DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/89

Digital Topographic Map of North and Northeast Greenland

Hans F. Jepsen, Naja Mikkelsen, Frants von Platen-Hallermund
Frands Schjøth and Willy Weng

(1 CD-Rom included)

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

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Contents

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DANCEA
Danish Cooperation for Environment in the Arctic
Ministry of the Environment

1 Abstract

The Greenlandic Parliament endorsed in August 2002 a strategy plan for the National Park in North and Northeast Greenland and the adjacent Scoresby Sund area. The data compilation for this plan required a reliable and homogenous digital topographic map, and a project was therefore launched in the fall of 2002 to compile the data set for this map.

The present report contains a CD-ROM with a digital topographic data set of North and Northeast Greenland at target scale 1:250 000. A data set at target scale 1:100 000 is also available covering approximately 90% of this area. The digital data are presented as an ArcView GIS project file and MapInfo workspace. The map projection is UTM Zone 24N, geodetic reference WGS84.

The CD-ROM can be accessed by users with an ArcView GIS and/or MapInfo software licence.

2 Introduction

The Greenlandic Parliament endorsed in August 2002 a strategy plan for the National Park in North and Northeast Greenland and the adjacent Scoresby Sund area. The plan outlined the need for compilation of a wide array of data, which should be based on a GIS platform.

In order to provide a background for the GIS platform a homogeneous digital topographic data set based on modern photogrammetry was needed.

A project financed by the Danish Cooperation for Environment in the Arctic, Ministry of the Environment (DANCEA) was therefore initiated in the fall of 2002 to compile a digital topographic data set.

The production of the digital map was undertaken by the Geological Survey of Denmark and Greenland (GEUS) and was supervised by a steering committee that included representatives from Ministry of Environment and Nature, Nuuk; Bureau of Minerals and Petroleum (BMP), Nuuk; Asiaq, Nuuk; the National Survey and Cadastre, Copenhagen; and the National Environmental Research Institute, Roskilde.

3 Digital Topographic Map

3.1 History

The history of the topographic mapping of North and Northeast Greenland is described in Dawes (2003) and Nielsen *et. al*. (1995). Maps covering the area prior to 1970 were compiled at 1:300 000 for North Greenland by Koch (1932, 1940), part of Northeast Greenland at 1:250 000 in the 1930s by the Geodetic Institute, and the entire region at 1:250 000 by the American Army Map Services in the 1950s.

Modern geodetic work in the present project area started in the 1970s, when modern technologies and funding became available (Madsen, 1984) and planimetric errors up to 20 km in the existing mapping of parts of North Greenland were discovered and documented (Lillestrand & Johnson, 1971).

Modern techniques (available from the mid 1970s) included: 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.

At the same time the Geological Survey of Greenland (GGU) needed modern topographic maps for compiling geological data at map scales of 1:100 000 and 1:500 000. In 1977 GGU established a Laboratory for Geological Applied Photogrammetry applying the new methods of high precision digital photogrammetry in 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 into 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.

3.2 Coverage, origin and description of data

The present project covers a region extending from latitude 80^{o}N on Greenland's northwest coast across North Greenland and down to latitude 70^{o}N on the east coast; it comprises an area of c. 220 000 km^2 (Figure 1) i.e. roughly half of Greenland's ice-free land area.

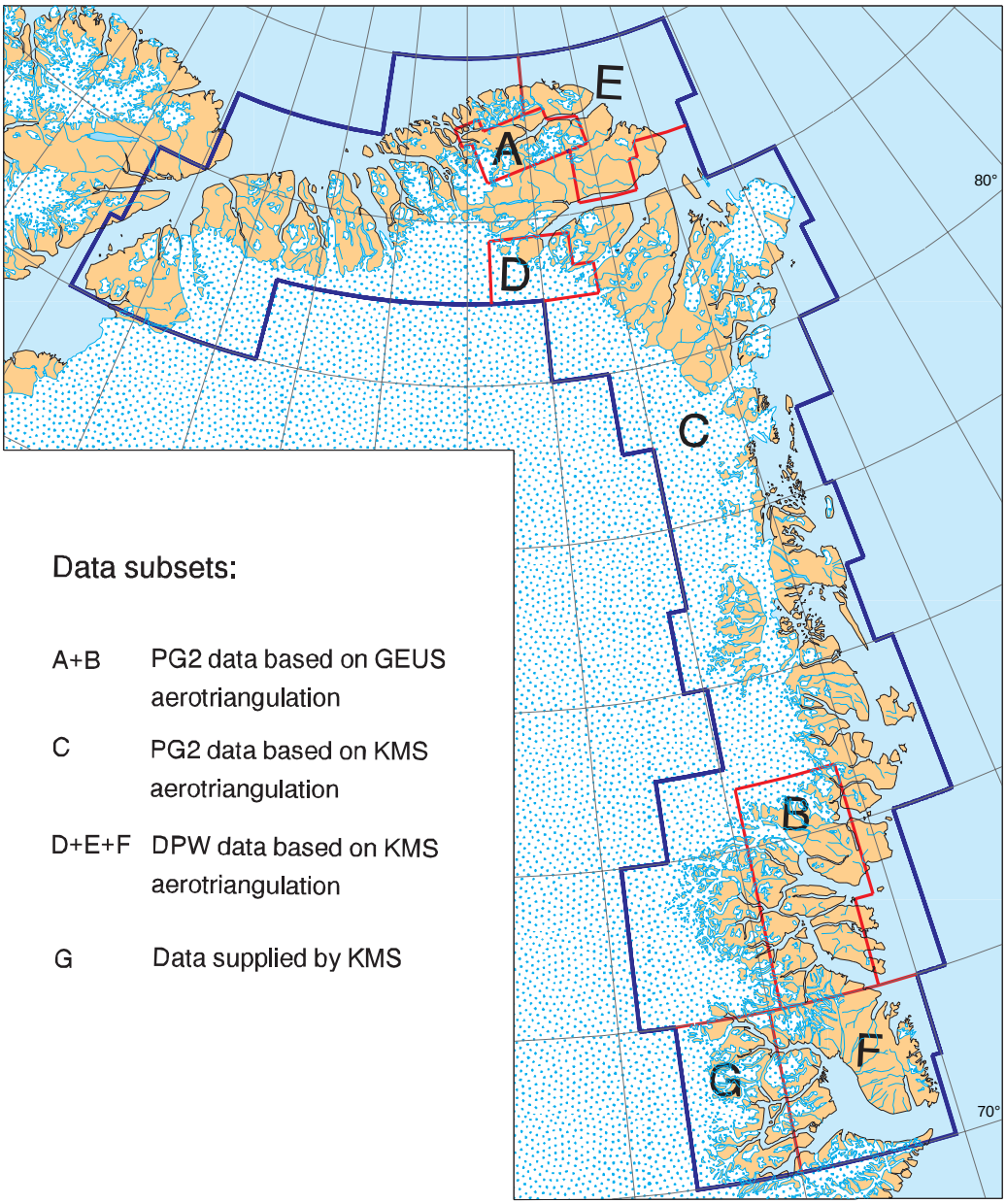

Figure 1. *Index map showing different data subsets in the area covered by the present data compilation.*

At the project start, digital topographic maps covering c. 80% of the project area already existed. Of these 70% were produced by the GGU/GEUS laboratory and 10% were supplied by the National Survey and Cadastre (KMS). The remaining 20% were produced by GEUS during the project period. The present topographic data set covering the National Park and Scoresby Sund areas is thus a combination of data produced over a period of more than 25 years.

Reflecting the technological evolution in that period, photogrammetric methods and the quality of ground control have changed over the years, and the data set can therefore be described with reference to several subsets corresponding to this evolution (Figure 1).

Aerial photographs at scale 1:150 000 and photographed from c. 14 km altitude with super-wide angle 9-inch photogrammetric cameras form the basis for all data. The aerial photographs campaigns were carried out by KMS over a 10-year period between 1978 and 1987 (Bengtson, 1983).

Ground control was established by KMS (Madsen, 1994). From 1976 the TRANSIT satellites and Doppler measurements were used at a large number of geodetic control points with a spacing of about 50-60 km. The Doppler-observations were supplemented with traditional trigonometric measurements, barometric observations and gravity and geoid determinations.

Most of the area has been aerotriangulated by KMS. In each aerial photograph 10+ points are measured, each of which are measured in 2–4 different overlapping photographs. The locations of the geodetic ground control points 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 photograph treated as a free bundle of rays. The adjusted xyz-ground coordinates have root mean square (rms.) errors better than 10 m.

The time-consuming measurement of the many photographs covering all of Greenland extended over some 25 years, and although the priority of the different areas being measured was planned in close co-operation between KMS and GGU, approximately 15% of the 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 c. 30 m and z-rms. errors of c. 10 m.

From 1978 to 1999 the topographic data from the GEUS laboratory was produced by a mechanical-optical 2nd order stereorestitution instrument of the type KERN PG2 using transparent photographic copies of the aerial photographs. Both the hydrographic themes (coast lines, lakes, rivers, ice margins) and the contour lines were generated manually. In the period up to mid-1988 the PG2 instrument was equipped with a slow prototype xyz-digitiser, which periodically would skip one or two vertices when the stereooperator was drawing at high speed.

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.

The data supplied by KMS were produced by Kampsax A/S (now Cowi Consult) on a digital photogrammetric workstation using digital scanned copies of the aerial photographs.

The data produced by GEUS and the data supplied by KMS are summarised as follow:

Data produced by GEUS:

Target map scale:	1:100 000
Topographic themes:	hydrography and 100 m equidistant contour lines both on ice-free land and on ice.
Areal coverage:	c. 90% of the target area
Subareas:	PG2 data based on GEUS aerotriangulation.
	PG2 data based on KMS aerotriangulation.
	DPW data based on KMS aerotriangulation.

Data supplied by KMS:

Target map scale:	1:250 000
Topographic themes:	hydrography and 100 m equidistant contour lines on ice-free land.
Areal coverage:	c. 10% of the target area. The area of coverage is located on the east coast west of longitude 27^{o}W between latitudes 70^{o}N and 72^{o}N.

The attributes DATE, SOURCE_ID and SO_DATAID (see section 4.3.3) can be used to distinguish between the different data subsets.

3.3 Place names

Place names are an important key to geographic information and the present map compilation therefore includes place names. In North and Northeast Greenland most place names record the activities of European and American exploration and scientific expeditions. However, where Greenlandic names exist both forms are used. Within the project area several thousand names have authorised status. Of these c. 1700 names are used in the 1:250 000 data set. Five different sources have been used during compilation of the place names:

- Laursen (1972) for North Greenland
- Higgins (in press) for East Greenland
- The Place Name Register (developed by KMS) for all area
- Reference maps of The Place Name Register for all areas
- Various maps produced by GEUS, based on KMS sources

The place name theme has been checked by Oqaasileriffik, The Greenland Place Name Committee, Nuuk. It should be noted that as a general rule no man-made features are included in the present data set.

4 Technical map specifications

4.1 The vector GIS-data

The raw 3D photogrammetric data are imported to the Esri ArcInfo GIS-platform as 2D data. 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 1:250 000 version using line smoothing, elimination of small areas and minor rivers. In the 1:250 000 data set consistency of the contour lines are further validated and place names are added. Data at the two target scales are each unified into seamless data sets. Both data sets are available on the attached CD-ROM.

As part of the quality control of the digital data set, a number of map sheets were test plotted. It turned out that these plots could be modified into a regular hardcopy map series, and GEUS has as a result compiled a total of 49 map sheets at scale 1:250 000 (Figure 2). These map sheets are not included on the CD-ROM, and no decision has yet been made as to making the maps generally available to the public.

Map sheet boundaries and map names are based on two KMS map series G/250 and G/100 Orto. Figure 3 shows a sample of the themes available in the digital data set on the CD-ROM.

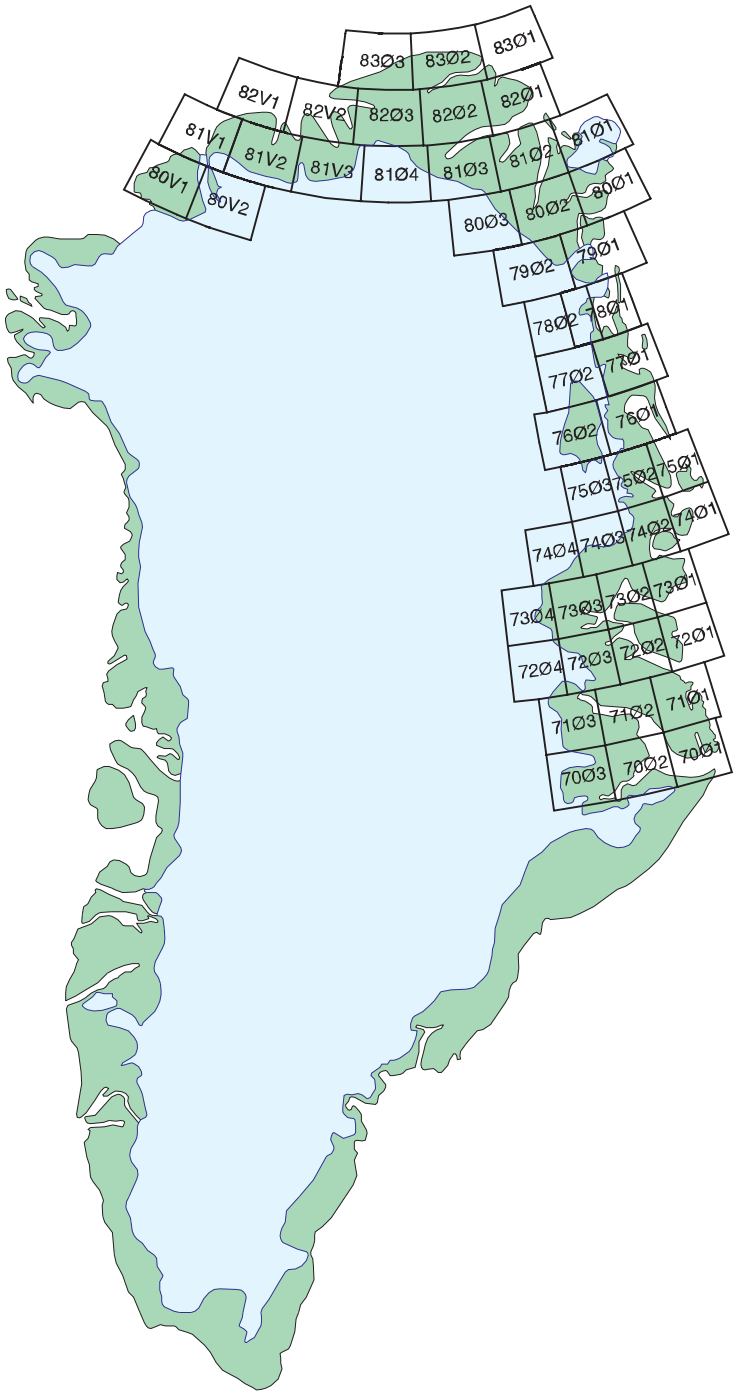

Figure 2. *Index map of 49 map sheets at scale 1:250 000. These maps are not included on the CD-ROM, and no decision has yet been made as to making the maps generally available to the public. The area covered by the map sheets corresponds to the coverage of the digital data set on the CD-ROM.*

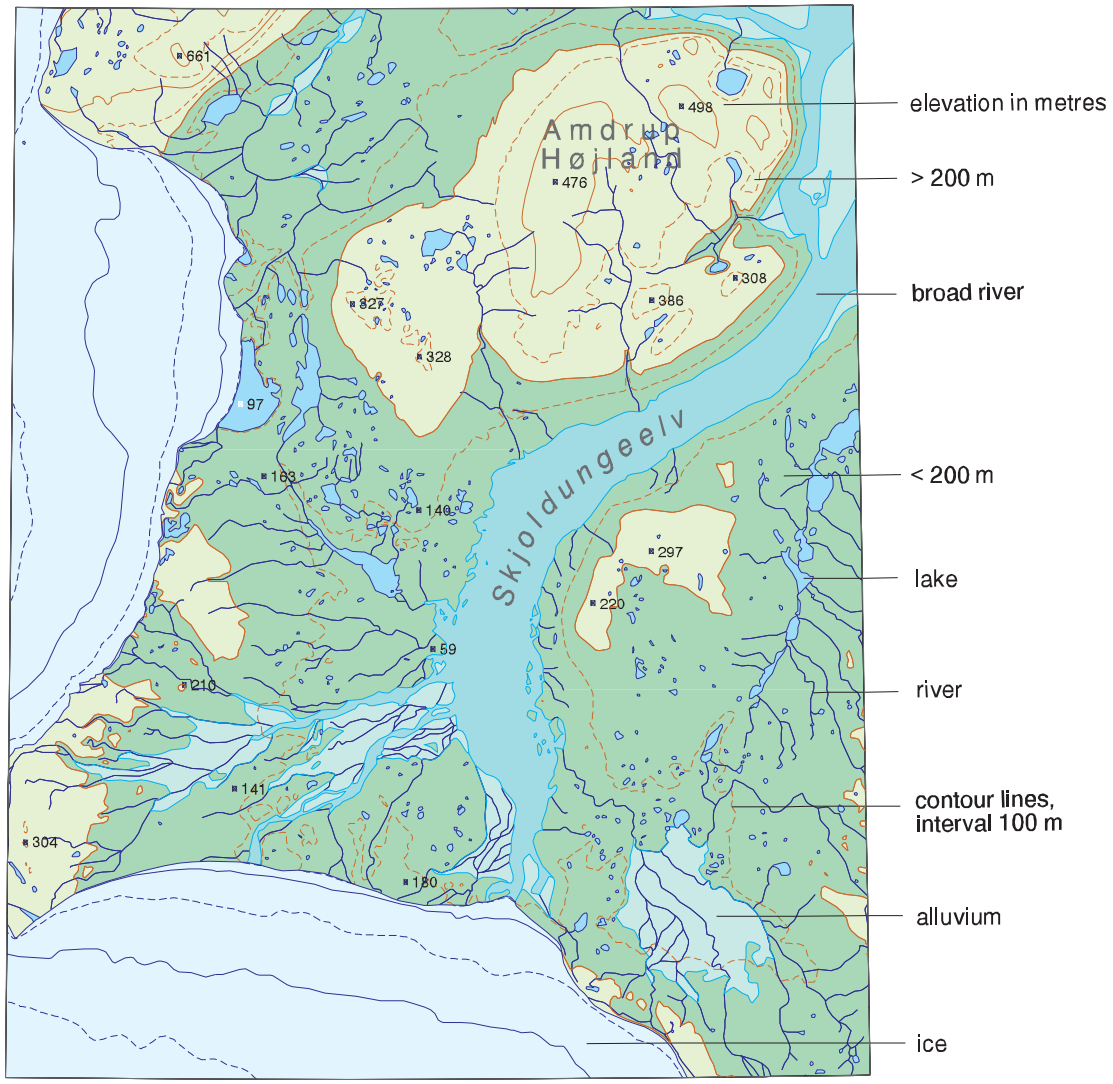

Figure 3. *1:250 000 map sample with themes available in the digital data set.*

4.2 The GIS data platforms

4.2.1 The conversion process

The result of the primary GIS-data production process is a library of ArcInfo (Areas, Rives, Contours, Points and Names). The data set covering the entire project-area have been converted to the native formats of ArcView and MapInfo. The details of this process are the following:

1) Using the ArcInfo Workstation application each coverage-type is "append"–ed or "mapjoin"–ed to one cover. At the same time a number of attribute fields, which are of importance only for internal purposes, are removed.

2) The place names are originally stored as ArcInfo annotation with text size in page units. The text size is now converted to map units assuming a map scale of 1:250 000. The internal annotation characteristics are copied to the TAT-file using command Addtext.

3) Using the FME universal translator the newly produced coverages are converted to ArcView shape files and MapInfo TAB files. In this process additional attribute fields are removed and most of the remaining fields renamed to shorter names

4) The original coverages are in the geodetic reference NAD83, which can be regarded as identical to WGS84.

5) Special issues of annotation: Since ArcView does not support a shape file-based annotation, but can use ArcInfo annotation directly, no conversion is done here. MapInfo does support text type TAB files, but only with text along straight lines. When the ArcInfo annotation is placed along a curved line, the FME conversion will split the text into single characters, which are placed to give the impression of a curved text line. Because of this splitting the number of features in the MapInfo text TAB file will be significantly higher than in ArcView. Horizontally written place names are in this context interpreted as "parallel to a parallel (certain degree of latitude)". This means that place names far from the central meridian of UTM zone 24 (39° west) will appear to be slanted.

6) Neither ArcInfo nor ArcView supports storing of colour and other symbol attributes directly in the GIS data set. Colours are produced by mapping attributes to colour tables via legends. In MapInfo colour and other symbol information can be stored directly in the TAB file. The FME conversion will store the standard GEUS symbolisation in the TAB files.

7) From the ArcView application the ArcInfo annotation cover is converted to a point shape file. The original place names may include extra blank characters to produce a more intuitive position of the name on the map. In an external program these extra characters are removed to produce a text field which is suitable for quick searching for place names. The result is a point shape file – also converted to a TAB file – which can be used for both searching and alternative labelling.

4.3 Data content of the CD-ROM

This chapter describes the following:

- Directory structure of the CD-ROM
- Filenames
- Attribute fields
- Codes for attribute field LABEL in the different themes
- The GIS applications

4.3.1 Directory structure of the CD-ROM

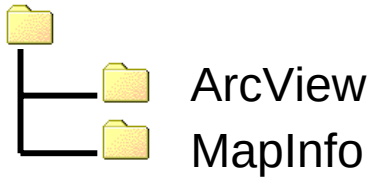

Figure 4. *Top level directory: CD-ROM. 2nd level directories: ArcView, MapInfo.* In the two 2nd level directories all data files for the corresponding software platform are found. Furthermore, the file containing the ArcView project (map.apr) and the MapInfo workspace (map.wor) are placed in the same directories.

4.3.2 Filenames

ArcView:

	1:250 000	1:100 000
Contents	**Name of shape file**	**Name of shape file**
Areas outlines	Areas_line.shp	Areas_line_100.shp
Areas polygons	Areas_poly.shp	Areas_poly_100.shp
Contours	Contours_line.shp	Contours_line_100.shp
Grid Lat:1° Long:5°	Grid_big.shp	no data
Grid Lat:15' Long 1°	Grid_small.shp	no data
Names as text	Names (Directory containing ArcInfo cover)	no data
Names as points	Namepoints.shp	no data
Points	Points.shp	Points_100.shp
Rivers	Rivers.shp	Rivers_100.shp

MapInfo:

	1:250 000	1:100 000
Contents	**Name of Tab file**	**Name of Tab file**
Areas outlines	Areas_line.tab	Areas_line_100.tab
Areas polygons	Areas_poly.tab	Areas_poly_100.tab
Contours	Contours_line.tab	Contours_line_100.tab
Grid Lat:1° Long:5°	Grid_big.tab	no data
Grid Lat:15' Long 1°	Grid_small.tab	no data
Names as text	Names_anno.tab	no data
Names as points	Namepoints.tab	no data
Points	Points.tab	Points_100.tab
Rivers	Rivers.tab	Rivers_100.tab

4.3.3 Attribute fields

Theme filename	**Name in ArcView table of contents**
Field name	Field content
Areas_line	**Areas outlines**
LENGTH	Length of feature in meters
AREAS_NO	Internal number
AREAS_ID	Internal number
DATE	Creation date
SOURCE_ID	Source type (PG2, DPW, KMS, FREE)
SO_DATAID	Data source
SO_DATUM	Original datum
ELEVATION	Mean elevation (z-value)
VALIDELEV	Valid elevation: 0=invalid, 1=valid
LABEL	Code for line type; controls symbology
CATEGORY	Number indicating importance (1:highest)
LEFT	Code for polygon on the left side of line
RIGHT	Code for polygon on the right side of line
Areas_poly	**Areas polygons**
AREA	Area if feature in square meters
PERIMETER	Length of perimeter in meters
AREAS_NO	Internal number
AREAS_ID	Internal number
LABEL	Code for polygon type; controls symbology
CENTROID_X	X-coordinate for centre of polygon

CENTROID_Y	Y-coordinate for centre of polygon
Contours_line	**Contours**
LENGTH	Length of feature in meters
CONTOUR_NO	Internal number
CONTOUR_ID	Internal number
DATE	Creation date
SOURCE_ID	Source type (PG2, DPW, KMS, FREE)
SO_DATAID	Data source
SO_DATUM	Original datum
ELEVATION	Mean elevation (z-value)
VALIDELEV	Valid elevation: 0=invalid, 1=valid
LABEL	Code for line type; controls symbology
CATEGORY	Elevation rounded to nearest 100; use for labelling and symbology
Grid_big	**Grid Lat:1° Long:5°**
LENGTH	Length of feature in degrees
ID	Internal number
NAME	Name; use for labelling
Grid_small	**Grid Lat:15' Long 1°**
LENGTH	Length of feature in degrees
ID	Internal number
NAME	Name; use for labelling
Names / Names_anno	**Names as text**
NAMES_	Internal number
NAMES_ID	Internal number
X	X-coordinate for start of text string
Y	Y-coordinate for start of text string
OFFSETX	X-Offset (always 0)
OFFSETY	Y-Offset (always 0)
HEIGHT	Height (always 0)
SYMBOL	Number of symbol from internal GEUS table. Can be mapped to fontname, size etc.
LEVEL	Number indicating importance (1:highest)
TEXT	The text string (including extra blanks)

Namepoints	**Names as points**
NAMES_	Internal number
NAMES_ID	Internal number
X	X-coordinate for start of text string
Y	Y-coordinate for start of text string
HEIGHT	Height in meters
SYMBOL	Number of symbol from internal GEUS table. Can be mapped to fontname, size etc.
LEVEL	Number indicating importance (1:highest)
TEXT	The text string (including extra blanks)
TEXT2	The text string with extra blanks removed
LENGTH	Number of characters in TEXT2
Points	**Points**
POINTS_NO	Internal number
POINTS_ID	Internal number
DATE	Creation date
SOURCE_ID	Source type (PG2, DPW, KMS, FREE)
SO_DATAID	Data source
SO_DATUM	Original datum
ELEVATION	Elevation (z-value)
VALIDELEV	Valid elevation: 0=invalid, 1=valid
LABEL	Code for point type; controls symbology
FEATURE	Alternative code for point type
STRING	Elevation as string; use for labelling
Rivers	**Rivers**
LENGTH	Length of feature in meters
RIVERS_NO	Internal number
RIVERS_ID	Internal number
DATE	Creation date
SOURCE_ID	Source type (PG2, DPW, KMS, FREE)
SO_DATAID	Data source
SO_DATUM	Original datum
ELEVATION	Mean elevation (z-value)
VALIDELEV	Valid elevation: 0=invalid, 1=valid
LABEL	Code for line type (always RIV)
CATEGORY	Number indicating importance (1:highest)

4.3.4 Codes for attribute field LABEL in the different themes

Areas_line	
ALVMRG	Alluvium margin
DELTFR	Deltafront
ICEMRG	Icemargin
LAKCST	Lake coast
NONE	Polygon borders that should not be drawn
RIV	Polygon border is a river
RIVBNK	Banks of wide rivers
RIVLAK	Border between lake and wide river
RIVSEA	Border between sea and wide river
SEACST	Sea coast
Areas_poly	
ALV	Braided rivers
ICE	Ice caps and glaciers
LAK	Lakes
LD	Land
RIVER	wide rivers
SEA	Sea
Con-tours_line	
CON	Contours on land
CONI	Contours on ice
BOUND	Boundary to ice cap
Points	
TSPOT	Hill tops
LSPOT	Lake surfaces

4.3.5 The GIS applications

The term "application" in this context is synonymous with an ArcView project file or a MapInfo workspace. The only difference between starting a "naked" ArcView or MapInfo session and starting these applications is that the GIS data files are attached to the map window and symbolised in a meaningful way. No extra functionality is added to the software.

It is assumed that the user of the data has a basic knowledge of ArcView or MapInfo. Hence this document will include no instructions for their use.

5 Conclusions and recommendations

The present DANCEA project has compiled and homogenised a wide array of topographic data that, over the last 25 years, has been produced and covers large parts of the North and Northeast Greenland National Park and the adjacent Scoresby Sund area. In addition supplementary topographic data has been produced covering areas where no modern topographic data previously existed.

The result is two digital topographic data sets available on GIS platforms at scale 1:250 000 (100% of the area) and at scale 1:100 000 (c. 90% of the area).

After completion of the project, inconsistencies, errors or omissions will undoubtedly appear. The project work has also shown that some issues related to this data set need to be re-considered at a later date.

Recommendations:

1. A follow-up project should be initiated when recommendations for additions, corrections etc. have been collected. The current data set will thus be updated and new layers can be introduced e.g. man-made features etc.
2. The 49 map sheets at scale 1:250 000 that were produced as test plots during the compilation phase deserve to be made available to a wider audience (expeditions, tourism, schools etc.). To reach that goal, it is necessary to establish funding for printing of these maps.

6 Acknowledgements

A major part of the compilation work was financed by the Danish Cooperation for Environment in the Arctic, Ministry of the Environment, (DANCEA).

The active co-operation of the members of the project Steering Committee is gratefully acknowledged. These members include: Mette-Astrid Jessen, Ministry of Environment and Nature, Nuuk; Jette Blomsterberg, Bureau of Minerals and Petroleum (BMP), Nuuk; Anders Dalgaard, Asiaq, Nuuk; Ole Berg, National Survey and Cadastre, Copenhagen; and Peter Aastrup, National Environmental Institute, Roskilde.

Qqaasileriffik, The Greenland Place Name Committee (Nuuk), undertook the tedious work of checking all the names. The active co-operation of this committee is greatly appreciated.

A group of persons tested the CD prior to the completion of the project and provided valuable comments and suggestions for improvements. This group included Anders Dalgaard, Asiaq, Nuuk; Jette Blomsterberg, (BMP), Nuuk; Peter Laulund, National Survey and Cadastre, Copenhagen; and Peter Aastrup, National Environmental Institute, Roskilde.

A. K. (Tony) Higgins, GEUS kindly checked the maps and the report.

Last, but not least, the dedicated work by Margareta Christoffersen, Anette Thorning Hindø, and Jørgen Neve all at GEUS, is gratefully acknowledged.

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8 Availability

The report is at present classified as ‘confidential’, but will be made available to the public when confidentiality expires.

When the report becomes de-classified this information will appear at www.geus.dk and the publication may then be ordered from (price not yet fixed):

Publication Sales
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E-mail: geus@geus.dk

Any comments or corrections to the digital data set are appreciated, and can be sent to the above E-mail address with following text in the subject line:

“Digital Topographic Map – GEUS 2003 R 89”