, selected samples additionally analysed for Au using Fire Assay combined with Inductively Coupled Plasma Emission Spectrometry (ICP). Table 6 gives a few parameters for analytical data selected for presentation on the DVD.

Map presentation

Distribution maps for the elements listed in Table 6 are shown as coloured dot maps, in which samples with high concentrations are enhanced.

Stream sediment < 0.25 mm					
	N (total)	Det. lim.	N > det. lim.	Maximum	98th percentile
AAS					
Ag_ppm	1381	0.1	748	1.6	1
Pb_ppm	1381	1	1381	105	25
Cu_ppm	1381	1	1381	504	93
Zn_ppm	1381	1	1381	439	110
Fire assay, ICP					
Au_ppb	142	1	1	11	

HMC < 0.25 mm					
AAS	N (total)	Det. lim.	N > det. lim.	Maximum	98th percentile
Ag_ppm	1397	0.2	1042	1.4	0.6
Pb_ppm	1397	1	1389	38	15
Cu_ppm	1397	1	1397	216	48
INA					
Au_ppb	1398	5	227	3820	93
Ag_ppm	1398	5	4	88	
As_ppm	1398	2	190	300	13
Ba_ppm	1398	200	420	1500	660
Co_ppm	1398	5	1381	110	63
Cr_ppm	1398	10	1398	2000	740
Hf_ppm	1398	1	1396	420	210
Mo_ppm	1398	20	15	700	
Sb_ppm	1398	0.2	115	2.7	0.7
Sc_ppm	1398	0.1	1398	210	82
Ta_ppm	1398	1	398	59	9
Th_ppm	1398	0.5	1394	800	430
U_ppm	1398	0.5	1286	210	28
W_ppm	1398	4	79	320	26
Ce_ppm	1398	3	1398	4920	1800
Yb_ppm	1398	0.2	1395	67.9	21.4

Table 6. *Statistical parameters for selected chemical data derived from stream sediment, fine and heavy mineral fractions, respectively. Based on data delivered by NunaMinerals A/S (formerly Nunaoil A/S). AAS = Atomic absorption spectrometry. ICP = Inductively coupled plasma emission spectrometry. Det. lim. = lower detection limit.*

View 4.3 Rock chemical data

The view illustrates the distribution of rock samples collected, analysed and stored during GEUS activities within the assessment region. The GEUS databases contain most of but not all locations and analytical data. The available analytical data are sorted and displayed in themes according to analytical method. The tables accompanying the themes document the analytical data.

Sampling

The samples have been collected by Survey geologists working in the area for various purposes, such as geological mapping, geochemistry, ore geology and mineral exploration. No systematic rock sampling has been attempted. The main activities comprise: 1988-1991 Disko Bugt project, geological mapping and investigation of mineral occurrences (Kalsbeek, ed.1999); 1994-1997 DLC research in the Nagssugtoqidian orogen (Marker *et al.* 1995; van Gool *et al.* 1996); 2000-2003 GEUS mineral resource assessment project (geological mapping and investigation of mineral occurrences) reported here, see the bibliography on the DVD.

Sample location and description

The table associated with the theme 'Rock description' contains the sample location, year of sampling, collector's name and five fields with sample-description parameters. The table uses *n.a.* (not available) for missing information.

The accuracy of the sample location is variable reflecting the changing conditions. Since 1997, field geologists have used the Global Positioning System. Before that time, sample locations were read or digitised from manually plotted points on topographic maps of variable quality. The introduction of the new 1:500 000 topographical base made it necessary to adjust sample positions recorded using the old topographic base. This has been done using a mathematical function that relates the old and new map base. Still, the user of the DVD should bear in mind that the position of samples collected before 1997 might not be very accurate. If an accurate position is needed, the reader is referred to the original sample location maps archived at GEUS.

Digital rock sample descriptions have been stored at GGU (GEUS since 1995) since 1991. Fig. 10 shows the layout of the rock sample description form used by GEUS in the field. The geologist marks the boxes, which appropriately describe the sample. The form is then digitised and entered into the database. The information extracted and contained in the table associated with the theme 'Rock description' is framed in red in Fig. 10.

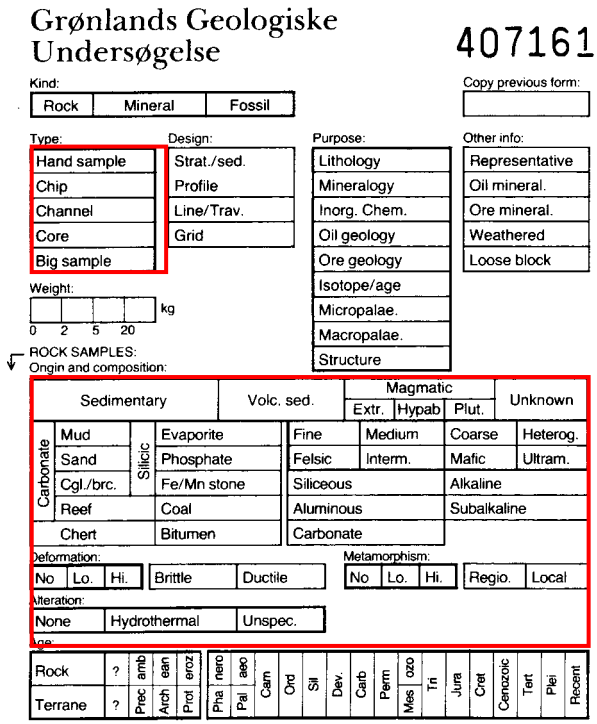

Figure 9. *Rock sample docket used in Greenland fieldwork since 1990 by GEUS (GGU before 1995). The sample number is unique. The rock_description file associated with the view contains the red-framed information. See text for further explanation.*

The column *Type* refers to the division within the upper red frame of the docket label. The column *Origin_comp* describes what has been marked in the fields of the lower red frame. A sedimentary rock is described by its composition using the boxes of the left-hand side, a magmatic rock by its grain-size, colour and composition using the boxes of the right-hand side. Thus when the field reads '*Magmatic Extr Fine Mafic*', it means that the sample is a fine-grained, mafic, extrusive magmatic rock.

Chemical analysis

The theme-maps presented in this view show the distribution of samples analysed by a particular laboratory and method. The analytical data are found in the tables associated with the themes. Information on the laboratory and method is given in abbreviated form in the theme names and in the table-headers of the analytical data. The file Rock-lab_method.txt contains the full names of the laboratories and methods, and the file Rock-lab_element.txt the suite of oxides and elements determined by each method. This enables the user to make a personal judgement regarding the quality of the data and based on that to what extent the analytical data from different sources may be merged. An evaluation of the quality of chemical data from some of the sources is given in Steenfelt (1999a,b). Results below the lower detection limit of the analysis method are given either as '0' or a negative number, meaning that the concentration is less than the number, in the analytical data tables.

Mineral occurrences **(Bo M. Nielsen, Henrik Stendal & Karsten Secher)**

View 5.1 Mineral occurrences

The mineral occurrences presented in this view have been compiled using published information, non-confidential company reports and results of fieldwork by GEUS researchers in 2001 and 2002. All known mineral occurrences have been registered, classified and described, and the mineral resource potential of the entire region has been assessed based on the abundance, spatial distribution, size, grade, age and genesis of the mineral occurrences (Stendal *et al.* 2004, 'GEUS2004R20.pdf' included on the DVD of this report). A list of company reports dealing with mineral occurrences in central West Greenland is also provided on the DVD.

The results of the grouping and classifications of mineral occurrences are listed in the 'Mineral occurrence table' associated with the view, and the distribution of the registered occurrences, groups and categories are displayed by seven themes. Further information on the principles used in the classification may be found in the report mentioned above.

Location

The theme shows the location of all registered mineral occurrences. The associated table contains the id. numbers and coordinates.

Type localities

Closely situated occurrences of the same type have been grouped, and the most important within each group has been termed 'type locality'. A description in standardised form has been made of each of the 53 type localities within the assessed region. The descriptions are stored individually in PDF files and are accessed using the 'hot-link' from the symbols on all theme maps.

Mineral occurrence groups

The theme shows how the mineral occurrences are grouped using a colour symbol for each group. The 'hot link' from each symbol opens the PDF file with the description of the appropriate type locality.

Economic significance

The economic significance of each mineral occurrence is estimated using a ranking from 1 to 4 of decreasing significance.

1. *Mineral deposit* - denotes an operating mine, abandoned mine or a mineral occurrence that is believed to have a high potential for becoming economically feasible, but which is presently uneconomic.
2. *Mineral prospect* - denotes a mineral occurrence, which has been drilled or investigated in some details and is believed to have a moderate or small potential for becoming economically feasible.
3. *Mineral showing* - denotes a mineral occurrence, which has a significant concentration of ore minerals, but is believed to have no economic feasibility on its own.
4. *Mineral indication* - denotes a mineral occurrence of minor extent, with only a small concentration of ore minerals, or an occurrence for which information is currently limited.

Commodity group

The mineral occurrences are classified according to their main potential commodity. The present theme displays the commodity groups represented by the occurrences according to the table below.

Commodity group	Geochemical elements/minerals
Precious metals	Au, Ag, PGE
Base metals	Cu, Pb, Zn, Sn
Light metals	Al, Mg, Ti, Li
Iron and ferroalloys	Fe, Mn, Cr, Ni, Co, Mo, W, V
Speciality metals	REE, Y, Zr, Li, Be, As, Bi, Sb, Cd, Ga, Hg, Nb, Ta,
Fissionable metals	U, Th
Industrial minerals	Graphite, phosphate, cryolite, sillimanite/kyanite, diopside, garnet
Gemstones	Diamond, cordierite (dichroite), ruby

Table 7. *Commodity groups.*

Commodity

Here the main potential commodities of the mineral occurrences are shown by symbols representing 18 different commodities.

GSC mineral deposit type

This theme refers to a classification into mineral deposit types used by the Geological Survey of Canada (GSC) for Canadian mineral deposits (Eckstrand *et al.* 1996), which has been adopted in a slightly modified version to accommodate Greenland mineral occurrences. The main categories of the Canadian classification are listed in Table 8, together with those subcategories that are used to classify mineral occurrences within the assessed region. Mineral deposit types relevant in the assessed region are marked in blue.

Category	Mineral occurrence types (Canadian mineral deposit types)
1.0	Placer uranium, gold
1.2	Placer (Placer Au, Pt)
2.0	Stratiform phosphate
3.0	Stratiform iron
3.2	Algoma-type iron-formation
4.0	Residually enriched deposits
5.0	Evaporites
6.0	Exhalative base metal sulphides
6.3	Volcanic-associated massive sulphide base metals
6.4	Volcanic-associated massive sulphide gold
7.0	Unconformity-associated uranium
8.0	Stratabound clastic-hosted uranium, lead, copper
9.0	Volcanic redbed copper
10.0	Mississippi Valley-type lead-zinc
11.0	Ultramafic-hosted asbestos
12.0	Volcanic-associated uranium
13.0	Vein uranium
14.0	Arsenide vein silver, uranium
15.0	Lode gold
15.2	Quartz carbonate vein gold
15.3	Iron-formation-hosted stratabound gold
16.0	Clastic metasediment-hosted vein silver-lead-zinc
17.0	Vein copper and hydrothermal alteration (Vein copper)
18.0	Vein-stockwork tin, tungsten
19.0	Porphyry copper, gold, molybdenum, tungsten, tin, silver
20.0	Skarn deposit

Table continues on next page

Category	Mineral occurrence types (Canadian mineral deposit types)
21.0	Granitic pegmatites
22.0	Kiruna/Olympic Dam-type iron, copper, uranium, gold, silver
23.0	Peralkaline rock-associated rare metals
24.0	Carbonatite-associated deposits
25.0	Diamond (Primary diamond deposits)
25.1	Kimberlite-hosted diamond
26.0	Mafic intrusion (Mafic intrusion-hosted titanium-ore)
27.0	Magmatic nickel-copper-platinum group elements
27.2	Magmatic platinum group elements
28.0	Mafic/ultramafic rocks and related minerals (Mafic/ultramafic-hosted chromite

Table 8. *Main categories and selected sub-categories of Canadian mineral deposits types (Eckstrand et al. 1996) used to classify mineral occurrences within the assessed region. The blue classes are used in this report. Where categories are modified, the original names are given in parentheses.*

Mineral licenses (Mette S. Jørgensen & Frands Schjøth)

View 6.1 Mineral exploration licenses 1992 – 2002

The mineral industry has been active in exploration in Central West Greenland for many years and in many ways. The administrative handling of exploration and exploitation licenses is undertaken jointly by the Bureau of Minerals and Petroleum (BMP) in Greenland and GEUS. The information on licenses (coverage, duration) is stored in a GEUS database (GREENMIN; Thorning *et al*. 2000), and all reports submitted by the license holders are registered and archived at GEUS.

The view is based on information in the GREENMIN database and contains nine maps (shapefiles), each showing the position and coverage of active exclusive exploration licenses within the Precambrian shield (i.e. excluding Disko and western Nuussuaq) for one of the years 1992 to 2002. The associated table can be reached via the ArcView GIS information tool and provides information on the licensee, GREENMIN identification number, Bureau of Minerals and Petroleum (BMP) license number, etc. Note that licensed areas may change from year to year as well as in the course of one year (reduction, termination, perhaps followed by new license to another company covering the same or a similar area). The maps presented here only shows the summary situation year by year (ultimo December). More exact data concerning license amendments may be obtained from the Bureau of Minerals and Petroleum.

Concluding remarks

The DVD contains an unprecedented collection of maps, data and literature references that will be an inescapable basis for further mineral exploration, scientific investigations and interpretation in the region. A proportion of the compiled data has been acquired before the initiation of the four-year programme. Thus, the Disko Bugt region (north of Jakobshavn Isfjord) was studied by GEUS 1988 to 1992, and the central part of the region was studied by the Danish Lithosphere Centre 1994 to 1997. However, much new knowledge and data have been acquired during the programme, in particular in the region from Jakobshavn Isfjord to Nordre Isortoq (see Fig. 1), and in the kimberlite province in the southern part of the region.

Although the work presented in the DVD and the four accompanying reports represents a major progress in our documentation and understanding of the geology and mineral potential, it should be pointed out that certain areas have received little attention. Thus, investigations in the southern part of the region have been concerned with dolerite, carbonatite and kimberlite intrusions, and the Archaean basement itself is still poorly known.

With regard to the mineral resource potential, the most encouraging discoveries during the assessment programme have been a shear zone-hosted gold occurrence (Attu, occurrence number 70, View 5.1, Stendal *et al.* 2002) and new diamond occurrences (Jensen & Secher 2004).

The compilation of data in a Geographical Information System (GIS) allows the examination of spatial relationships between the topographical, lithological, geophysical and geochemical features presented here as well as easy comparison with other kinds of GIS-related data, such as vegetation and climate. Thus, in addition to geological studies and mineral exploration, the compiled data may be useful to environmental research and land use planning.

The activities reported here have been part of one of the main issues included in GEUS' performance contract (2000 – 2003) with The Ministry of Environment. The goals set up for the activities at the outset have been fully achieved and the near future will see the publication of several scientific papers dealing in depth with some of the many scientific issues of relevance for this region of Greenland. During the next performance contract, GEUS will continue the work in the diamond province of central West Greenland and intensify investigations initiated in 2003 related to the gold potential of the Nuuk region (Appel *et al.* 2003). Both activities will be carried out in co-operation with the Bureau of Minerals and Petroleum in Nuuk.

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Appendix

List of publications related to the mineral resource assessment and geological mapping of the Precambrian shield of central West Greenland 2000–2003

Four reports describe the accomplishments of the assessment programme:

Schjøth, F. & Steenfelt, A. (eds), 2004: Mineral resources of the Precambrian shield of central West Greenland (66° to 70°15' N). Part 1. Compilation of geoscience data. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/16**, 45 pp., 1 DVD.

Stendal, H., Nielsen, B.M., Secher, K. & Steenfelt, A. 2004: Mineral resources of the Precambrian shield of central West Greenland (66º to 70º 15' N). Part 2. Mineral occurrences. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/20**, 212 pp.

Nielsen, B.M. & Rasmussen, T.M. 2004: Mineral resources of the Precambrian shield of central West Greenland (66° to 70º 15' N). Part 3. Implications of potential field data for the tectonic framework. Danmark og Grønlands Geologiske Undersøgelse Rapport **2004/21**, 165.

Tukiainen, T. & Krebs, J.D. 2004: Mineral resources of the Precambrian shield of central West Greenland (66° to 70°15'N). Part 4. Mapping of kimberlitic rocks in West Greenland using airborne hyperspectral data. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004**/(in prep.).

Other publications comprise:

2002

Nielsen, B.M. & Thrane, K. (eds) 2002: Workshop on Nagssugtoqidian and Rinkian geology, West Greenland. Abstract volume. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2002/9**, 52 pp. Contains 21 abstracts.

Jensen, S.M., Hansen, H., Secher, K., Steenfelt, A., Schjøth, F. & Rasmussen, T.M. 2002: Kimberlites and other ultramafic alkaline rocks in the Sisimiut–Kangerlussuaq region, southern West Greenland. Geology of Greenland Survey Bulletin **191**, 57–66.

Nielsen, B.M. & Rasmussen, T.M. 2002: Geological correlation of magnetic susceptibility and profiles from Nordre Strømfjord, southern West Greenland. Geology of Greenland Survey Bulletin **191**, 48–56.

Østergaard, C., Garde, A.A., Nygaard, J., Blomsterberg, J., Nielsen, B.M., Stendal, H. & Thomas, C.W. 2002: The Precambrian supracrustal rocks in the Naternaq (Lersletten) and Ikamiut areas, central West Greenland. Geology of Greenland Survey Bulletin **191**, 24–32.

Stendal, H., Blomsterberg, J., Jensen, S.M., Lind, M., Madsen, H.B., Nielsen, B.M., Thorning, L. & Østergaard, C. 2002: The mineral resource potential of the Nordre Strømfjord – Qasigiannguit region, southern and central West Greenland. Geology of Greenland Survey Bulletin **191**, 39–47.

van Gool, J.A.M., Alsop, I., Árting, U.E., Garde, A.A., Knudsen, C., Krawiec, A.W., Mazur, S., Nygaard, J., Piazolo, S., Thomas, C.W. & Thrane, K. 2002: Precambrian geology of the northern Nagssugtoqidian orogen, West Greenland:mapping in the Kangaatsiaq area. Geology of Greenland Survey Bulletin **191**, 13–23.

2003

Abstracts from the 2003 workshop on Nagssugtoqidian and Rinkian geology have not been published.

Jensen, S.M., Lind, M., Rasmussen, T.M., Schjøth, F. & Secher, K. 2003: Diamond exploration data from West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/21**, 50 pp., 1 DVD.

Jensen, S.M., Secher, K., Rasmussen, T.M., Tukiainen, T., Krebs, J.D. & Schjøth, F. 2003: Distribution and magnetic signatures of kimberlitic rocks in the Sarfartoq region, southern West Greenland. 8th International Kimberlite Conference, Victoria, B.C., Canada. Extended abstracts on CD-ROM, 5 pp.

Madsen, H.B. 2003: Besshi-type vulkansk associeret semi-massive sulfid forekomster i Ataneq området, Vestgrønland, 141 pp. Unpublished M.Sc. thesis, University of Aarhus.

Stendal, H. & Schønwandt, H.K. 2003: Precambrian supracrustal rocks and mineral occurrences, Northeast Disko Bugt. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/24**, 57pp.

Tukiainen, T., Krebs, J.D., Kuosmanen, V., Laitinen, J. & Schäffer, U. 2003: Field and laboratory reflectance spectra of kimberlitic rocks, 0.35–2.5µm, West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/43**, 25 pp

2004

Garde, A.A., Christiansen, M.S., Hollis, J.A., Mazur, S. & van Gool, J.A.M. 2004: Low-pressure metamorphism during Archaean crustal growth: a low strain zone in the northern Nagssugtoqidian orogen, West Greenland. Geological Survey of Denmark and Greenland Bulletin **4**.

Hollis, J.A. & Nielsen, B.M. (eds) 2004: Workshop on Nagssugtoqidian and Rinkian Geology 2004. Abstract volume. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/17**, 61 pp. Contains 21 abstracts.

Jensen, S.M. & Secher, K. 2004: Diamond content of three kimberlitic occurrences in southern West Greenland. Danmark og Grønlands Geologiske Undersøgelse Rapport **2004/19**, 41 pp.

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Nielsen, B.M. 2004: Crustal architecture and spatial distribution of mineral occurrences in the Precambrian shield of central West Greenland based on geophysical and geological data. Ph.D. thesis 2004. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/26**, 63 pp., 8 appendices.

Steenfelt, A., Stendal, H., Nielsen, B.M. & Rasmussen, T.M. 2004: Gold in central West Greenland – known and prospective occurrences. Geological Survey of Denmark and Greenland Bulletin **4**.