DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2000/57

Mineral resource potential of South Greenland: the CD-ROM

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Else Moberg, Troels F. D. Nielsen, Thorkild Maack Rasmussen,
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(1 CD-ROM included)

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

G E U S

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G E U S

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Geological Survey of
Denmark and Greenland (GEUS)
Thoravej 8
DK - 2400 Copenhagen NV
telephone: + 45 38 14 20 00
telefax: + 45 38 14 20 50
e-mail: geus@geus.dk
homepage: www.geus.dk

Frontispiece: *The southern tip of snow-covered Greenland as seen from the Space Shuttle March 1992, when the planning of the first field season (summer of 1992) of project SUPRASYD was taking shape. (STS045-152-105, courtesy NASA)*

Contents

Abstract

The South Greenland CD-ROM released with this technical report contains the hitherto most comprehensive digital compilation of earth science data from south of 62° northern latitude. The digital data now available are part of the final reporting for the assessment of the mineral resource potential of South Greenland, a project carried out under GEUS' First Performance Contract (1997–1999) with the Ministry of Environment and Energy. The public release of this collection of digital data sets and the accompanying description, continue the tradition initiated in the early nineties with the first publication of thematic maps on paper.

The South Greenland CD-ROM contains an ArcView project file and accessory data and text files. Topographic, geological, geophysical, geochemical, mineral occurrence, mineral exploration and remote sensing spatial data sets are presented as maps or images in the views of the project file. Tables give detailed information on samples, chemical analyses, geo-referenced literature and company reports. Files in PDF format, reachable by hot-links from the ArcView environment, provide a geological summary and descriptions of 107 mineral occurrences. Original data on which the images are based are available at cost from GEUS.

Introduction

The assessment of the mineral potential of South Greenland has been a major activity of the Department of Economic Geology in the period 1997 to 1999, during GEUS' first Performance Contract with the Ministry of Environment and Energy. Following the SUPRASYD project 1992 to 1996, the defined goal was to assess all existing geoscience data from the region, transfer the information into the digital domain, and publish reports and papers on the economic potential of South Greenland. It has been an integral part of the activity to compile and make available all digital data on a CD-ROM, especially aimed at the professional users in mining and exploration companies, but also useful for any geo-scientist interested in South Greenland. Another GEUS report (Steenfelt *et al.* 2000) provides a brief description of the project, discusses information and data, gives an overview of the geology, shows examples of how the digital data may be used, and reviews the mineral potential indicated by the data.

The presentation of the underlying data on CD-ROM follows a standard for sharing of data with the public. This principle was first applied in the early nineties with the published collections of thematic maps on paper (Steenfelt *et al.* 1990; Thorning *et al.* 1994; Ady & Tukiainen 1994; Schjøth *et al.* 1996). The tradition was taken into the entirely digital domain with the re-issue in 1998 of Schjøth *et al.* (1996) as a digital ArcView version of spatial data sets and enclosed maps as PDF-files (Schjøth & Thorning 1998). A more limited study of Pedersen (1999) applied the same principle to the reporting of a single project dealing with a comparatively small area. With the publication of the South Greenland CD-ROM, the digital publishing of regional geoscience data is reaching its intended full form.

The present report includes the CD-ROM with the digital information compiled from South Greenland (south of 62°N) and supplies the necessary technical background for the use of the data, including brief descriptions of the processing which the various types of data have been put through. The data are presented as an ArcView project file with appropriate accessory files. The data behind the maps on the CD-ROM can be obtained from GEUS in original form, if users of the ArcView project file develop the need to go deeper into the data for their own purposes.

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. Projects like the one reported here help augmenting and enhancing GimmeX in terms of both content and facilities. Further technical developments of GimmeX will be directed towards presentation of meta-data on the Internet, addition of facilities for acquisition of digital geological data directly in the field, and fine-tuning of the various software interfaces inherent in the system. Geographically, the attention will during 2000 be shifted to West Greenland in accordance with the Second Performance Contract (2000 – 2003) between the Ministry of Environment and Energy and GEUS.

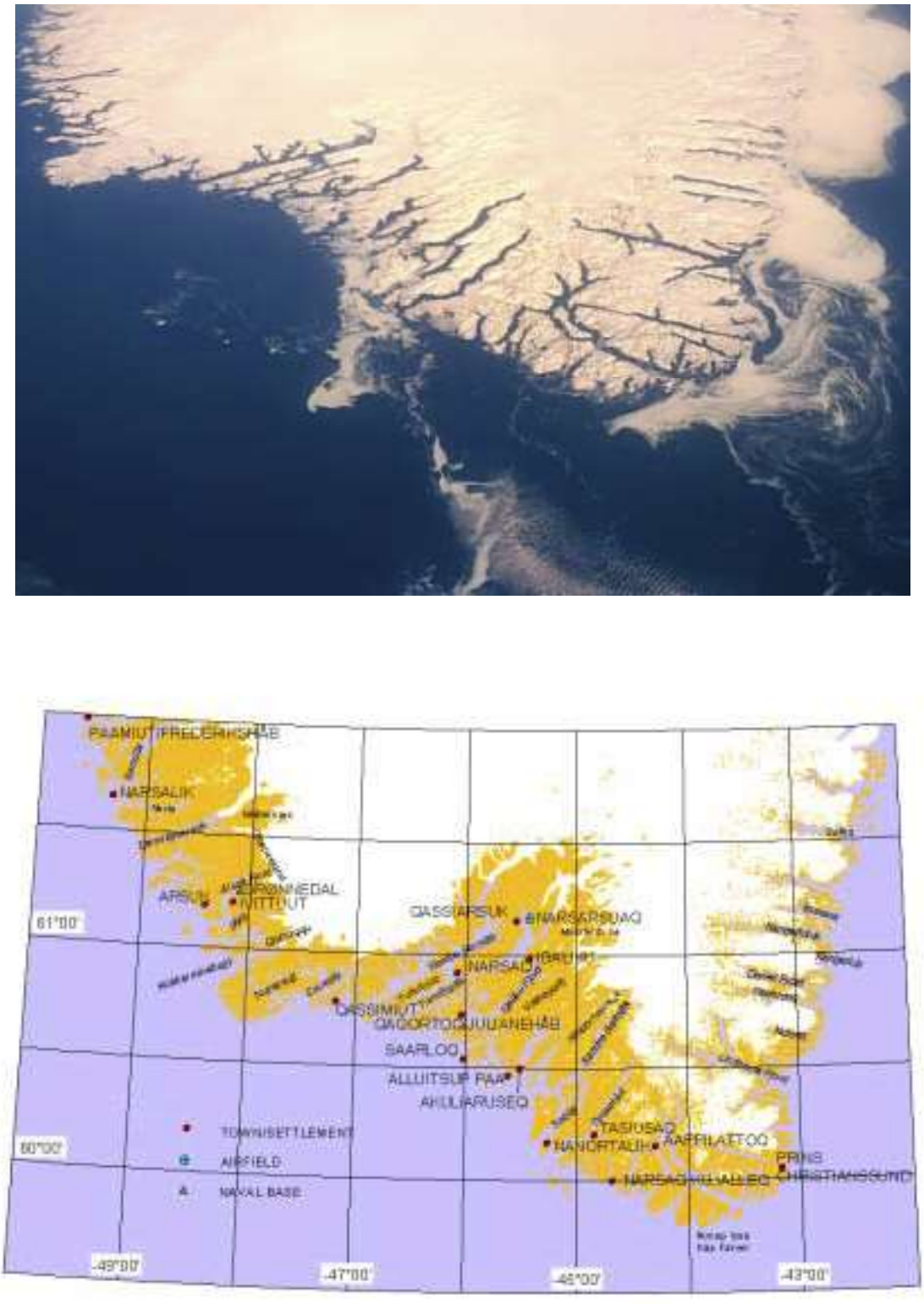

Figure 1. *South Greenland is the target area for the assessment of the mineral resource potential reported here and in Steenfelt et al. (2000). The top of the figure is a cut from the frontispiece, a photo taken from the Space Shuttle in March 1992, when the ground was still covered in snow and ice. The lower part of the figure is a map based on view 1.1 from the South Greenland Project File, showing names of main habitation, fjords and regions.*

The CD-ROM

The *South Greenland CD-ROM* accompanying this report contains the hitherto most comprehensive, quality controlled, digital geo-data set from South Greenland. Its production has demanded considerable efforts over a prolonged period of time. In agreement with the stated strategy of the Greenland Home Rule Government, the CD-ROM 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. First, general information concerning the use of the CD-ROM is presented. A fair knowledge of ArcView and its use is assumed and normal functions of ArcView are not explained.

The South Greenland Project File has been constructed using ArcView version 3.2 and makes full use of many of the facilities in this version of the program. This means that ArcView 3.2 or later versions should preferably be used on a reasonably powerful machine, though it will probably work with version 3.1. The project has been designed and tested in Windows NT 4.0 and Windows 98. The screen layout of views etc. has been fitted to be optimal for a 17” screen size. Recommended minimum requirements are stated on the cover of the CD-ROM, as are the regulations and limitations for the use of the data.

It has not been possible to store the original data for all types of information on one CD-ROM. The grids representing geophysical and geochemical anomalies are only included as geo-referenced TIF-files to save space on the CD-ROM. They are thus only available as image themes. The original data can, however, be acquired at cost from GEUS. One of the TIF-files (the Landsat mosaic) has been compressed using MrSid, and therefore needs the MrSid Image Support extension to ArcView. As not all UNIX versions accept MrSid compression, this CD-ROM may not work on all UNIX systems.

Some information is provided as PDF-files for use in the Adobe Acrobat Reader program. A free installation kit for Acrobat Reader, version 4, is included on the CD-ROM for those users who do not already have access to this program.

The PDF-files can be reached via hot-links from certain themes in the South Greenland Project File, see later. On most views a special button has been added to ArcView to provide a hot-link to a PDF version of this report. It allows the user to look up information in the report without leaving the electronic environment.

Place names follow the new Greenlandic orthography, changing the spelling of most place names. However, if a geological formation has been named by a nearby place *before* the introduction of the new orthography the spelling is maintained for this particular formation. Therefore, the Tugtutôq intrusion lies on the island Tuttutooq, and the Ivigtut Granite lies in Ivittuut.

Figure 2. *Directory structure of the CD-ROM; on the same level as the SouthGreenland directory are the directory with the installation kit for Acrobat Reader (not shown here).*

Directory structure of the CD-ROM

In Fig. 2 is shown a view of the directory structure of the CD-ROM. The South Greenland Project File itself is the *SouthGreenland.apr* in the subdirectory ***SouthGreenland****,* where also the PDF-file with the Legend for the geological map can be found for easy printing. Most of the PDF-files are in subdirectories under ***Hotlink*** (see Fig. 7) and the tabled data (in DBF-format) are in shapefiles placed under further subdirectories of ***Avdata***.

Use of the CD-ROM

Before opening the ArcView GIS project file for South Greenland, a user defined environment parameter must be set, because the ArcView 3.2 project file on the CD-ROM uses a

variable to support easy access to, and portability of, the GIS data on the CD-ROM. The variable is also important for the links to the PDF-files on the CD-ROM. It must be given the name 'GMXSOUTH'. In the two operation systems, Windows NT 4.0 and Windows 98, this is done as follows, assuming that the CD-ROM drive letter on the PC is 'G':

Windows 98:
- edit *autoexec.bat* file
- add a new line 'set GMXSOUTH=G:\SouthGreenland'

Windows NT 4.0:
- open Start>Settings>Control Panel>System>Environment>Uservariable
- add Variable = GMXSOUTH and Value = G:\SouthGreenland

Having defined the variable, an appropriate restart of the computer may be necessary.

No automatic start-up functionality is build into the CD-ROM. Use of the data on the CD-ROM can be initiated in the following way:

1. Place the South Greenland CD-ROM in the slot
2. Start ArcView 3.2 on your computer
3. Open the South Greenland Project File; it will probably take some time to load
4. The South Greenland Project file will open on a view (1.0), which only contains the opening page (JPEG Image Support extension). When this is closed, a list of views will become visible. Choose the desired view and start exploring the data

The PDF-files can be accessed through *SouthGreenland.apr* in ArcView. For instance, the descriptions of mineral occurrences are hot-linked to localities on the map in view 7.1. The PDF-files can of course also be accessed directly; if *Minoccsubmap.pdf* is opened first, the navigational links between PDF-files will be directly available, see Fig. 7.

If desired, the entire directory structure of the CD-ROM with all the files can be copied to your hard disk as long as the same structure is maintained. If the GIS data are moved from the CD-ROM to the hard drive, the user has to redefine the value of the variable accordingly. The user defined environment parameter must be re-set to the new PC drive letter and directory to which the South Greenland CD-ROM directories and files have been copied. The total amount of data on the CD-ROM does not exceed *c.* 500 MB.

Description of digital data

The different types of geo-data are arranged as views in the ArcView project file (*South Greenland.apr*). The headings of the sub-sections on the subsequent pages of this report refer to the views.

View 1.1 Topographic base map

The base map used for the geoscience data is based on the G250 Vektor 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. This can be seen locally in South Greenland, *e. g.* by comparing the topographic base map in line form with the satellite map, see later.

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

Ellipsoid & Datum:	WGS84
UTM-zone:	23 (*i.e.* the central meridian is 45° West)
False Easting:	500 000

Please note that although the ArcView implementation of the digital map on the CD-ROM has been produced by GEUS, **the copyright to G250 Vektor belongs to KMS**. There are restrictions on the use of the data. In short, the digital map must only be used in conjunction with the CD-ROM and must not be copied or distributed in any way. For further information, see the cover of the CD-ROM.

Through the years, the location of samples and observations taken in the field have been relative to different reference systems, which seldom fit perfectly together. This causes problems when compiling positions determined over a period of many years. In the subsection on sample locations (view 5.1), some comments are given on the accuracy of positioning of the various sample types.

The aeromagnetic data acquired in 1995 and 1996 is positioned using differential GPS (DGPS) according to modern UTM parameters and thus pose no problems in the absolute positioning. However, because of the inconsistencies in the base map mentioned above, there may locally be some differences in position noticeable, *e. g.* if the in-flight video of the flight path is compared with the digital map of G250 Vektor.

The digitised topographical data are contained in a number of themes as ArcView shape-files, combining a number of geographical features, see Table 1. Some of the features are available as both polygons (_P) suitable as background for observations and lines (_L) suitable as overlays on top of grids. Some features are scale sensitive: lakes only appear when the scale is larger than 1 : 500 000, and rivers only appear when the scale is larger than 1 : 250 000. The view also contains a graphics layer with selected names for the region.

Table 1. *Features included as themes in the base map view. Suitable combinations of these features are also present in the geoscientific views as base map for the data included there.*

Geographical feature	Name of shape-file	Includes	Maximum scale*
Coast-land-ice	map_l	Lines	1 : 500 001
Coast-land-ice	map_p	Polygons	
Lakes	lakes_l	Lines	1 : 250 001
Lakes	lakes_p	Lines	1 : 500 001
Rivers	river	Lines	1 : 250 001
Contour of 200 m	con200	Lines	1 : 250 001
Geonet 1 degree	snet60	Lines	
Geonet ½ degree	snet30	Lines	1 : 500 001
Place names	placenames	empty shape-file holds names as graphic in view 1.1	

* If the scale is smaller, the feature is not visible on the screen.

View 1.2 Digital Elevation Model

The aeromagnetic survey flown in project Aeromag 1995 (Thorning & Stemp 1997) provided accurate GPS data for the aircraft. Combining these data with radar altitude data also recorded by the survey aircraft, an approximate Digital Elevation Model (DEM) can be calculated for the region. Though not very accurate, this can give a useful view of the topography. Therefore, the geophysical contractor flying the Aeromag 1995 survey (Sander Geophysics Limited, Ottawa), was asked to produce a DEM sampled into a 100 by 100 metre grid. View 1.2 show an image of the DEM in geo-referenced TIF-format. The DEM is limited to the Aeromag 1995 survey area and does not cover the NW corner of the map.

The production of the DEM met a few problems, *e. g.* occasional, poor calibration of the radar data, but these were carefully handled during processing. In a few places of high relief, the aircraft ground clearance exceeded the radar altimeter range and accurate radar altimeter data could not be recorded. The radar altimeter data were reconstructed in the processing, except in five cases when no data could be recovered. Fortunately, these gaps in the data total less than two minutes of flying, mostly over fjords, where the elevation can be assumed to be close to sea level. This means that all of the DEM is based on data from lines 500 metres apart. The grid of the DEM has been calculated from the line-based data using the minimum total curvature method of interpolation with tension.

View 2.1 Mosaic of Landsat TM scenes

South Greenland is fairly well covered by Landsat TM data. However, because of the unfavourable location of South Greenland in relation to the Landsat ground receiving stations, the availability of good quality Landsat TM data for *geological* purposes has been sporadic, especially in the eastern part of the area, until the launch of the Landsat TM 7 satellite. In the future, improved data will be more easily available from the new satellite. Based on the selection of scenes shown in Fig. 3, a satellite image map of South Greenland has been produced. The map is included as a geo-referenced TIF-file compressed with MrSid. The MrSid extension to ArcView (included with ArcView 3.2) is necessary for the display of the satellite mosaic.

The satellite image map is a mosaic of seven Landsat TM scenes. Landsat TM bands 4 (red), 3 (green), and 2 (blue) have been used for the colour composite included as a view. The mosaic layout is detailed in Fig. 3.

For most parts of the area the image is of reasonable quality. Because of partial snow cover, the data in the Nunarsuit area (Figure 1, south-western part of the region) are of a more modest quality. There are some major dropouts of scanning lines in the original data in the scenes covering the southern part of the area. Because of the magnitude of the dropouts, no cosmetic corrections have been applied to remove these.

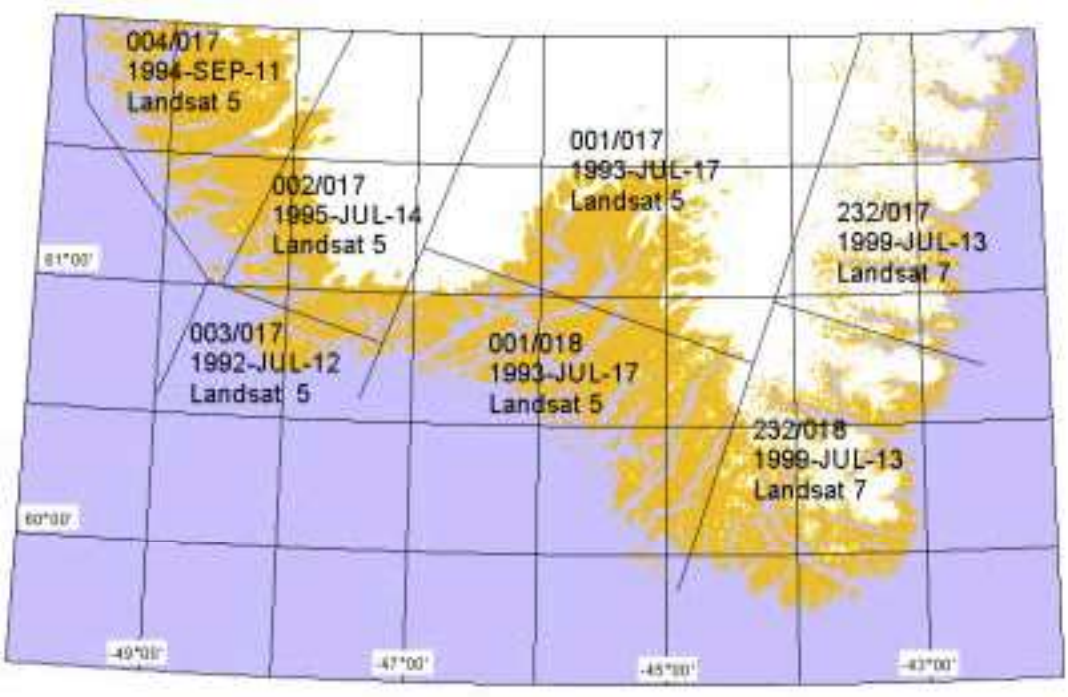

Figure 3. *The Landsat TM scenes used for production of the satellite mosaic image of South Greenland. For each scene the path/row, acquisition date and satellite are given.*

The following information briefly summarises some cardinal points in the processing of the data:

- To minimise the atmospheric differences between scenes, 'black pixel' extraction was applied to each scene separately
- Transformation of the pixel co-ordinates to the UTM projection was based on a 2nd order polynomial fit using selected ground control points (GCP)
- GCPs were selected as prominent topographic features from the digital KMS G250 Vektor topographic map. An overlay of the topographic data on the transformed satellite image map indicates that the quality of registration in general is fairly good, *i. e.* the fit between the two maps is acceptable, but not perfect. Especially, the area around the inner part of Lindenows Fjord exhibits a strikingly poor registration. Taking the nature and origin of the Landsat TM data and the applied transformation method into consideration, it is probable that G250 Vektor map data from this area are of only moderate quality
- The pixel re-sampling method used (8 point Sin(x)), determines the grey level from the weighted average of the 64 closest pixels to the specified input co-ordinates and assigns the average value to the output co-ordinates
- The final image mosaic was prepared by histogram matching of the re-sampled images. In order to prepare an aesthetically pleasing product, several combinations have been tried before one was chosen. The illumination and atmospheric conditions vary remarkably for the scenes used. Sensor saturation due to the intense reflection from ice and snow make the scenes covering the eastern part of the area particularly problematic. Not all effects from these difficulties have been successfully removed
- To enhance the contrast in the mosaic, a final subtractive smoothing method was applied to the mosaic image

View 3.1 Geological map (scale 1:500 000)

The production of the digital geological map presented in this view has been an essential part of the preparation of the CD-ROM, because existing geological maps of South Greenland were not in digital form.

The 1:500 000 scale geological map published by the Geological Survey of Greenland (Allaart 1975) was chosen as a basis for the digital map. The map was scanned and then vectorised. It was a complication in this process that the topographical base of the existing map (Lambert conformal conic projection) was different from the improved topographical base in UTM projection (G250 Vektor) used for this CD-ROM. Thus, all geological units had to be individually fitted to match the new map base. This operation was carried out in ArcView and ArcInfo.

Geological observations and mapping during the SUPRASYD project (Garde & Chadwick 1996; Garde *et al.* 1998b) demonstrated that the map by Allaart (1975) needed significant revision. The revision was made during the digitisation process, so that the resulting map represents a new updated edition of the 1 : 500 000 scale geological map. Also the legend has been thoroughly revised to reflect the improved understanding of the tectonostratigraphy and plate-tectonic evolution of South Greenland achieved during the SUPRASYD project (Chadwick & Garde 1996; Garde *et al.* 1998a). The new edition provides much more information on the previously poorly known east coast section of South Greenland and also on inland areas, along the margin of the Inland Ice.

The view presents the litho-stratigraphy of South Greenland with accessory themes containing dykes and structural information (Table 2). The latter themes are only visible when the scale of a viewed region is larger than 1 : 1 250 000. The map legend is created as an ArcView layout and can be reached by hot-links from each of the lithological units anywhere on the map. A PDF-version of the legend is located in the ***SouthGreenland*** directory to enable easy overview and printing.

From the geological map there is hot-link access to a summary geology description (PDF-file) based on Steenfelt *et al.* (2000).

The view contains a number of themes visible on the map and summarised in Table 2. They can be turned on and off as needed using normal ArcView facilities.

Table 2. *Geological map elements included as separate themes in the view 3.1.*

Geographical feature	Name of shape-file	includes	Maximum scale:*
Lithology	geol_l	lines	1 : 1 250 001
Lithology	geol_p	polygons with hot-links to legend in Arcview Layout	
Fault structures: fault, mylonite, thrust & unconformity	Fault	lines	1 : 1 250 001
Dykes: microsyenite, dolerite & metadolerite	Dykes	lines	1 : 1 250 001
Strike and dip: lithological layering & foliation	strike_p	points	1 : 1 250 001
Geonet 1 degree	snet60	lines	
Names from the legend	Geolnames	empty shape-file holds names as graphics in view 3.1	
Geological description	PDFlink	polygon with hot-link to PDF file	

Notes: Faults, dykes and strikes taken from Allaart (1975).
Topographic outline taken from G250 Vektor.
* If the scale is smaller, the feature is not visible on the screen.

View 4.1 Airborne magnetics

Several magnetic anomaly maps from different sources are included in this view. The most comprehensive magnetic data set is from the regional, airborne geophysics projects Aeromag 1995 and Aeromag 1996 covering the coastal region from the Inland Ice to the ocean (see Thorning & Stemp 1996, 1997). Both surveys were flown with fixed-wing aircraft at a gentle drape at a nominal height of 300 metres above ground level and with 500 metres between survey lines. The line direction was 30° NW for the Aeromag 1995 survey and 37° NW for the Aeromag 1996 survey. Orthogonal control lines were flown with a separation of 5 000 metres for both surveys. Only the southern part of the Aeromag 1996 survey is within South Greenland. The Aeromag 1995 survey was flown by Sander Geophysics Limited and the Aeromag 1996 survey was flown by Geoterrex-Dighem Limited.

The data from the two surveys have been merged into a uniform data set and are presented as magnetic total field anomalies and calculated first vertical derivative anomalies in

grid form. The grids were calculated at 100 metres cell sizes and are presented as images in the form of geo-referenced TIF-files.

In project AEM Greenland 1996, a helicopter borne multi-sensor geophysical survey (Stemp 1997) included magnetic measurements in five detailed areas in the north-western corner of the South Greenland project area. Aerodat Inc. flew the survey with their helicopter EM system. The data were collected at a nominal ground clearance of 45 metres for the magnetic sensor, along flight lines spaced 200 metres apart and with orthogonal control lines at intervals of 2 000 metres. The sampling interval of 0.1 of a second between measurements corresponds to a sampling distance of four metres. The flight line directions are different for the five survey blocks:

- Sermiligaarsuk North: 30° NW
- Midternæs: 30° NW
- Grænseland: E-W
- Sioralik South: E-W
- Arsuk Ø: N-S

Magnetic anomaly maps (total field and first vertical derivative) from the AEM Greenland 1996 survey are included in view 4.1 as separate themes. To ensure consistency, the total field data for the five small survey areas have been shifted by a constant value of 75 nT. This means that the data after upward continuation to the height of the Aeromag 1995 and 1996 surveys have a zero mean difference from the data of the Aeromag projects. The magnetic data sets from the AEM Greenland 1996 project are presented in a grid with 50 metres sampling distance. An Akima spline technique was used for the interpolation.

Magnetic data over the ocean and the Inland Ice are provided by a number of previous reconnaissance flights and surveys, see *e. g.* Thorning *et al.* (1994) and Verhoef *et al*. (1996). The data compiled by Verhoef *et al*. (1996) and low-pass filtered data from the Aeromag 1995 and 1996 projects have been merged into one grid of total field anomalies with a sampling distance of 2 500 metres. This is presented as a separate image in TIF-format. The low pass filtering removed anomalies with less than 15 kilometres wavelength. The processing for the grid included:

- Low-pass filtering with a cut-off wavelength of 15 kilometres of the merged data from the Aeromag 1995 and Aeromag 1996 projects
- Re-sampling of filtered data with a sampling distance of 1 250 metres
- Merging of the filtered and re-sampled data with the data compiled by Verhoef *et al.* (1996)
- Re-sampling of merged data with a sampling distance of 2 500 metres
- Low-pass filtering with cut-off wavelength 15 kilometres in order to remove some high gradients at the intersection of the high-resolution data with the reconnaissance data

The original line and grid data for the geophysical surveys, including those described below, have not been included on the CD-ROM, because they would take up to much space. The geo-referenced TIF-files provide images, which will allow an initial evaluation and use of the data. Note that the pixel size of the TIF-formatted image is not equal to the grid cell

size of the original, geophysical grids. For all of the surveys flown in 1995 and 1996 the original data, grids and processing reports from the geophysical contractor are available from GEUS at a price of presently 23 000 DKK per survey (c. USD 3 000; may be changed without notice).

The calculations of the geophysical grids were mostly done using the Oasis Montaj version 4.3 geophysical software package from Geosoft Ltd.

View 4.2 Airborne electromagnetics

Airborne electromagnetic data are also available from project AEM Greenland 1996, see above and Stemp (1997). The results are presented in two anomaly maps, as apparent resistivity from controlled source measurements and as anomalies of measured VLF signals. The data are presented in a 50 metres by 50 metres grid in the form of images.

The survey was flown with the Aerodat Inc. helicopter EM system, with a five frequency vertical co-axial and horizontal co-planar loop at a nominal height of 30 metres above ground. The co-axial systems used frequencies of 920 Hz and 4 600 Hz and the co-planar system used frequencies of 515 Hz (or 860 Hz), 4 200 Hz and 33 000 Hz. The nominal height of the VLF-sensors was 45 metres above ground level. The flight line separations and directions are as described above for the magnetic data.

The following anomaly maps are available on the CD-ROM as geo-referenced TIF-file images:

- Apparent resistivity calculated as the resistivity of a 200 metres thick layer above a resistive basement, which fit the measured in-phase and quadrature data at 4 200 Hz for the co-planar loop
- VLF-anomaly data from the Rugby (GBR) transmitter at 16.0 kHz and the Cutler (NAA) transmitter at 24.0 kHz. The data are presented as the ratio between the vertical and horizontal components of the measured field in percent

The interpolation of the data sampled at intervals of four metres along flight lines was accomplished with an Akima spline technique.

Note that a number of other digital data, such as in-phase and quadrature components at the five frequencies from vertical co-axial and horizontal co-planar loops, also are available from GEUS.

View 4.3 Airborne radiometrics

Radiometric data are available from project Syduran and from project AEM Greenland 1996. The data include measurements from helicopter of the radiation from uranium, thorium, potassium and total count.

An Exploranium GR820 – 256 channel gamma ray spectrometer (16.8 litre NaI crystal) was used for the measurements in the AEM Greenland 1996 project. The radiometric anomaly maps are presented as grids with 50 metres sampling distance. An Akima spline technique

was used for the interpolation. The data were collected at a nominal height of 60 metres and with line separations and directions as described above for the magnetic data.

The data from the Syduran project are described in Armour-Brown *et al.* (1982). A four-channel gamma-ray spectrometer (7.413 litre NaI crystal) installed in a helicopter was flown at a nominal height of 30 metres over the terrain. The flying was not along straight lines, but done as 'contour flying'. The grids based on the data from the Syduran project were calculated at 1 060 metres grid cells using the minimum total curvature method.

Note that the units used for presentation of the results from the Syduran project differ from those of the AEM Greenland 1996 survey. In the Syduran results, measured counts per second are converted into quantitative estimates of mean surface concentrations of radioactive elements. Equivalent uranium (eU) and equivalent Th (eTh) are used as a reminder of the fact that the measured radiation is emitted from daughter products, ^{214}Bi and ^{208}Tl respectively, and the assumption is made that the ^{238}U and ^{232}Th decay series are in equilibrium. The total count measurements from the Syduran project are presented as the internationally recommended 'unit of radioelement concentration (Ur)'. One Ur is defined as the radioactivity equivalent of one part per million of uranium in radioactive equilibrium. Further information on equipment and data presentations can be found in Løvborg *et al*. (1976) and Breiner *et al.* (1976).

View 4.4 Gravity

Gravity data from the database maintained by the KMS are presented as Bouguer and free-air anomalies (GRS80 standard and IGSN71 system) in separate geo-referenced TIF-files. The irregularly distributed data points have been transformed into a grid with a sampling distance of 2 500 metres. Gridding of the data was done using a minimum total curvature algorithm.

View 5.1 Sample locations

This view provides an overview of the coverage of samples used in the preparation of the views 6.1 (stream sediment – fine fraction), 6.2 (heavy mineral concentrates of stream sediment) and 6.3 (rock analyses) as three corresponding shapefiles.

An obvious prerequisite for using data in GIS is that all data points have a common spatial reference. However, location data from South Greenland have been registered over a long period of time, during which both the topographic reference and the positioning methods have changed. Hence, bringing the existing location data to match a common reference has required critical examination of how previous location data were obtained and subsequent correction of those at mismatch with the current reference. The spatial reference for the CD-ROM (KMS G250 Vektor, described in view 1.1.) was introduced relatively late in the project, and a great majority of the data for South Greenland have been obtained using different reference systems. The correction of positions for older data has been a major task in the preparation of data for the CD-ROM.

Many samples have originally been positioned on former 1 : 250 000 scale maps from KMS (Lambert conformal conic projection) or geological maps in 1 : 100 000 scale (with modifications relative to the KMS maps). Their digital locations have been determined by digitisation from these maps. In addition to the change of projection to UTM (Universal Transverse Mercator) the current KMS map base has an improved triangulation basis. As a result, the position of features such as certain stretches of coast, lakes or ice caps may deviate significantly – in worst cases up to a kilometre – from the position they had on the former maps. The locations of samples collected within the past five to seven years have been plotted and digitised using the new map base or they have been measured on the sample site by means of GPS (Global Positioning System).

A mathematical function was defined to predict direction and distance of adjustment for each of the digitised sampling points, based on known translation data for all nearby geodetic control points used in the 'warping' of digitised data which produced G250 Vektor. Like the 'warping' of the map data, this was not an accurate process in all instances for the translation of sample positions. A comparison of transformed locations with original sample maps showed that in some parts of the region the mathematical correction was not fully sufficient to accurately relocate sample positions.

In summary, the final relocation of sample positions have been undertaken as follows:

- *Stream sediment (fine fraction):* Sample locations were originally digitised using former KMS maps at the scale 1 : 100 000. The old sample positions are individually transferred to their correct position on the new reference map. The resulting sample locations are as accurate as the original positions.
- *Heavy mineral concentrates:* Nunaoil A/S supplied the locations. Presumably, the company has digitised locations plotted on former KMS maps. Sample positions have been relocated using the mathematical function, but have not been controlled after relocation because the original sample maps have not been available. The resulting sample location is satisfactory for regional overviews, but the accuracy in the position of individual samples varies.
- *Rock samples:* Sample positions registered hitherto in the GEUS database have originally been determined in several ways and their accuracy varies. In the preparation of the location data for the CD-ROM, sample positions, which have been derived by digitisation of locations plotted on the new KMS map base, are used directly and are assumed to be accurate. Positions determined by GPS measurements (since 1993) are also used directly. As implicit in GPS positioning, the accuracy varies depending on the instrument and the circumstances (time and topography). Most other positions (stored in the GEUS database and obtained before the SUPRASYD project) are derived from locations plotted on old KMS maps. They have been relocated using the mathematical transformation.

Thus the accuracy of especially rock sample locations varies, and if the location of a particular sample is critical, the user is advised to consult the collector (the name is listed in the table) or the administrator for the GimmeX database for Greenland samples.

In the ArcView project file the sample numbers and positions are available in the shapefiles as tables with data extracted from the GimmeX database. Using the ArcView information tool, information on individual samples can be extracted from the tables.

View 6.1 Stream sediments

The element distribution map images in this view are based on analysis of stream sediment samples (fine fraction) collected during three surveys, carried out in 1979, 1992 and 1993, respectively.

Geochemical surveys

(1) SYDURAN (South Greenland Uranium Exploration project). This project was conducted by the Geological Survey of Greenland (GGU) in collaboration with Risø National Laboratory (Armour-Brown *et al.* 1982). For geochemical purposes *c.* 2300 samples were collected with an average sampling density of 5-6 samples per km² in South Greenland, covering up to Sermiligaarsuk (61°30′N) on the west coast, and up to Lindenow Fjord (60°30′N) on the east coast, *i. e.* within the area covered by aeroradiometry (see View 4.3). The < 0.1 mm grain size fraction was analysed at Risø National Laboratory, Denmark, for U by delayed neutron counting (DNC), and for major and trace elements by isotope excited energy dispersive X-ray fluorescence spectrometry (XRF; Kunzendorf & Løvborg 1981). The results were reported as geochemical maps by Armour-Brown *et al.* (1982) and by Olesen (1984). At a later stage (1990) the samples were analysed at Activation Laboratories Ltd. for 34 major and trace elements by instrumental neutron activation (INA) analysis. These analyses were financed by Nunaoil A/S. Later (1990-1992), the remaining sample material was analysed at GGU for major element oxides and 5 trace elements by X-ray fluorescence spectrometry (XRF) on fused glass discs using sodium tetraborate as flux. Na_2O and Cu were determined by atomic absorption spectrometry (AAS).

(2) SUPRASYD. As part of GGU's reconnaissance geochemical mapping programme (Steenfelt 1993) and the 'Suprasyd' programme (Nielsen *et al.* 1993) a total of 142 stream sediment samples were collected in 1992 in the area along the east coast of South Greenland from Lindenow Fjord to Otte Rud Øer (62° N). Due to steep topography and extensive ice cover in this area the sample spacing is very irregular (see View 5.1). An average figure for the sample density is in the order of 1 sample per 50 km². The < 0.1 mm grain size fractions of the samples were analysed at Activation Laboratories Ltd. for major element oxides by XRF on fused discs using lithium tetraborate as flux, for 14 trace elements by XRF on pressed powder tablets, and for 35 major and trace elements by INA. The results are reported in Steenfelt *et al.* (1992). 126 data points from this survey are included in the present data set.

(3) The Paamiut region. This area was sampled in 1993 in the course of GGU's reconnaissance geochemical mapping programme (Steenfelt 1993; 1994). The <0.1 mm grain size fractions of the stream sediment samples were analysed at GGU by XRF using fused glass discs for major elements (except Na_2O) and 5 trace elements. Na_2O and Cu were determined by AAS. The samples were further analysed at Activation Laboratories Ltd for 35 major and trace elements by INA and for 14 trace elements by XRF using pressed powder tablets. The results are reported in Steenfelt *et al.* (1994). 57 sample points from this survey lie within the present map area.

All samples are not analysed for the same suite of elements. In addition, the quantity of sample material available did not always allow three or four different consecutive analyses. Hence, the number of samples that have been analysed for a particular element or a suite of elements varies (Table 3).

Data quality and calibration between data sets

The repeated analyses of samples from the three surveys resulted in several analytical data sets, which have been combined to form one consistent data set as a basis for producing element distribution maps. The quality of the analyses, *i.e.* the precision and accuracy, vary with method and element, and careful examination of the data has been necessary before the selection of the most reliable and suitable analyses could be made. Intercalibration of data from different sources has been done by means of internal standards and reanalysis of selected sample batches as described in Steenfelt (1999a).

Grids

Prior to gridding, major element oxide concentrations were recalculated as volatile-free concentrations to compensate for the effect of variable contents of organic matter and carbonate. The grids were produced using software from Geosoft Ltd. (OASIS montaj version 4.3). The grid values are calculated by kriging using a spherical model. The parameters for the model (nugget, range and sill) were determined for each element using variograms. The Geosoft kriging software is based on Journel & Huijbregts (1978). A grid cell size of 2 500 metres, and a blanking distance of 5 000 metres was used. The colour scaling of the grids is determined individually for each element with the intention of emphasising regional features reflecting litho-stratigraphical changes and areas of high concentrations. Noisy variation in grid values close to the analytical detection limit is suppressed. The grids are included in the view as images in the form of geo-referenced TIF-files. An example is shown in Fig. 4. The calibrated analyses behind the images can be obtained from GEUS at cost.

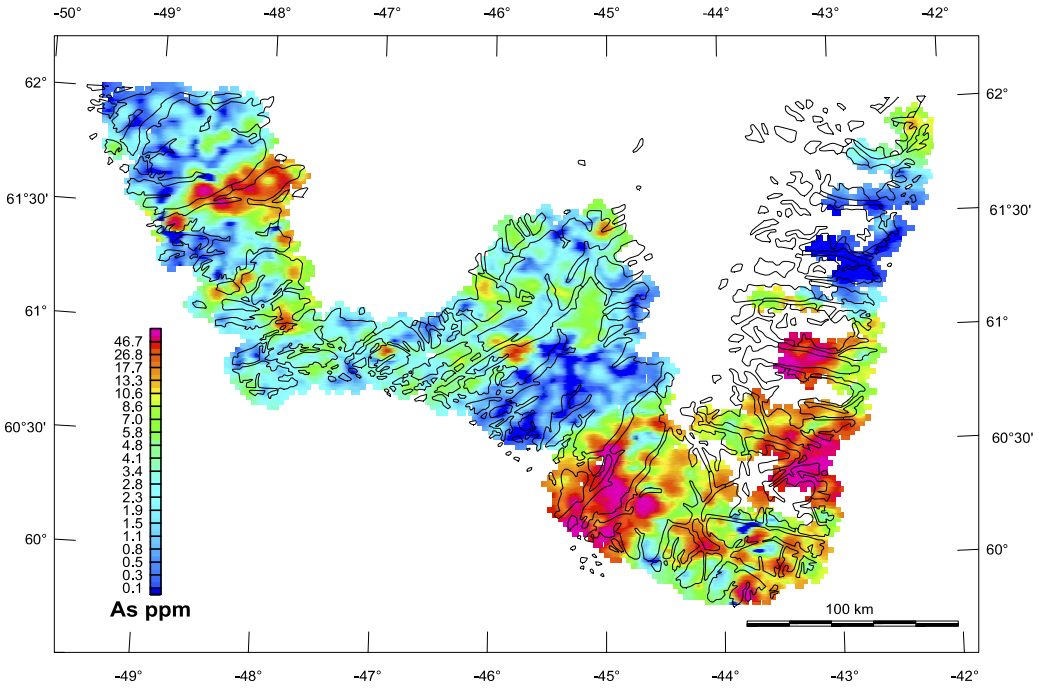

Figure 4. *Example of geochemical map based on chemical analyses of the < 0.1 mm grain size fraction of stream sediments collected systematically over South Greenland. The distribution of arsenic (As) is shown as a grid map. The grid values are calculated by means of kriging. Known gold mineralisation occurs within the districts of high arsenic concentrations.*

Table 3. Statistical parameters for stream sediment data from South Greenland

				Grid values*					Sample values*			
	Lower limit of detec-tion ppm	No. of samples	Ana-lysis[1]	Grid min	Grid max	**mean**	Std. dev.	Me-dian	**Mean**	Max	Min	Median
SiO_2		1346	XRF	42.23	72.73	**62.62**	3.89	62.93	**62.50**	74.28	37.19	63.14
TiO_2		1346	XRF	0.29	4.29	**1.11**	0.43	1.02	**1.13**	5.18	0.18	0.98
Al_2O_3		1346	XRF	11.17	20.27	**15.21**	0.92	15.17	**15.23**	24.22	9.05	15.17
Fe_2O_3		1346	XRF	2.44	28.94	**7.50**	2.42	7.10	**7.63**	34.60	1.58	6.90
MnO		1346	XRF	-0.95	9.03	**0.15**	0.33	0.11	**0.14**	9.22	0.02	0.11
MgO		1346	XRF	0.61	13.84	**2.53**	1.16	2.23	**2.55**	14.75	0.30	2.10
CaO		1346	XRF	1.11	11.85	**3.66**	0.91	3.61	**3.63**	15.98	0.58	3.46
Na_2O		1346	XRF	1.66	6.77	**3.43**	0.49	3.43	**3.46**	6.89	0.00	3.49
K_2O		1346	XRF	0.71	5.78	**2.63**	0.77	2.65	**2.60**	5.79	0.59	2.63
P_2O_5		1346	XRF	-0.02	2.00	**0.42**	0.21	0.38	**0.42**	2.90	0.05	0.36
As	2	2478	INA	-9	323	**10.6**	21.2	3.84	**9.249**	1100	0	3
Au	0.005	2478	INA	-29.6	331	**3.9**	12.6	1.28	**3.7312**	850	0	0
Ba	100	2443	I+X	195	1631	**582**	170	551	**591.81**	5223	107	557
Br	1	2478	INA	-3.5	439	**55.8**	47	43.3	**58.49**	660	0	39
Ce	3	2478	INA	19.8	1269	**165**	115	138	**185.15**	2071	16	139
Co	5	2478	INA	1	100	**21.2**	10.4	18.5	**21.747**	147	0	17
Cr	10	2443	I+X	-12.6	1558	**77.8**	71.5	58.9	**72.28**	4346	0	45
Cs	2	2478	INA	-0.26	13.8	**2.46**	2.11	1.95	**2.4673**	19	0	2
Cu	10	2540	XRF	5.5	170	**31.5**	17.4	27.6	**31.49**	220	3	25
Eu	0.2	2478	INA	0.56	21.7	**2.7**	1.4	2.31	**2.958**	77.3	0	2.3
Ga	10	2539	XRF	5.92	66.1	**20.1**	6	19.2	**20**	97	0	18
Hf	1	2478	INA	1.08	335	**22.6**	18.9	17.9	**22.821**	480	3	16
La	1	2478	INA	10	794	**97.3**	74.2	78.1	**109.82**	1432	8.1	78
Lu	0.05	2478	INA	0.14	4.31	**0.59**	0.38	0.5	**0.6204**	6.35	0.05	0.47
Mo	5	2314	INA	-2	41.7	**1.59**	2.53	0.75	**1.5085**	81	0	0
Nb	20	2539	XRF	-13.5	636	**35.4**	54.1	21.9	**42.699**	902	0	24
Nd	5	2478	INA	10	421	**68.5**	43.4	58	**77.025**	1000	0	57
Ni	10	2539	XRF	6.7	283	**43.8**	26.1	36.4	**45.175**	511	2	34
Rb	20	2539	XRF	19	257	**81.4**	32.6	75.5	**84.916**	329	15	77
Sb	0.2	2478	INA	-0.4	6.3	**0.41**	0.41	0.32	**0.1295**	14	0	0
Sc	0.1	2478	INA	7.7	45.8	**17.2**	4.7	16.3	**17.296**	52	4.4	15.5
Sm	0.1	2478	INA	0	80	**12.1**	7.42	10.25	**13.459**	171	2.5	10.4
Sr	20	2539	XRF	86	834	**330**	118	307	**325.41**	1224	49	301
Ta	1	2478	INA	-0.58	33.6	**1.31**	2.78	0.51	**1.615**	49	0	0
Th	0.5	2478	INA	1.38	149.8	**15.8**	12.1	12.1	**16.282**	270	1.1	11
U	0.5	2356	DNC	-12.4	609	**30.7**	37.7	19.9	**32.733**	1400	0	14.8
V	50	1353	XRF	24.4	310	**90.8**	27.2	86.1	**93.349**	513	0	84
W	4	2478	INA	-2.5	44	**0.95**	2.4	0.08	**0.7421**	64	0	0
Y	20	2539	XRF	9.2	402	**47**	32.2	39.2	**51.703**	542	8	39
Yb	0.2	2478	INA	1.5	52.4	**5.19**	3.7	4.32	**5.4348**	66	1.2	4
Zn	10	2539	XRF	19.5	1096	**111**	62.9	101	**123.53**	1585	16	103
Zr	20	2539	XRF	-269	7989	**610**	560	453	**647.53**	9241	90	457

*Major elements calculated as volatile-free percentages

Trace element values in ppm except Au, which are in ppb

[1]XRF: X-ray fluorescence spectrometry, INA: Instrumental neutron activation analysis, I+X: combined XRF and INA, DNC+I: Delayed neutron counting and INA

View 6.2 Heavy mineral concentrates of stream sediments

The data originate from a geochemical survey carried out in 20 sub-areas by Nunaoil A/S in 1990 (Olsen & Pedersen 1991).

The selection of these sub-areas was based on the gold distribution pattern in the stream sediment samples collected by GGU in 1979 (Steenfelt 1990). The main aim of the survey was to confirm the anomalous gold values in the stream sediments and pinpoint targets for gold exploration.

The raw samples consisted of 15 – 20 kg of unsorted stream sediment. After wet-sieving, a heavy mineral concentrate was produced from the <0.5 mm fraction on a vibrating gold screw. Subsequently the <0.25 mm fraction of the concentrate was analysed for 34 trace elements by instrumental neutron activation and for Cu and Pb by atomic absorption spectrometry after aqua regia digestion.

Coloured dot maps illustrate the distribution of 16 elements. The class intervals for the colours are chosen so that the upper class represents anomalous values defined by visual inspection of the frequency distributions (Table 4).

Please note that for stream sediments – heavy fraction - the original chemical analyses have been included on the CD-ROM.

Table 4. *Heavy mineral concentrates, summary statistics*

INA	det. lim.	max	min	mean	median	98th perc.
Au_ppb	5	6570	0	58.22	0.0	649
As	2	1500	0	18.40	4.0	150
Ba	100	27000	0	283.32	0.0	1100
Co	5	300	0	34.33	29.0	97
Cr	10	83000	0	315.97	170.0	1100
Hf	1	770	0	50.04	25.0	280
Ni	50	3100	0	24.49	0.0	390
Sb	0.2	32	0	0.91	0.4	8.6
Sc	0.1	200	3.8	34.47	29.0	110
Ta	1	110	0	7.76	4.0	43
Th	0.5	1500	0	53.21	15.0	470
U	0.5	170	0	14.46	8.5	71
W	4	5400	0	31.81	0.0	250
Zn	50	5300	0	116.19	0.0	568
AAS						
Cu	1	720	0	42.65	24.0	222
Pb	2	754	0	13.61	8.0	57

INA: Instrumental neutron activation analysis
AAS: Atomic absorption spectrometry
Except for Au, units are ppm

View 6.3 Rock analyses

This view contains chemical analyses of all GEUS rock samples with a digital sample locality from South Greenland. The rock samples have been collected and analysed for various purposes, including classification, petrogenesis and economic interest. For each sample batch submitted for analysis the purpose and budget have influenced the choice of laboratory and analytical method. Chemical analyses vary substantially in accuracy and precision depending on the element and source (*i.e.* laboratory and method). It has also been demonstrated that analytical data acquired from different sources, or from the same source at different times, are commonly biased (Steenfelt 1999a). In the case of stream sediment (fine fraction) careful calibration of analytical data from different sources has been completed to create a consistent data set for the entire region. This is not the case for rock samples. The analytical results listed in this view are extracts of analytical data as they are delivered from the laboratories. Information on the sources is given in a special ArcView table and in abbreviated form in the table-headers of the analytical data. 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). Information on relationships between sample, element, method and laboratory is contained in two ArcView tables, *rocklab_elements.txt* (to allow long attribute names) and *rocklab_method.dbf.*

Analytical results are available in the shapefiles listed as themes in the view. Results below the lower detection limit of the analysis method are given as '0' in the tables containing the results of the analyses.

The view also contains a shapefile (*Rock_description.shp*) which provides attributes on administrative information about each sample and extracts of selected fields of the digital sample description, which in this view look like this:

GGUnr	Latitude	Longitude	Proj_area	Year	Collector	Type	Orig_comp	Defrm	Defrmstyle	Metamorph	Meta_type	Alteration

The information in the table comes from 'dockets' filled out in the field. Since 1990, this docket information for rock samples has been stored in digital form. There is no digital docket information for samples collected before 1990, which is indicated by 'n.a.' (not available) in the corresponding columns.

Fig. 5 shows the layout of the GEUS rock sample description form used in the field and later input to the GimmeX database. The geologist marks the boxes, which appropriately describe the sample. The form is then digitised and entered into the database. The information extracted for this view is lined in red in Fig. 5. The column *Type* refers to the division within the upper red rectangle of the docket label. The column *Origin_comp* describes what has been marked in the fields of the lower red rectangle. A sedimentary rock is described by its composition using the boxes of the left-hand side. Grain-size, colour and composition using the boxes of the right-hand side describe a magmatic rock. Thus when the field reads '*Magmatic Extr Medium Mafic*', it means that the sample is a medium-grained, mafic, extrusive magmatic rock. In all cases *n.a.* (not available) is used for missing information.

Figure 5. *Rock sample docket used in Greenland fieldwork since 1990 by GGU, and now by GEUS. The number is unique. See text for further explanation. A hand-held palm computer system is expected replace the paper based docket system in coming fieldwork in West Greenland in 2001.*

View 7.1 Mineral occurrences

The presentation of mineral occurrences in South Greenland south of 62°N included in this view is based on published information, non-confidential company reports, and fieldwork during the SUPRASYD project (1992–1996). All identified mineral occurrences, which might be of interest from either an economic or a genetic point of view, have been included. In total, 107 numbered descriptions (grouped in a number of PDF-files) are available on the CD-ROM.

The descriptions vary in size and detail because the available information is inhomogeneous. In general, important and major occurrences (*e.g.* Nalunaq (#5) from which many company reports and published papers exist) have more information available than small occurrences (*e.g.* site at West of Sønderarm (#36) with only one *pers. comm.).*

For practical reasons, South Greenland has been divided into six sub-regions, see Fig. 6, which can be seen as a theme in view 7.1. The first three sub-regions were included in the SUPRASYD project. Sub-region 4 has benefited from numerous investigations of the

Gardar Province, and sub-regions 5 and 6 were studied by GGU, mainly in the 1970's and 1980's. In addition to this, mining and exploration companies have explored many parts of South Greenland. The sub-regions are:

1. South-East Greenland
2. Nanortalik peninsula
3. Niaqornaarsuk peninsula
4. Narsaq – Narsarsuaq – Julianehåb
5. Kobberminebugt – Ivittuut – Arsuk Ø
6. Sermiligaarsuk – Midternæs – Grænseland

Descriptions of the six sub-regions can be reached from the 'sub-regions' theme in the view. Hot-links have been established from the number of the sub-region to PDF-files. Table 5 lists information on commodities, type of mineralisation, and location.

Each mineral occurrence has been given a number and can be seen in the 'occurrences' theme in the view. Hot-links have been established from the locations to PDF-files; in many cases, the descriptions of closely related localities of mineral occurrence have been grouped into one PDF-file. When in the Acrobat Reader environment, descriptions and maps of sub-regions and mineralised sites are available, see Fig. 7 for hints on the navigation between the PDF-files.

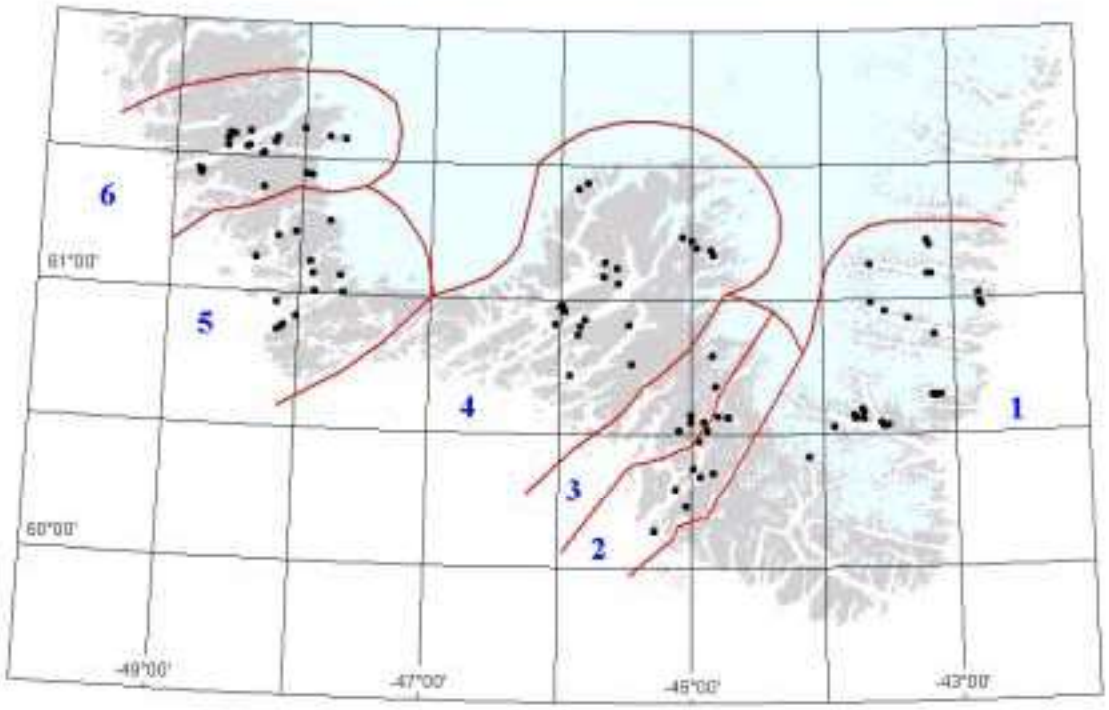

Figure 6. *Map of sub-regions (blue numbers) and mineral occurrence sites (black dots). Equivalent maps are present in the South Greenland Project File and as a PDF-file.*

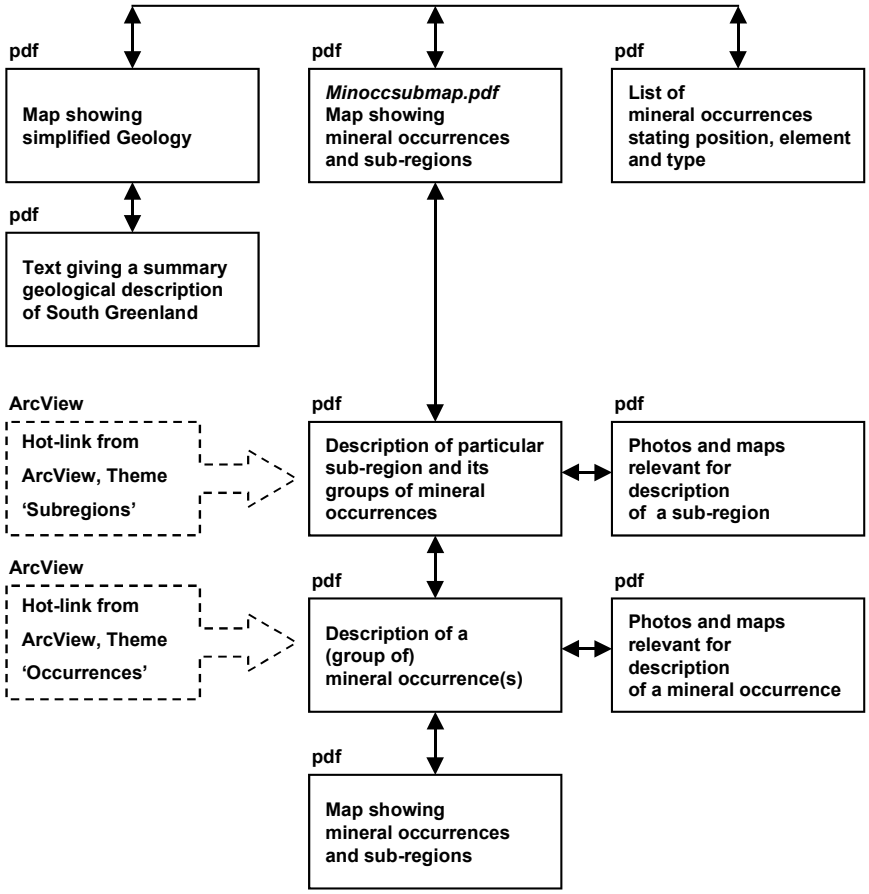

Figure 7. *To assist the user in the navigation between PDF-files in the Acrobat Reader environment, this schematic presentation is provided. In all of the three maps at the top, links are attached to a label giving the destination of the link, i.e. another of the maps. From the simplified geological map a brief summary of the geology can also be reached. From the map of mineral occurrences and sub-regions, clicking on the number of a sub-region will bring up a description of that sub-region. From there, additional maps and photos enhancing the description of the sub-region can be reached. Finally, links to a detailed description of a particular (group of) mineral occurrence(s) are provided.*

The PDF-environment can be reached from the ArcView environment via themes in view 7.1, from either the occurrences.shp or the subregions.shp themes. Closing down the Acrobat Reader, will return the user to the same view in ArcView. Any of the PDF-files can of course also be opened directly in Acrobat Reader. It is convenient to begin with the file indicated on the figure (Minoccsubmap.pdf).

Table 5. *List of South Greenland mineral occurrences included on the CD–ROM*

#	Name	Commodity	Type of mineralisa.	UTM_X	UTM_Y	Latitude	Longitude
1	Amitsoq	PGE	Magmatic	500774,07	6693052,27	60° 22' 26"	-044° 59' 10"
2	Lake 410	Au	Quartz vein	497930,59	6676534,72	60° 13' 32"	-045° 02' 15"
3	Amitsoq	Graphite	Stratabound	493715,43	6683855,74	60° 17' 29"	-045° 06' 49"
4	Sissarissoq	Graphite	Stratabound	484595,56	6666225,87	60° 07' 58"	-045° 16' 38"
5	Nalunaq	Au-As	Quartz vein	509148,95	6691055,08	60° 21' 21"	-044° 50' 03"
6	Søndre Sermilik-Waldorf	PGE	Magmatic	511466,70	6714581,88	60° 34' 01"	-044° 47' 27"
7	Ippatit-1	Au	Quartz vein	515234,37	6713904,54	60° 33' 39"	-044° 43' 20"
8	Søndre Sermilik	Au	Quartz vein	510471,86	6726752,73	60° 40' 35"	-044° 48' 30"
9	Isortup Qoorua	Cu-Au	Quartz vein/shear zone	508715,03	6739325,76	60° 47' 21"	-044° 50' 24"
10	Qoorormuit Valley	Au	Quartz vein	499867,34	6714497,21	60° 33' 59"	-045° 00' 09"
11	Niaqornaarsuk Valley-1	Au	Quartz vein/shear zone	499994,34	6711809,04	60° 32' 32"	-045° 00' 00"
12	Kutseq-3	As-Au	Granitic dyke	601444,70	6723805,56	60° 38' 14"	-043° 08' 43"
13	Kutseq-6	As	Shear zone	600436,99	6724340,46	60° 38' 32"	-043° 09' 49"
14	Kangerluk	As-Au	Shear zone	619285,76	6763261,15	60° 59' 10"	-042° 47' 43"
15	Kangerluk	Au	Hydrothermal altera-tion zone	619201,09	6762583,82	60° 58' 49"	-042° 47' 50"
16	Sorte Nunatak	Cu-Au	Quartz vein/shear zone	574306,50	6761906,48	60° 59' 06"	-043° 37' 36"
17	Kangerluluk	Cu-Au	Quartz vein/shear zone	597795,49	6774420,53	61° 05' 32"	-043° 11' 11"
18	Head of Kangerlu-luk-1	Cu-Au	Quartz vein	573385,75	6777823,85	61° 07' 41"	-043° 38' 15"
19	Head of Kangerluluk-2	Pb-Zn	Shear zone/carbonatised	573491,58	6777887,35	61° 07' 43"	-043° 38' 08"
20	Kangerluk	Graphite	Stratabound	618661,34	6766584,33	61° 00' 58"	-042° 48' 17"
21	Igutsait South	Au	Aplite dyke	598230,17	6786057,70	61° 11' 48"	-043° 10' 20"
22	Kutseq-2	Fe-Ti	Stratabound	603128,10	6724075,10	60° 38' 21"	-043° 06' 52"
23	Kangerluluk - East	Au	Hydrothermal altera-tion/shear zone	599238,78	6774552,18	61° 05' 35"	-043° 09' 35"
24	Danell Fjord - North	Sulphides	Stratabound	589676,18	6755577,59	60° 55' 30"	-043° 20' 45"
25	Head of Danell Fjord	Au	Hydrothermal altera-tion/shear zone	579812,41	6758589,43	60° 57' 15"	-043° 31' 35"
26	Illukulik-1	Sulphides	Stratabound	581092,44	6711152,95	60° 31' 42"	-043° 31' 21"
27	Illukulik-3	Sulphides	Stratabound	579059,45	6712432,98	60° 32' 25"	-043° 33' 32"
28	Illukulik-2	Sulphides	Stratabound	580188,89	6711002,36	60° 31' 37"	-043° 32' 20"
29	Illukulik-4	Sulphides	Stratabound	581995,99	6711303,54	60° 31' 46"	-043° 30' 21"
30	Stendalen-1	Sulphides	Stratabound	568066,23	6714164,79	60° 33' 28"	-043° 45' 31"
31	Stendalen-2	Sulphides	Stratabound	567614,46	6715520,12	60° 34' 12"	-043° 45' 59"
32	Stendalen-3	Fe-Ti-V	Magmatic	571605,14	6713788,31	60° 33' 13"	-043° 41' 39"
33	Stendalen-4	Cu-Ni-Co	Magmatic	568593,30	6714691,86	60° 33' 44"	-043° 44' 56"
34	Stendalen-5	Cu-Ni-Co	Magmatic	571680,44	6716800,15	60° 34' 51"	-043° 41' 30"
35	Stendalen-6	Fe-Ti-V	Magmatic	571002,78	6717703,70	60° 35' 20"	-043° 42' 14"
36	West of Sønderarm	Cu-Au	Quartz vein/ shear zone	559181,30	6710324,70	60° 31' 29"	-043° 55' 18"
37	Kutseq-5	Fe-Ti	Stratabound	600015,97	6724205,68	60° 38' 28"	-043° 10' 16"
38	Kutseq-1	As-Au	Shear zone	603695,74	6724105,55	60° 38' 21"	-043° 06' 14"
39	Kutseq-4	As-Au	Shear zone	600391,46	6723955,36	60° 38' 20"	-043° 09' 52"
40	Danell Fjord - South	Sulphides	Stratabound	600407,47	6749272,68	60° 51' 57"	-043° 09' 04"
41	Illorssuit	U	Stratabound	549257,68	6697663,38	60° 24' 44"	-044° 06' 21"

#	Name	Commodity	Type of mineralisa.	UTM_X	UTM_Y	Latitude	Longitude
42	Ippatit-2	Sulphides	Stratabound	515869,39	6713781,12	60° 33' 35"	-044° 42' 38"
43	Søndre Sermilik-2	PGE	Magmatic	505314,81	6712019,76	60° 32' 39"	-044° 54' 11"
44	Sarqaa	PGE	Magmatic	503701,07	6689503,08	60° 20' 31"	-044° 55' 58"
45	Søndre Sermilik-3	Sulphides	Stratabound	506655,01	6708492,70	60° 30' 45"	-044° 52' 44"
46	Søndre Sermilik-4	Sulphides	Stratabound	503279,07	6703991,46	60° 28' 20"	-044° 56' 25"
47	Niaqornaarsuk Valley-2	Au	Quartz vein/shear zone	495094,11	6708758,12	60° 30' 54"	-045° 05' 22"
48	Frederik VII´s Mine	Cu	Quartz vein	449668,74	6731586,65	60° 43' 00"	-045° 55' 21"
49	Josva Mine	Cu	Vein/shear zone	330746,44	6753067,58	60° 52' 36"	-048° 07' 05"
50	Lilian Mine	Cu	Vein	330427,65	6752266,43	60° 52' 09"	-048° 07' 24"
51	Sorttop/Rødtop	Cu	Vein	328421,89	6751485,17	60° 51' 41"	-048° 09' 34"
52	Qoornoq	Cu-Pb	Vein	342978,13	6779110,14	61° 06' 55"	-047° 54' 52"
53	Kiinaalik	Cu	Vein	343823,25	6774232,79	61° 04' 18"	-047° 53' 41"
54	Karret	Sulphides	Disseminated	355170,50	6773193,07	61° 04' 00"	-047° 41' 02"
55	Qipisarqo - North	Cu	Conglomerate	344085,12	6766918,83	61° 00' 23"	-047° 53' 02"
56	Qipisarqo - South	Sulphides	Stratabound	356156,84	6766403,78	61° 00' 22"	-047° 39' 38"
57	Borgs Havn	Sulphides	Stratabound	328739,68	6762681,33	60° 57' 43"	-048° 09' 49"
58	Rinks Havn	Cu	Disseminated	336596,55	6756525,53	60° 54' 36"	-048° 00' 48"
59	Skjortesø	Sulphides	Stratabound	351093,56	6796229,64	61° 16' 19"	-047° 46' 39"
60	Arsuk Ø	Au	Quartz vein	320004,42	6781042,90	61° 07' 21"	-048° 20' 31"
61	Ivittuut	Cryolite /siderite/ fluorite	Hydrothermal /magmatic	329705,19	6789898,69	61° 12' 23"	-048° 10' 12"
62	Jernhat	Fe	Magmatic	336871,80	6791361,85	61° 13' 21"	-048° 02' 17"
63	Motzfeldt-1	Nb-Ta	Magmatic	508050,85	6782992,10	61° 10' 53"	-044° 51' 01"
64	Motzfeldt-2	Nb-Ta	Magmatic	502219,31	6784133,05	61° 11' 30"	-044° 57' 31"
65	Motzfeldt-3	Nb-Ta	Magmatic	500571,27	6787302,36	61° 13' 12"	-044° 59' 22"
66	Motzfeldt-4	Nb-Ta	Magmatic	496514,55	6788823,63	61° 14' 01"	-045° 03' 54"
67	Motzfeldt-5	Nb-Ta	Magmatic	509094,25	6781162,03	61° 09' 53"	-044° 49' 52"
68	Igutsait North	Sulphides	Shear zone	596927,49	6788212,51	61° 12' 59"	-043° 11' 44"
69	Nuuluk-1	Fe	Stratabound	296897,66	6817929,07	61° 26' 30"	-048° 48' 35"
70	Nuuluk-2	Au	Quartz vein	298072,55	6817047,90	61° 26' 04"	-048° 47' 12"
71	Nuuluk-3	Au-As-Zn	Stratabound	297680,92	6816264,64	61° 25' 38"	-048° 47' 36"
72	Iterlak - West Valley	Cu-Zn	Stratabound	309136,13	6831048,71	61° 33' 56"	-048° 35' 39"
73	Iterlak-1	Fe	Stratabound	308842,41	6830363,36	61° 33' 33"	-048° 35' 57"
74	Iterlak-2	Fe	Stratabound	309038,22	6827524,03	61° 32' 02"	-048° 35' 33"
75	Iterlak-3	Fe	Stratabound	309919,39	6832908,96	61° 34' 57"	-048° 34' 53"
76	Western Midternæs	Fe- Cu- Zn- Pb- Ag	Stratabound	328717,69	6829090,56	61° 33' 26"	-048° 13' 28"
77	Sioralik-1	Fe	Stratabound	323724,39	6824488,89	61° 30' 49"	-048° 18' 50"
78	West Midternæs	Fe	Stratabound	317752,02	6827524,03	61° 32' 17"	-048° 25' 44"
79	Iterlak-4	Fe	Stratabound	311877,55	6832223,61	61° 34' 39"	-048° 32' 38"
80	North Midternæs	Au- Fe	Stratabound	318241,56	6833496,41	61° 35' 31"	-048° 25' 32"
81	Sioralik-2	Cu	Stratabound	323136,95	6823999,35	61° 30' 33"	-048° 19' 28"
82	West Midternæs	Zn-Cu	Stratabound	316870,85	6826936,59	61° 31' 57"	-048° 26' 41"
83	Perledal - Midternæs	Cu	Stratabound	340647,24	6834230,99	61° 36' 30"	-048° 00' 17"
84	Grænseland -West	Fe	Stratabound	341151,07	6815589,06	61° 26' 29"	-047° 58' 45"
85	Grænseland -East	Graphite	Stratabound	343996,67	6815167,33	61° 26' 20"	-047° 55' 32"
86	Pyramidefjeld	Diamond	Magmatic	323860,23	6810459,04	61° 23' 17"	-048° 17' 53"

#	Name	Commodity	Type of mineralisa.	UTM_X	UTM_Y	Latitude	Longitude
87	Kvanefjeld-1	U-Th	Magmatic	445964,85	6759924,41	60° 58' 14"	-045° 59' 54"
88	Ilimaussaq-1	Sodalite	Magmatic	454155,68	6751787,12	60° 53' 55"	-045° 50' 42"
89	Kvanefjeld-2	Nb-Ta	Magmatic	446203,06	6760254,17	60° 58' 25"	-045° 59' 38"
90	Kvanefjeld-3	F	Hydrothermal	446662,39	6760566,83	60° 58' 35"	-045° 59' 08"
91	Ilimaussaq-2	Be	Hydrothermal	448022,97	6758399,00	60° 57' 26"	-045° 57' 35"
92	Ilimaussaq - Kringlerne	Zr-Y-REE	Magmatic	453265,73	6748407,51	60° 52' 05"	-045° 51' 38"
93	Qagssiarssuk-1	U	Vein	469392,47	6776060,18	61° 07' 05"	-045° 34' 05"
94	Qagssiarssuk-2	U	Vein	464447,72	6778349,42	61° 08' 17"	-045° 39' 37"
95	Qagssiarssuk-3	U	Vein	463898,31	6772214,26	61° 04' 59"	-045° 40' 09"
96	Qagssiarssuk-4	U	Vein	469941,89	6769375,61	61° 03' 29"	-045° 33' 24"
97	Nordre Sermilik-1	U	Vein	457825,73	6811403,70	61° 26' 03"	-045° 47' 26"
98	Nordre Sermilik-2	U	Vein	453672,21	6808664,15	61° 24' 33"	-045° 52' 04"
99	Qoormuit Valley	Au	Quartz vein	499826,09	6714863,50	60° 34' 11"	-045° 00' 12"
100	Appat	Zr-Y-REE	Magmatic	456327,98	6754870,21	60° 55' 35"	-045° 48' 20"
101	Midternæs	Cu-Zn-Pb-Ag	Unconformity	329513,33	6830909,78	61° 34' 26"	-048° 12' 40"
102	Nuna 810	Fe	Stratabound	350886,78	6831051,80	61° 35' 02"	-047° 48' 33"
103	Nuna Qernertoq	Fe	Stratabound	357490,53	6829631,64	61° 34' 25"	-047° 41' 02"
104	Narsaq	Quartz	Sedimentary	443860,02	6752669,15	60° 54' 19"	-046° 02' 06"
105	Vatnaverfi	U	Vein	475205,37	6735989,35	60° 45' 31"	-045° 27' 18"
106	Puissattaq	U	Vein	474172,79	6752192,84	60° 54' 15"	-045° 28' 34"
107	Kangerluk	Au-Cu	Stratabound	620083,67	6761376,15	60° 58' 09"	-042° 46' 54"

View 8.1 Mineral exploration licenses 1992 – 2000

The mineral industry has been active in exploration in South Greenland for many years and in many ways. A view has been constructed based on information in GEUS' GREENMIN database (Thorning *et al*. 2000). The view contains nine maps (shapefiles) showing the position and size of active exclusive licenses each of the years 1992 to 2000. The associated table can be reached via the ArcView 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 and at different dates through a given year (reduction, termination, perhaps followed by new license to another company covering the same or a similar area). If exact dates for changes to licenses are essential, the Bureau of Minerals and Petroleum should be contacted; the primary GREENMIN database also contains the detailed information.

View 9.1 Existing maps from South Greenland

The Department of Geological Mapping has through many years maintained a meta-database of original field maps used or produced during fieldwork in Greenland. Some years ago, the meta-data were transferred to digital format as a PC-based (Reflex) database, which late in this project has been transferred into the GimmeX system (Thorning 2000) as a relational database co-ordinated with other databases in GimmeX. This view in

the South Greenland Project File includes the meta-data on the sub-set of maps relevant for South Greenland.

The view also contains meta-data on printed KMS maps in scale 1:250 000, GEUS' geological maps in scale 1:100 000, and geophysical print-on-demand maps in scale 1:50 000 from Aeromag 1995, Aeromag 1996 and AEM Greenland 1996.

Altogether this view contains information of well over a thousand maps. To avoid cluttering, the field maps, the topographic maps from KMS,and the geological maps from GEUS have been split into different shapefiles according to scale. The geophysical maps are also in a separate shapefile. In the shapefiles the order of sorting is according to size, so that the largest maps are plotted first on the view. Use of normal ArcView tools for sorting, selection and zoom to selection provides useful ways of handling the information.

View 10.1 Bibliography and exploration company reports

The view provides access to a general, geo-referenced bibliography and a separate list of company reports.

The back-bone of the bibliography is references extracted from the "Bibliography of Greenland Geology and Related Topics", which have been available at GEUS for some years in printed, but unpublished form and which is being finalised for digital release. To this, internal reports, field reports and university theses with geological and general information on South Greenland south of 62^{o}N have been added. Most of the references are available in the international literature or archived at GEUS.

The bibliography included here is simply in the format of a table. All bibliographic entries have been characterised by up to five key words, such as type of investigation or disciplines (Key_group), region (Key_area), main theme (Key_topic1, Key_topic2), locality, (Key_place), to provide search possibilities using normal table handling facilities in ArcView. Administrative information is given by the GEUS bibliography number (Ref_no) and UDC code (Universal Decimal Classification). Each entry is also geo-referenced by latitude and longitude limits (north, south, east and west) for the subject area. This makes it possible to search by area on the map provided as a part of the view. The bibliography has been vetted as carefully as possible within the time available. However, it may still contain errors and omissions from the original sources.

The bibliography on the CD-ROM was finalised by the end of 1999. To supplement the bibliography and bring the record of publications from the recent activities in South Greenland up to date, papers on South Greenland which have been published during the first half of year 2000 are listed after the references.

In ArcView the information tool is often used to obtain details about a theme. However, it is recommended not to do so when working with the bibliography. The geo-referencing of many of the entries in the bibliography define quite large areas, and pointing the information tool to a specific location may consequently produce very long list of references. This may take quite a long time. To ease its use, three shapefiles with sub-sets of references according to area within the geo-referencing limits (*e.g subset_area_bt25k_125k.shp, all references where the area are between 25.000 and 125.000 km^2)* have been added to the

view. All reports from the Ujarassiorit mineral hunt have been arranged in a separate shapefile. Alternatively, use the 'select feature' tool to mark an area of interest and subsequently open the table for the theme. References related to the area will then be highlighted.

The list of company reports expresses a different approach to the region. Mining exploration companies operating in Greenland must submit reports on their exploration activities to the Government authorities (the Bureau of Minerals and Petroleum (BMP), Government of Greenland).

Each report is confidential for a period of time stated in the licence, under which the work was conducted. After expiry of confidentiality the reports are open for public inspection. A complete report set is housed at GEUS in Copenhagen, while the BMP in Nuuk has copies of all reports submitted since 1996. Reports up to *c.* 1994 are also available on microfiche. Microfilm or photocopies of released reports are provided at reproduction and handling costs. The *GEUS Report File no* is essential for identification when ordering copies of a report.

A compilation of such, now publicly available reports from South Greenland have been included in the CD-ROM. The compilation comprises 204 reports containing information of relevance for areas south of latitude 62°N. Only reports for which confidentiality has expired before June 1st, 2000 are included. The reports are identified by a 'GEUS Report File no' ("GEUS no" in the index list). The cited author(s) is either given as such in the report, or failing that it is the person(s) signing the report; if there is no personal name mentioned, the company name is used. If no year is given, the reports are dated as the year of receipt by the authorities. Supplementary information (marked by square brackets) intended to help the reader, has on occasion been added to the "Author(s)" and "Title" fields.

The index was produced from the GREENMIN database using Seagate Crystal Reports 7 software as bundled with ArcView 3.2. It comprises three files:

- *assess_rep.rpt*
- *assess_rep.exe*
- *assess_rep.crf*

Readers with access to Seagate Crystal Reports for ESRI 7.0 can open the *assess_rep.rpt* file directly and use the sorting and querying facilities provided by this software.

For readers without Seagate Crystal Reports 7, a browser is included; the sorting options of the proper Seagate Crystal Reports are not available, but it has a very useful tool for text string-querying:

- double-click on the *assess_rep.exe* icon to activate a report dialog window
- click on the "Print" button to produce a new window displaying the index
- use the navigation arrows to the left on the tool bar to go to the top of the file
- write the query string in the field to the left of the "binocular" button
- press the "binocular" button to go to the first occurrence of the query string (if available)
- repeat to get the next occurrence

When using "year" to query the index it should be borne in mind, that many reports are dated the year following the investigations.

Final comments

South Greenland has seen many geoscientific activities during the second half of the last century, and much of the available information was in non-digital formats, such as paper maps, field notes, etc. The transfer of information to the digital domain has been a difficult, but worthwhile process, leading to a number of offshoot problems, which had to be solved without loosing the momentum of the main project.

During the course of the work it has been evident that the need for digital versions of all data, preferably with a GIS association, is ever increasing. Based on comments from potential users of geo-data from Greenland it will probably be true that unless the data exist in easily accessible digital format, valuable information may well escape notice of busy researchers. Often there is only a limited time available for a first look at the potential for a given commodity in a new region. The developing trend is to depend on GIS compilations of the available data for the first overview on which decisions are based, though the careful search for information in more obscure places may become necessary later in the process. The South Greenland CD-ROM is intended to provide the best solution to that first look.

With the exception of the latest field projects from the eighties and onward, much information has remained in personal archives and the retrieval of the information has to a large extent been based on the good memory of many individuals and the inputs they could provide. The transfer of older information to digital files has highlighted the methods, lines of thinking and the political priorities in mineral exploration/geological research in the last century, including the inconsistencies and biases of the work. Similarly, rather than regarding the South Greenland CD-ROM as the definitive information package on South Greenland, the CD-ROM and the reports should be appreciated as the present (year 2000) compilation and selection of geological information. As far as possible, the data selection is based on the quality of the information but it may still, to some extent, reflect current priorities and focuses. Priorities may change and information that may seem irrelevant today may be key information in the exploration of tomorrow.

The work with the digital data sets from South Greenland has of course not been directed solely towards the production of the CD-ROM. All the original data have been stored in GimmeX, which will serve as the primary environment for present and future work. Whereas much data on the CD-ROM are in image form, GimmeX also contain original data in suitable formats for the programs, maps, and databases used. Up-dated CD-ROM's may be produced in the future, especially because forthcoming new data to a large extent will be of a digital nature.

The problems encountered during the work with the South Greenland CD-ROM have also given impetus to the development of further facilities in GimmeX. It has been decided to add new databases and additional processing programs, and the design phase of a new, interactive meta-data facility in digital map form has been initiated.

The project team will gratefully receive communication on any errors, omissions or advantages of the CD-ROM observed by users.

Acknowledgements

The production of the South Greenland CD-ROM has involved a large number of people. Most of them are included in the author list of this report, but the project group would like to acknowledge the support and understanding of additional colleagues, especially during periods when the problems of consistency and conversion of old data took up a significant part of their efforts. Stuart Watt is the originator and keeper of the Greenland Bibliography, which has formed the basis for the bibliography for South Greenland. The work of Kort- og Matrikelstyrelsen on G250 Vektor made the updating of positional data possible.

The Bureau for Minerals and Petroleum, Government of Greenland, is acknowledged for financial and moral support in the process towards the digital world and to various geophysical and geochemical GEUS projects, which have produced much of the new data now available.

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