DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2001/46

Geochemical atlas of Greenland – West and South Greenland

Agnete Steenfelt

(1 CD-ROM included)

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

GEUS

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GEUS

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Frontispiece. *Helicopter-supported stream sediment sampling in West Greenland.*

Contents

Abstract

The 'Geochemical atlas of Greenland – West and South Greenland' is released on a CD-ROM accompanying this report. The atlas is based on compilation of chemical analyses of stream sediment samples collected from 1977 to 1998 in geochemical mapping and mineral exploration surveys, undertaken by the Geological Survey of Denmark and Greenland with financial support from the Bureau of Minerals and Petroleum, Greenland.

The atlas is based on data from 7122 stream sediment samples. It contains maps of 43 chemical elements, a map of volatile contents of stream sediment, a map of gamma radiation and five maps of kimberlite indicator minerals recovered from stream sediment. A geological map and a map of aeromagnetic anomalies are also enclosed. The maps may be accessed using Geosoft OASIS montaj™ Free Interface software included on the CD. This report and a bibliography are also stored on the CD in .pdf format and may be accessed using Adobe Acrobat® Reader (included).

The atlas data may be used for geological mapping and modelling, mineral resource assessment, and environmental studies and management.

The geochemical data set behind the atlas is available at cost from GEUS.

Introduction

An atlas of geochemical maps covering all ice-free parts of Greenland (c. 410 000 km^2) is the ultimate goal of the programme 'Reconnaissance geochemical mapping of Greenland'. The programme is undertaken by Geological Survey of Denmark and Greenland (GEUS) with financial support from the Bureau of Minerals and Petroleum at the government of Greenland. The present publication, 'Geochemical atlas of Greenland – West and South Greenland', is a first step in achieving that goal. The geochemical maps presented here cover West and South Greenland with the exception of Disko island and outer Nuussuaq peninsula where data are lacking (Fig. 1).

The atlas presents the result of a compilation of chemical analyses of stream sediment samples collected from 1977 to 1998 as part of mineral exploration surveys within the area. Results of individual surveys have been reported previously, and compilation of data for larger areas have been made and published in Thematic Map Series of the former Geological Survey of Greenland (GGU) and later GEUS. However, this is the first time that a compilation of geochemical data for the entire West and South Greenland can be presented.

The great interest for diamond exploration in the mid-nineties encouraged the search for high-pressure minerals derived from mantle xenoliths enclosed by kimberlites, in surficial material like till and stream sediment. Inspired by this, an investigation of these kimberlite indicator minerals, e.g. pyrope, picro-ilmenite, chromite and chrome-diopside, in the 0.25 to 1 mm grain size fraction of stream sediment samples from southern West Greenland was carried out, and the results are presented in the atlas.

The CD-ROM atlas thus presents maps of 43 chemical elements, a map of volatile contents of stream sediment, a map of gamma radiation, five maps of kimberlite indicator minerals recovered from stream sediment. For comparison, a geological map and an aeromagnetic anomaly map are also presented.

The geochemical maps demonstrate, for the first time, the magnitude of the considerable natural variation in the concentration of chemical elements that exists over the atlas area. This recognition has implications for mineral resource assessment and geological modelling as well as for environmental management and land-use planning in Greenland.

The geochemical data set for West and South Greenland quantifies geochemical differences between rock complexes of different age and geological setting which may be used for modelling of the Earth's geological and geochemical evolution. As importantly, the data set is a documentation of the natural geochemical background over a large area and a contribution to the growing coverage of geochemical data world-wide. Baseline data of this type are important to understanding natural variations in the surface environment on a global scale.

The CD-ROM presents the geochemical and associated maps together with this report, describing the data acquisition, map presentation and application possibilities. In addition, a bibliography relating to geochemical exploration and mapping within the atlas area is included. Procedures for compilation, quality control and levelling of chemical data are reported separately (Steenfelt 1999, 2001).

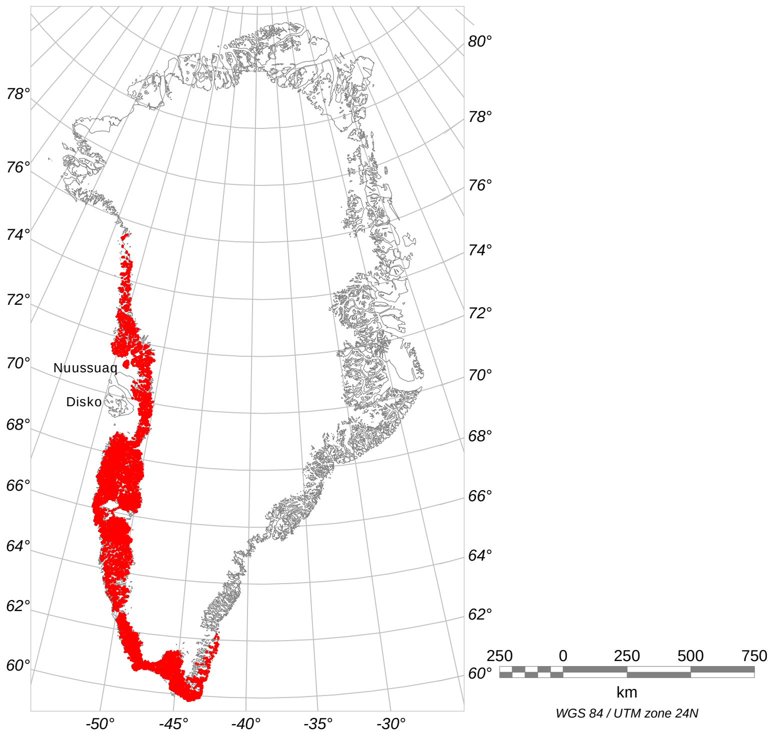

Figure 1. *Map of Greenland with atlas coverage indicated by location of samples in red.*

Physiography

Topography

The most pronounced landscape feature of Greenland is the large ice cap, the Inland Ice, covering c. 80 % of the entire land surface and reaching an estimated thickness of 3.4 km (Fig. 2). At a local scale, ice caps and perennial snowfields are characteristic elements at altitudes over 600 m everywhere in Greenland. The ice-free margin of Greenland is generally mountainous, but displays great topographical variation, from alpine terrain to lowlands and widespread archipelagos. The landscape is primarily formed by glacial erosion. Numerous lakes and fjords, aligned more or less perpendicular to the Ice margin, are carved by glaciers during and after the last glaciation. Glacial deposition is limited. Moraines or remnants of moraines are seen in valleys and in front of glaciers, but till is thin and scarce. Glacifluvial deposits, on the other hand, are abundant and fill valleys and lakes along the ice margin. Aeolian silt deposits occur in the surroundings of large melt water streams. The Quaternary map of Greenland, 1:2 500 000 (Weidick 1971) gives an overview of glacial features and also shows the distribution of raised beaches and marine deposits giving evidence for considerable post-glacial uplift.

Climate

The climate of the atlas area is arctic, but the south-western coastal zone enjoys the effect of the north-western branch of the warm Gulf Stream running northwards into Labrador Sea. The stream prevents the formation of sea ice in the winter, leaving the harbours south of about 68°N accessible all year. Mean temperatures for the warmest month varies between +7°C in the south to +5°C in the north, while means for coldest month are -4°C in the south and -20°C in the north. Permafrost prevails over most of the area.

Precipitation varies in abundance. The coastal zone and South Greenland gets much precipitation (c. 90 cm per year) due to frequent passages of low-pressure systems. Inland areas from 66°N northwards as well as areas north of 69°N receive much less precipitation (around 22 cm per year).

Soil and vegetation

Residual soil has developed on rock debris in depressions in rock surfaces, on till, glacifluvial deposits and marine terraces. The soil is commonly thin and well-developed podzol profiles are rare. A decimetre-thick brownish black organic (humus-rich) root-zone is usually developed between the substrate and the vegetation.

The vegetation is very scarce in the highlands. The sub-arctic to high-arctic tundra of the lowlands has moderate to dense vegetation dominated by mosses, lichens, herbs, shrub (*Empetrum, Vaccinium* and *Cassiope* are some of the commonest species) and arctic dwarf species of trees mainly birch and willow. In sheltered valleys and ravines the trees may form waist-high thickets. The landscape photos linked to Fig. 2 also show examples of vegetation.

Drainage

A major system of glaciers and large melt water rivers radiate from the margin of the Inland Ice towards the coast and segment the country. Steep cliffs along fjords as well as slopes of large U-shaped valleys are drained in a pattern of parallel small streams. The nature of the many small drainage systems developed in the land between the fjords and glaciers depends on local topography in combination with the structure underlying rocks. In northern West Greenland high-altitude plateaus between fjords are covered by local blocks and have no stream systems at all. Very steep slopes of glacier-filled valleys or flat skerries of

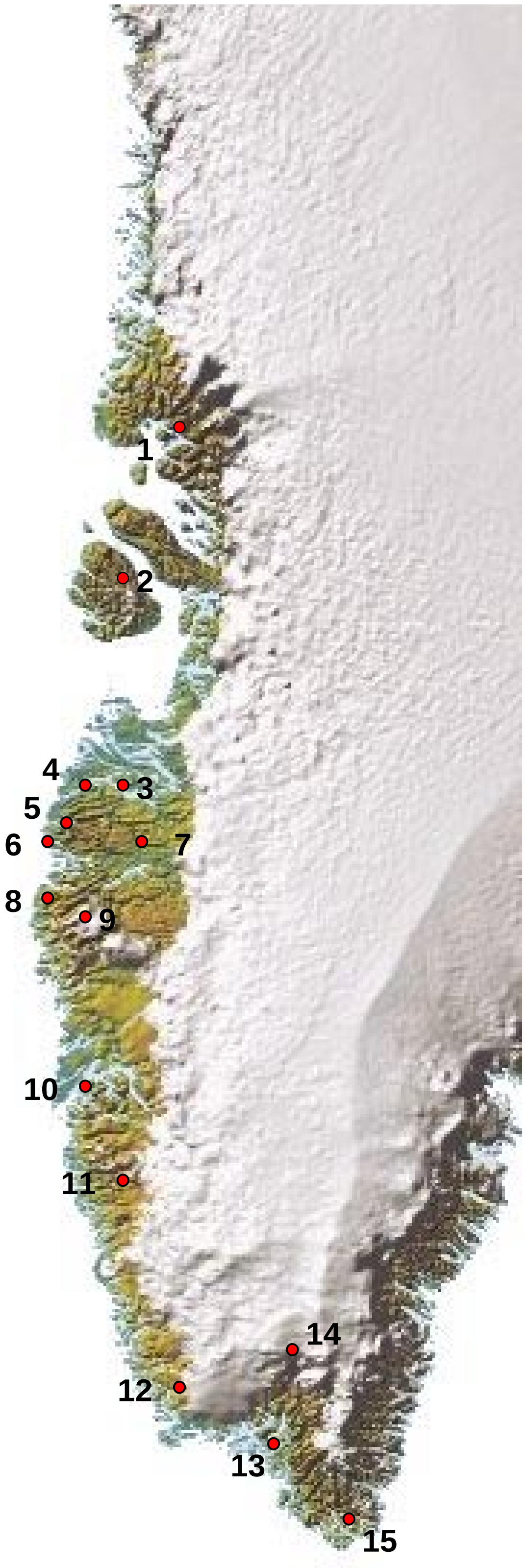

Figure 2. *Topographic map of the atlas area. Red dots contain links to photographs illustrating different kinds of landscape. Numbers refer to photos in directory 'Photos' and in Appendix 3.*

the archipelago also lack proper streams. Strongly deformed belts have elongate depressions with many lakes and only few streams across structure (Photo 4). However, large areas have well-developed stream systems suitable for systematic stream sediment sampling. See photos 16, 17, 18, 19, 20, and 21 in directory 'Photos' or in Appendix 3.

Because of the arctic climate, streams flow only during spring and summer. Streams draining lakes, perennial snowfields, or local ice caps flow all summer, while streams, serving as run-off channels for rain and snow, are intermittent in nature.

Infrastructure

The majority of the 55 000 inhabitants of Greenland lives within the atlas area. The capital, Nuuk, with more than 10 000 inhabitants and a number of towns with 1000 to 3000 inhabitants are located along the West Greenland coast. The remaining population lives in small settlements. The CD provides a map of towns and settlements with more than 200 inhabitants. Main trades in West and South Greenland are fishery, services and education, tourism, and sheep farming.

International passenger traffic into the area takes place through the airports of Kangerlussuaq and Narsarsuaq, which have regular connections to Copenhagen in Denmark, Reykjavik in Iceland, and Eqaluit in Canada. Domestic air transport connects the capital of Greenland, Nuuk, with towns and settlements. There are also ship connections along the west coast of Greenland. Freight into the area is by air or by transatlantic shipping from Denmark. Inland areas can only be reached by helicopter or by foot.

Overview of geology and mineral occurrences

Only the main geological features are mentioned here. Henriksen *et al.* (2001) provides an updated overview of the geology of Greenland and a comprehensive list of literature references. A simplified geological map is provided on the CD.

Most of West and South Greenland is underlain by Precambrian terrain comprising an Archaean craton, three Palaeoproterozoic orogens, and a Mesoproterozoic alkaline igneous province. A province of Mesozoic to Tertiary sediments and mafic lavas (Nuussuaq Basin) occurs in West Greenland between latitudes 69° and 72° N.

The Archaean Craton comprises rock assemblages with ages ranging from more than 3800 Ma to c. 2500 Ma. Tonalitic gneisses are predominant, and supracrustal enclaves dominated by mafic metavolcanics occupy an estimated ten to twenty per cent of the exposed rock. In the simplified geological map of the atlas intrusive units are divided into felsic (granodiorite and granite) and mafic (diorite, gabbro, anorthosite). Mineral occurrences are mainly associated with mafic intrusives, (chromite, nickel, platinum, olivine) or mafic supracrustals (W, Au).

The orogens in the north, the Rinkian and Nagssugtoqidian, both incorporate large proportions of reworked Archaean gneiss. The northernmost, the Rinkian orogen, comprises kilometres thick units of metasediment (the Karrat Group) and a granitic intrusion, the latter having an age of 1860 Ma. An important lead-zinc deposit, 'Black Angel', hosted by a carbonate member of the Karrat Group, was mined from 1973 to 1990. Gold mineralisation is hosted in Archaean supracrustal rocks within the Rinkian. No boundary between the two orogens has been drawn on the map because it has not yet been clearly established. The Nagssugtoqidian orogen, adjacent to the Archaean craton, is currently believed to extend as far north as 69°N. It comprises only minor volumes of Palaeoproterozoic supracrustal and intrusive rocks. Two Palaeoproterozoic intrusive units, not shown on the map, deserve to be mentioned because they are reflected in the geochemical maps. One is a Ba-Sr-rich quartz-dioritic complex at 67°N, the other a dolerite dyke swarm affecting the northernmost Archaean craton and boundary region to the Nagssugtoqidian orogen. A small graphite occurrence located within the Nagssugtoqidian area has been mined.

The orogen in the south, the Ketilidian, comprises largely juvenile Palaeoproterozoic rocks. The felsic intrusions (granodiorite to granite) and the metasediments to the south-east are regarded as products of an accreted volcanic arc forming in the interval c. 1850 to c. 1800 Ma. A prominent igneous suite, rapakivi suite, intruded the region around 1740 Ma. The Ketilidian orogen hosts widespread gold mineralisation, among which one prospect is approaching the mining stage. Small deposits of graphite and copper have been mined.

The Mesoproterozoic province of rifting and volcanism, the Gardar province, has a strong influence on the geochemical maps because of the strongly alkaline character of the intrusive magmas (mostly felsic syenites), and their enrichment in incompatible elements. In addition to the major intrusive complexes shown on the geological map, there are several alkaline dyke swarms, which have contributed to geochemical anomalies within the province. The Gardar province has significant occurrences of uranium and 'high technology metals', such as niobium, tantalum, zirconium and rare earth elements. A cryolite mine, closed in 1987, operated more than a century.

The simplified geological map shows two carbonatite complexes, 600 Ma and 170 Ma of age, respectively, and three provinces with dykes or sheets of kimberlites (*s.l.*) within the Archaean Craton. Kimberlites fall into three age groups, c. 1200 Ma, c. 600 Ma and c. 200 Ma (Larsen & Rex 1972). The carbonatites host occurrences of pyrochlore (niobium, tantalum) apatite and rare earth elements. Both micro- and macro-diamonds have been found in kimberlite dykes.

The Nuussuaq Basin is dominated by thick formations of plateau basalts. Lower units are picritic, while uppers are largely tholeiitic. Predictably, the basalt province is very pronounced in most element maps of the atlas. On Disko island coal has been mined from sedimentary layers, and dykes with native iron and nickel-platinum mineralisation has been located.

Data acquisition

Stream sediment sampling

In selecting a *sample medium* for geochemical exploration and mapping in Greenland, stream sediment appeared an obvious choice. The mountainous terrain together with melting snow and ice has created well-developed stream systems, and, contrary to soil or vegetation, streams are ubiquitous in Greenland. The *sampling density* has varied, but large parts of West and South Greenland have been sampled at reconnaissance scale, i.e. one sample per 20 to 40 km^2.

Two-man crews supported by helicopter undertook most of the reconnaissance sampling. Rubber boats were also used for transport in South and northern West Greenland.

Suitable sample sites with an even distribution have been selected by stereoscopic inspection of aerial photographs prior to the fieldwork. Second or third order streams with catchment areas less than 20 km^2 are preferred. When visited, the selected site may have been inaccessible or unsuitable in other way, and an alternative site has been sought in the same or neighbouring drainage system. In certain low-relief landscapes, proper streams were absent, and samples have been collected from sediment on the shores of small lakes instead. Photos 16, 17, 18, 19, 20, and 21 show a variety of sampled streams.

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

At each sediment sample site, a water sample contained in a 100-ml polyethylene bottle was collected, the gamma-radiation was measured and a short site description was made.

Until 1992, the sample locations were noted on aerial photographs, transferred to topographic maps at 1:250 000 scale, and then digitised. From 1992 onwards, the Global Positioning System (GPS) was used.

Sample preparation

Sample bags were provisionally dried in the field, i.e. in tent camps, indoors or aboard ships, before wrapped, packed and shipped to the Copenhagen office. See Photo 22.

Samples were oven-dried at 60°C and then dry-sieved using two polyethylene screens. The fraction above 1 mm grain size was discarded, the 0.1 to 1 mm size fraction stored, and the < 0.1 mm size fraction was submitted for analysis.

Chemical analysis

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

Compilation of atlas data

Stream sediment data

The data set used for presenting element distribution maps has been compiled from geochemical stream sediment surveys carried out from 1977 to 1998. Sampling and sample preparation have followed the standard procedures described above throughout this period. Analytical treatment has been less systematic (Steenfelt 1999), partly because of progress in analytical methodology and partly because of differences in the aim and analysis budget of individual surveys. Also the sampling density varied depending on the character of individual exploration campaigns. In most of the atlas area systematic reconnaissance sampling had a density of one sample per 20 to 30 km^2. Where local detailed surveys have contributed to the atlas coverage, samples have been selected to conform to this density. By contrast, data from all samples collected in a stream sediment survey covering a large part of South Greenland were included, even if the average sample density was higher (one sample per 6 km^2). It was desirable to maintain the higher resolution in that area so that distinct litho-chemical units could be mapped.

The greatest challenge in the compilation of the analytical data was the necessary selection of the most reliable data and the subsequent levelling of data from different analytical batches. The latter was necessary because analytical bias was found both between methods and over time. Internal standards have been used to monitor the quality of chemical analyses, and these standards have also been analysed together with international reference material so that the Greenland data can be made consistent with geochemical data from elsewhere in the world. The procedures used for selection and calibration of the analytical data are documented in Steenfelt (1999, 2001). Steenfelt (1999) also contains a bibliography on geochemical exploration and mapping in the atlas area. The bibliography is enclosed on the CD.

The final data set comprises a total of 7122 samples, analysed for up to 43 elements. The data set used to calculate the grids is summarised by statistical parameters in Table 1, placed at the end of this report, just before the appendices. The several analysis methods involved required considerable amounts of sample material. Samples with limited material in the < 0.1 mm size fraction did not permit more than one or two types of analysis. This explains the varying number of analyses performed for specific elements.

Data from water samples are not considered in the atlas. Measurements of electrical conductivity and analyses for uranium and fluorine have not been consistent are not easily made compatible and worth presenting at the scale of the atlas. Results may be found in reports from individual surveys, cf. the bibliography on the CD.

Gamma radiation

Gamma radiation emitted during the decay of naturally occurring radioactive isotopes in rocks and minerals has been measured at each stream sediment sample site using a scintillometer. This instrument measures total radiation, the sum of radiation from the gamma-emitters, decay products of primarily U, Th, and K. The measurements are made preferably on rock surfaces, alternatively on boulders or, if such surfaces are absent, on soil or gravel near the stream. An average value for the radiation has been estimated at each site.

Kimberlite indicator minerals

While the less than 0.1 mm grain size fraction of stream sediments of the geochemical mapping programme was used for chemical analysis, the 0.1 to 1 mm grain size fractions remained in storage at GEUS. In a joint agreement between GEUS and some exploration companies operating in Greenland, and financed by the latter, about 3000 stream sediment samples covering the Archaean craton of West Greenland were submitted to laboratories for recovery of non-magnetic, heavy mineral concentrates. Kimberlite indicator minerals were hand-picked from the concentrates and selected grains were analysed for major element composition to confirm their high-pressure origin. Despite the small amounts of available material in most samples (averaging 130 g with a range of 2 to 500 g in the 0.25 to 1 mm grain size fraction), one or more indicator minerals were found in about 20 % of the samples. A flow sheet of the sample preparation is given in Appendix 1

Data presentation

Directory structure of the CD-ROM

The geochemical and associated maps composing the atlas are stored in the CD in Geosoft OASIS montaj^{TM} map format. The maps may be opened and enlarged, copied and printed using the OASIS montaj Free interface software included on the CD, see below.

Users with licence to run OASIS montaj, preferentially with CHIMERA applications, will be able to perform various operations on the grids supplied with the maps, such as combining and windowing grids.

Accompanying reports are presented as text files in .pdf format, and they may be opened and read using Adobe Acrobat® Reader software, also included on the CD.

The directory structure (Fig. 3) shows that the atlas maps are all stored in subdirectories to the main directory 'GeochemicalAtlasWestSouthGreenland'. This report and the bibliography are located in the 'Report' directory. The remaining directories contain the installation software for OASIS montaj Free Interface and Adobe Acrobat Reader, as well as a tutorial for OASIS montaj Free Interface.

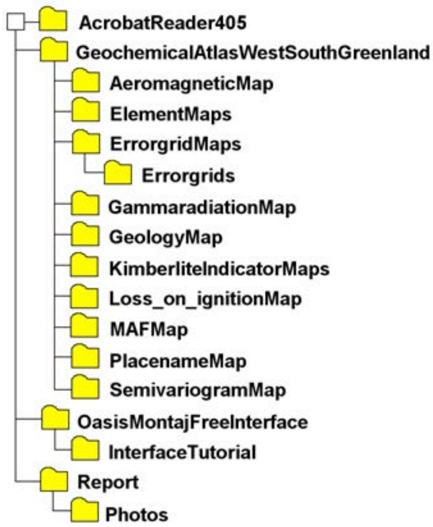

Figure 3. *Directory structure of the CD 'Geochemical atlas of Greenland – West and South Greenland'.*

Installing OASIS montaj™ Free Interface and Adobe Acrobat® Reader

The following software and hardware is required to install and run OASIS montaj Free interface:

- Windows NT® 4.0, Windows®95, or 98 required (NT is recommended)
- A Pentium® CPU
- RAM memory: 32 Mb or more recommended, 16 Mb minimum
- A 16 or 24-bit graphics card is recommended and required for full colour imaging
- VGA resolution minimum. 8-bit (256 colour) devices are also supported
- Any Windows® supported colour printer

- Microsoft® Internet Explorer browser (5.0 or later version) is required to take advantage of the help service and upgrading facilities provided by Geosoft via the internet.

The directory ‘OasisMontajFreeInterface’ contains two .exe files and a subdirectory with a tutorial to OASIS montaj free interface. Double-clicking ‘Interface.exe’ opens an on-screen demonstration of the OASIS montaj software. Double-clicking ‘OASISmontaj.exe’, using Windows Explorer or Start/Run, opens wizard instructions to install the program. The program should not be installed in a root directory, nor in a directory having a space in its name.

The directory ‘InterfaceTutorial’ contains a document in .pdf format together with data and map files used in the tutorial. The tutorial provides an understanding of the Geosoft environment and explains how data and maps can be accessed, converted and shared via the Free Interface. There are also more elaborate instructions for installing the software than given above.

The current version of OASIS montaj is 5.06; newer versions will be announced at the Geosoft homepage http://www.geosoft.com/, and may be downloaded from there.

Adobe Acrobat® Reader is installed by double-clicking ‘rs405eng.exe’ in the Acrobat-Reader directory.

Working with OASIS montaj maps

The Interface Tutorial explains how to work with maps and grids in the Geosoft environment. The atlas maps may be opened directly from the CD using the ‘Map | Open map’ menu and selecting a map via the browser. However, this way will prompt a message that the map is write-protected, and if the reader wants to open many maps the answering to this message every time can be annoying. Instead, it is recommended to copy the maps from the CD to a working directory, remove the protection, create a Geosoft workspace in the same directory (see Tutorial), and then open the maps from the directory.

Description of map contents

Element distribution maps

Each map displays a grid image of the variation in element concentration, a colour scale giving class intervals for the grid colours, histograms showing the frequency distributions of sample values and grid cell values, respectively, and statistical parameters for measured concentrations in samples and for the grid cell values.

All element concentrations below the lower limit of detection for the analytical method have been set to zero for simplicity, and in accordance with their registration in the GEUS database. Major element oxide concentrations have been recalculated as volatile-free concentrations to compensate for the effect of variable contents of organic matter and carbonate.

Each element map is composed of a number of groups listed in the ‘Map View/Group manager’-tool of OASIS montaj. For example, the map of barium, *Ba.map*, (Fig. 4) contains the groups listed and explained below:

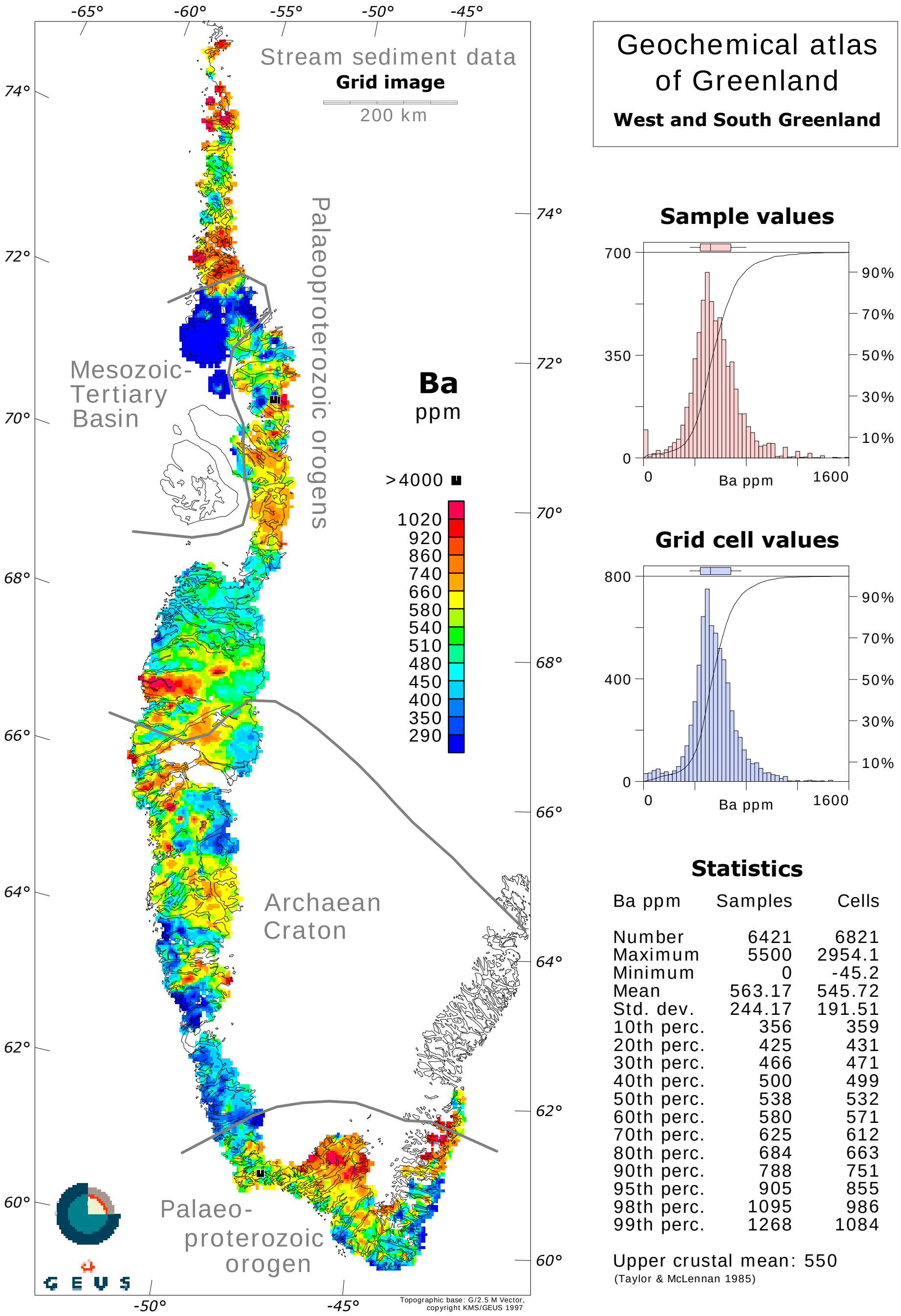

Figure 4. *Geochemical map of Ba in the < 0.1 mm fraction of stream sediment.*

Map Groups

Group name	explanation
Base view:	
STAT_Ba_grid.txt	text block with grid statistics
STAT_Ba_sample.txt	text block with sample analyses statistics
HIST_Ba_grid	histogram (frequency distribution) of grid cell values for Ba
HIST_Ba_sample	histogram (frequency distribution) of sample concentrations of Ba
COLORBAR_Ba	colour legend for grid values, element name, unit of concentration, and a symbol denoting exceptionally high sample concentrations of Ba
Stat.txt	text block with statistical parameters
Titles	fixed text on each map, headings and references
Scale_Bar	bar showing 200 km on map
Data view:	
Sample_location	location of samples analysed for Ba. The group is hidden when map is opened. Notice varying sample density, see data acquisition.
CHSYMB_anomaly	location of samples with highest Ba concentrations, compare legend
AGG_Ba	colour-grid of Ba variation. Grid cells 5x5 km. Gridding procedure: kriging
AGG_logo-rgb	GEUS logo
Terranes	grey text and lines showing main tectono-stratigraphical terranes
Coastline	coast and Inland ice margin meant for display at 1:2 500 000 scale. Copyright KMS/GEUS 1997.
Coordinates	frame with ticks for latitude and longitude degrees. The minus sign in front of longitude denotes western longitude. Projection: Universal Transverse Mercator (UTM), zone 24. Datum: WGS 84.

The **gridding** was performed using the kriging method in the gridding facilities provided by Oasis montaj (KRIGRID program). The program is based on Journel & Huijbregts (1978). A grid cell size of 5x5 km and a blanking distance of 5 km were used. Semi-variograms (termed variograms in Oasis montaj) were constructed for all elements, and parameters (range, nugget and sill) for a spherical model were adjusted so that the model curve matches the first part of the semi-variogram best possible (see section on Semi-variogram maps). The choice of kriging model is based on experience obtained from gridding stream sediment data from South Greenland (Olesen 1984; Thorning *et al.* 1994; Schjøth *et al.* 1999). A test made with atlas data showed that the differences between grids produced using different models or gridding methods are small except for the Gaussian model, which is unsuitable (see Appendix 2).

The square outline of individual grid cells is seen at the margin of the grid image only. Oasis montaj has a default interpolation procedure for smoothing boundaries between differently coloured cells similar to contouring.

The **colour scaling** of the grids is determined individually for each element. As a starting rule the 14 intervals are chosen to represent the 5th, 10th, 15th, 20th, 30th, 40th, 50th (median), 60th, 70th, 80th, 90th, 95th, 98th and 99th percentile of the frequency distribution, respectively. However, it was, in many cases, considered appropriate to deviate from the strict division and subjectively structure the scale to ensure that regional features reflecting litho-stratigraphical changes and areas of high concentrations are emphasised by the grid image. Likewise, noisy variation in grid values close to the analytical detection limit has been suppressed, and for elements with concentrations largely below detection limit the colour scale has fewer intervals. The tables of statistics permit the reader to judge how the colours correspond to intervals in the frequency distribution for the entire data set.

Anomalies, defined as unusually high concentrations of an element in a stream sediment sample, are marked with black squares. Notice that, whereas the colour scale applies to grid values, the anomalies represent actual concentrations measured in samples. The red areas of the grids typically show the distribution of the upper 1 to 5 % of the frequency distribution of grid cell values (compare statistics and legend). Only sample values clearly above the 99th percentile of the sample statistics (outliers) are called anomalies.

The **histograms** are made using the CHIMERA applications of OASIS montaj. Grids of elements with many values below the lower detection limit of the analytical method contain cells with negative values. The statistical parameters will show where this is the case, but the negative values are not shown in the histogram. The histogram scale is chosen so that the major part of the histogram is displayed, which means that the uppermost part of the distribution is cut off in some cases.

Map of loss on ignition

This map shows the variation in loss on ignition, as measured in all samples analysed for major elements by XRF, when they are fused in preparation of glass discs. Loss on ignition is a measure of the content of volatiles, usually derived from carbonates or organic matter in the samples. The map groups are the same as for element distribution maps.

Gamma radiation map

The map is a documentation of the variation in natural gamma radiation at the surface in West and South Greenland. For geological applications the map reflects the variation in rock concentrations of radioactive elements. The gamma radiation (or radioactivity) is measured in counts per second. The map groups are the same as for the element distribution maps.

MAF map

The map presents the result of maximum autocorrelation factor analysis (MAF), which is a type of spatial analysis of multivariate data, previously successfully applied to stream sediment data from South Greenland (Nielsen *et al.* 2000, Steenfelt *et al.* 2000). MAF analysis is related to conventional factor and principal component analysis. A data set consisting of all samples analysed for all of the trace elements As, Ba, Co, Cr, Cu, Cs, Hf, La, Ni, Rb, Sc, Sm, Sr, Th, U and Zn was used for the spatial analysis. Any value below the analytical detection limit was given a random value between 0 and the detection limit, because the method involves logarithmic transformation of the data. The map presents the variation in the first factor (MAF 1) displayed as a grid produced by kriging.

Semi-variogram maps

The spatial variation in the data for an element is displayed in a semi-variogram (variogram in Geosoft terminology). The following description is quoted from the Geosoft help-ware, in which h denotes the distance:

"This variogram shows the anticipated increase in variability as h increases. At the right end of the variogram, the variability may appear to decrease in many cases (somewhat so in the example above), but this is usually the result of too few pairs of samples for the statistics to be valid. Kriging requires a model of the observed variogram to determine the weighting factors used in the kriging matrix. Although observed variograms can appear quite noisy, it is important that the model used is both smooth and has increasing variability with increasing h. KRIGRID offers a number of standard models which you can use to best approximate the observed variogram. The statistical accuracy of kriged results is related to how close the model is to the observed variogram".

The semi-variograms presented here are produced by the KRIGRID program of OASIS montaj. The only change made is the addition of the element name. The semi-variogram is composed of three map groups (Fig. 5). VG is the semi-variogram itself, where the X-axis is the distance and the Y-axis is the variance. NP is a diagram describing the number of sample pairs averaged to calculate the variogram as a function of distance. The border contains a frame and the text on the right-hand side of the diagrams.

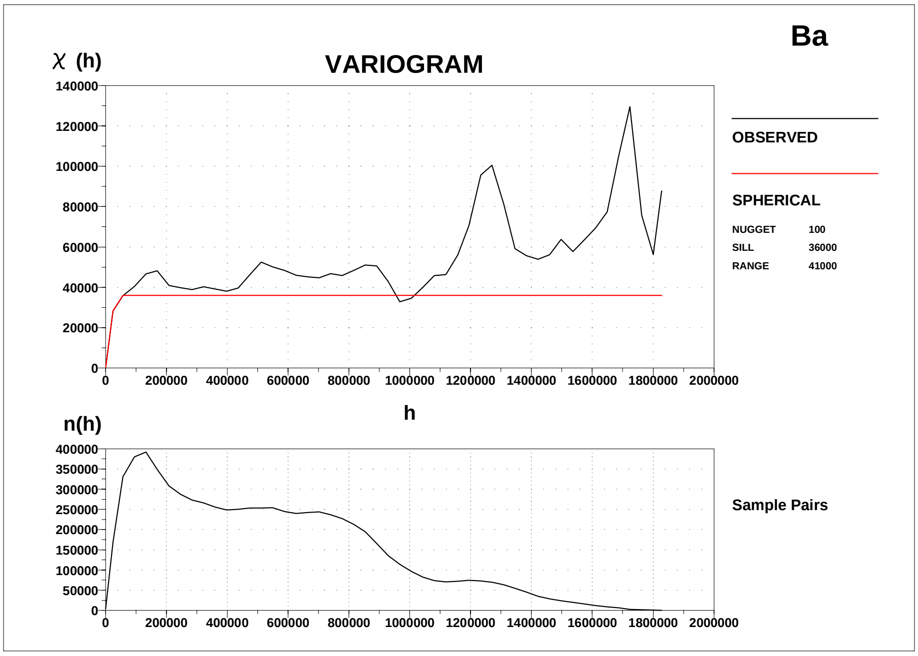

Figure 5. *Semi-variogram of Ba measured in 6421 stream sediment samples from West and South Greenland.*

The choice of variogram model has been discussed in the section on element distribution maps, gridding procedure. See also the test of semi-variogram models in Appendix 2.

There is a semi-variogram map for each element.

Errorgrid maps

The KRIGRID program for gridding (kriging method) also produces errorgrids displaying the reliability of the grid values. The errorgrid contains the standard deviation of the kriging process at each grid point. Provided that the model is correct, the results are within two standard deviations of the actual value 95% of the time.

The error increases when the data density decreases, and errorgrids for elements determined in the same number of samples are identical. Because of this only three examples of errorgrids are included in the directory 'ErrorgridMaps'. The examples comprise one element (As) from the analytical package from instrumental neutron activation, one major element (Al_2O_3) and one trace element (Ni) determined by X-ray fluorescence spectrometry and inductively coupled plasma emission spectrometry. All errorgrids are stored in the directory 'ErrorgridMaps/Errorgrids' and may be displayed at convenience using the 'Display grid' function under the 'Grid' menu in OASIS montaj.

Maps of kimberlite indicator minerals

These maps display the results of an investigation of the 0.25 to 1 mm grain size fraction of stream sediments from the area between 61° and 67° northern latitude, or largely the Archaean craton. The layout of a map is displayed in Fig. 6.

Map groups (using *Pyrope.map* as example)

Base view:

Titles, Scale-Bar,	self-explanatory
MaxMean.txt	the text within histogram of picked grains
Histogram	frequency distribution of number of mineral grains collected per sample
Scatter_plot	a plot used to distinguish high-pressure origin of mineral grains

Data view:

Coastline, Coordinates, AGG_logo, see element maps

kimberlite_localities	known kimberlite occurrences including floats
highCr_lowCa	location of grains with high-pressure signature, selected (red coloured) in the scatter plot
pyrope_analysed	location of samples in which pyrope grains have been analysed
picked_pyrope	location of samples in which pyrope has been identified
grains_anomaly	location of samples with many pyrope grains
sample_area	frame showing the area of investigation
treated_samples	location of all treated and examined samples

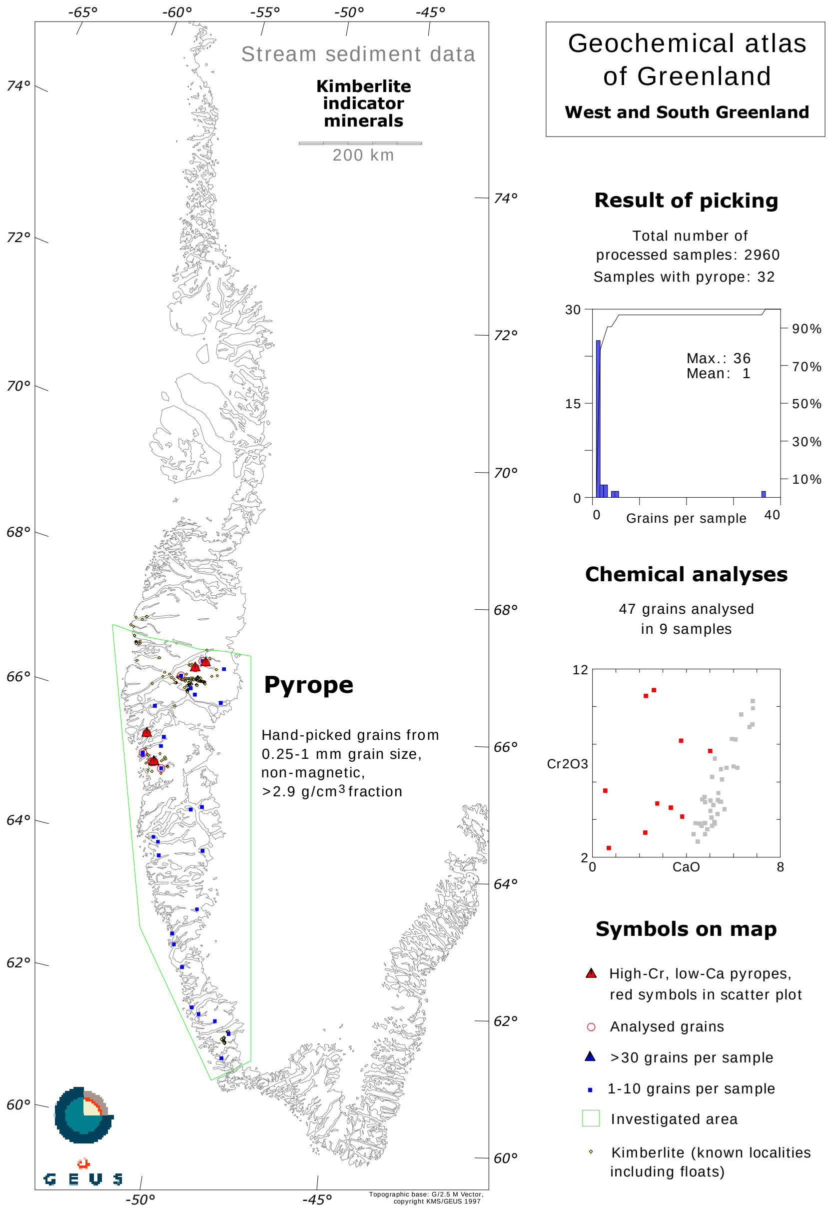

Figure 6. *Pyrope.map showing location of samples with pyrope grains, location of pyrope grains with high-pressure signature, and known kimberlite occurrences.*

Geological map

The geological map is based on 'Geological map of Greenland, 1: 2 500 000 (Escher & Pulvertaft 1995). This map comprises 86 numbered lithological units, which have been digitised by Department of Geological Mapping at GEUS using ESRI ArcView/ArcInfo software. ArcView shape files with lithological units occurring within the geochemical atlas area together with some topographical features such as Inland Ice, ice caps and lakes were imported into Oasis montaj. The resulting map was simplified to suit presentation at a scale range from about 1:8 000 000 up to 1:5 000 000 corresponding to printing the atlas area on

A4 to A3 paper size. Thus the smallest lithological units were omitted, and lithologically related units were given the same colour. A legend was made using the CAD tools provided by Oasis montaj. The location of main mineral occurrences including former mines within the atlas area was extracted from the GREENMIN database at GEUS (Thorning *et al.* 2000).

Map groups:

Base view:

Titles, Legend, Scale_Bar,	self-explanatory
AGG_logo.rgb	GEUS-logo

Data view:

Terranes, Coordinates	see element distribution maps
Min_occ	main mineral occurrences
Mines	former mines
Kimberlite	known kimberlite occurrences including floats. This group is hidden when the map is opened
Carbonatite	two blue diamond-shaped symbols marking location of major carbonatite complexes
ARCVIEW_88	lakes
ARCVIEW_89	surficial deposits
ARCVIEW_87	ice caps
ARCVIEW_99	Inland Ice
ARCVIEW_6 to _86	imported ArcView shapefiles of lithological units

Aeromagnetic map

The magnetic total field anomaly data presented in this map is compiled from aeromagnetic surveys carried out jointly by the Bureau of Minerals and Petroleum and GEUS in the years between 1992 and 1999. Descriptions of the data can be found in Rasmussen & van Gool (2000) and references therein. All but one survey were flown at a nominal terrain clearance of 300 m and line distance of 500 m with orthogonal tie-lines at 5000 m intervals. The 1992 survey covering an area largely between 68° and 69° N in West Greenland utilised a 500 m terrain clearance and line distances of 1000 m and 10000 m, respectively.

The map displays a 'geotiff'-image of the gridded aeromagnetic data together with colour-scale, coastline, terranes, coordinates and GEUS-logo. The grid behind the image is not accessible on the CD.

Map of place names

This map contains a group with location and names of towns, settlements and international airports together with coordinates, coastline and GEUS-logo.

Data application

This section outlines how the geochemical data and maps may be useful in some scientific and administrative areas of interest. The publication of the data in digital form instead of conventional paper form, eases the use of the data, makes it possible to work with the atlas maps, combine them, change the colour scales, zoom in on areas and produce prints of selected parts and at various map scales. The software tools to identify the same spot in a number of maps facilitate the comparison of maps. The map images can be exported to other Geographic Information Systems (GIS) and compared and combined with other GIS related data such as geophysical, structural, biological and environmental data, in addition to administrative information on protected areas, water management, recreation etc. Conversely, regional data from other sources may be imported into the Geosoft environment and displayed in combination with the geochemical data. Hopefully, these advantages will promote a wider use of the information contained on the CD than anticipated here.

Composition and architecture of the Precambrian crust

The geochemical atlas provides the first overview of the geochemical variation over the Precambrian crust in West and South Greenland. The maps show how different segments of the crust have distinct geochemical signatures, an information, which adds to the understanding of crustal composition and growth. The stream sediment data are important because rock analyses from Greenland, particularly trace element data, are irregularly distributed, and systematic data on the chemical composition of large lithological units are lacking. During the evolution of the continental crust a chemical differentiation takes place with the result that lithophile elements, e.g. Rb, U, La and Cs are concentrated in the upper parts of the crust. The distribution of lithophile elements as displayed by the atlas can, therefore, be interpreted to reflect differences in the depth, to which segments of the crust have been subjected. The atlas also shows the existence of distinct geochemical boundaries that may represent tectonic contacts between crustal blocks.

Geological mapping and modelling

Stream sediment chemistry reflects chemical variations in rock complexes, and many element distribution patterns can be related to known lithological features. Although the rock exposure rate is generally very high in Greenland, there are inland areas in West Greenland where overburden and vegetation create problems for geological mapping. The geochemical maps helps to outline rock boundaries in such a surface environment. Also where high-grade metamorphism has obscured original textures and boundaries between lithological units, the geochemical maps may contribute valuable information. This is the case in central West Greenland where high-grade Archaean and Palaeoproterozoic gneiss complexes cannot be distinguished in the field. However, the younger gneiss has a strong geochemical signature, which is reflected in the maps of Ba and Sr. Thus an approximate outline of the younger gneiss can be drawn, based on the geochemical data. Several other cases are known from West and South Greenland, where stream sediment geochemical patterns have drawn the attention to rock complexes that had not previously been recognised.

The geochemistry of a rock unit, and its trace element signature, in particular, is an important factor in determining its origin. Many trace elements are hosted in scarce, fine-grained minerals in the rocks, e.g. apatite, zircon and monazite. These minerals are resistant to weathering with the effect that their abundance is upgraded in the stream sediments relative to their abundance in the source rocks. Again, because the stream sediment data cover regions with little or no geochemical data on rocks, the stream sediment chemical maps may assist in identifying rock complexes of a certain origin.

Mineral resource assessment

The philosophy behind the use of stream sediment in mineral exploration is that weathering products from mineral deposits exposed at the surface will be transported downhill and deposited in streams. Elevated concentrations of the ore metal(s) in systematically collected stream sediment samples will therefore often be indicative of mineralisation. The low sampling density used for the geochemical atlas precludes a high probability of striking small isolated deposits. However, many kinds of significant ore deposits are located within an area hosting many additional small mineralised occurrences, and this enables the identification of such an area as one of slightly elevated concentrations in streams.

The use of the atlas data to identify high values, anomalies, is straightforward and is facilitated by showing the location of anomalies on the atlas maps. Several of these element anomalies are, in fact, located near known mineral occurrences containing the element in question, while others are located in areas where mineralisation is presently unknown. The latter category is particularly interesting and merits further investigation.

A more indirect way of using the data, is to identify geological environments with a high potential for formation of ore deposits. These environments, e.g. volcanic arcs, marine shales along escarpments and alkaline intrusions, may be identified using their geochemical signature together with information on structure, age, tectonic setting etc. For example, sedimentary sequences enriched in arsenic are considered a favourable source environment for gold deposits, and the high-arsenic regions in West and South Greenland are clearly outlined by the map of arsenic. The map of gold confirms the location of gold anomalies within the arsenic provinces, but also suggests that gold mineralisation, unrelated to arsenic, has taken place. A mineral resource evaluation for South Greenland (Steenfelt *et al.* 2000) shows several examples of the use of regional geochemical data to outline areas with mineral potential.

Environmental studies and baseline documentation

The chemical composition of rocks and soil influences the growing conditions for the vegetation, and also influences the chemistry of stream and lake water. In turn, the health of animals and humans may be affected if concentrations of certain elements in consumed plant material or water are too high or too low. Major elements such as calcium, potassium and phosphorus, along with trace elements like zinc, are essential to good health, and low intake will cause deficiency symptoms. Other elements like arsenic, uranium and antimony are toxic if consumed in even small amounts. Many trace elements (e.g. copper, molybdenum, fluorine) are essential in small amounts and toxic in large. In fact, few of the elements presented in the atlas are insignificant in relation to their interaction with the biosphere. The relationship between geochemistry and health is the subject of a new scientific discipline, medical geology or geomedicine, and the growing amount of regional geochemical data has promoted the insight in these relationships.

Soil and stream sediment are both products of decomposed rocks, and their chemical compositions are closely related to each other as well as to the rocks. The atlas maps can, therefore, provide an overview of the chemical properties of the substrate for the vegetation in West and South Greenland, and outline where problems of deficiency or toxicity may occur. Likewise, the data gives an impression of the chemical properties of the rocks surrounding fresh water supply systems for towns and settlements. The toxicity of a given element depends on several factors, such as plant or animal species, pH and other chemical and environmental circumstances. This means that high concentrations of certain elements in stream sediment are not necessarily toxic to e.g. plants or fish fry. On the other hand, if an essential element is deficient in a certain area, the circumstances do not matter, and biota will suffer or not survive. The geochemical data are useful to biologists, veterinarians, agronomists and other environmental scientists. The data may also be useful in the planning of recreational areas and tourism.

Pollution from mining and industry is a matter of concern, as the number of incidents where human or other life has been affected by pollution is growing. Defining or estimating the amount of pollution within an area requires a documentation of the natural state, the state before the polluting activity commenced. The atlas data provide such baseline documentation for 43 inorganic elements and for radioactivity. The data demonstrate that the natural background varies from place to place, a fact that should be taken into consideration when environmental regulations are made.

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	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	l.o.i.
Number	5398	5398	5398	5398	5398	5398	5398	5398	5398	5398	5398
Conc. unit	%	%	%	%	%	%	%	%	%	%	%
Max.	82.66	9.90	31.00	44.83	9.22	28.65	78.28	6.89	5.79	5.29	48.96
Min.	8.24	0.05	0.45	0.47	0.02	0.30	0.35	0.12	0.07	0.02	0
Mean	63.84	0.84	14.86	6.82	0.11	2.93	4.44	3.39	1.94	0.28	7.16
Std. Dev.	5.83	0.52	1.50	3.11	0.14	2.23	2.99	0.71	0.80	0.23	6.32
10th perc.	56.95	0.43	13.65	3.84	0.06	1.41	2.61	2.41	1.19	0.13	1.35
20th perc.	60.54	0.48	14.14	4.45	0.07	1.72	3.17	2.98	1.39	0.15	2.39
30th perc.	62.40	0.54	14.42	5.05	0.08	1.95	3.61	3.27	1.51	0.17	3.39
40th perc.	63.83	0.61	14.63	5.59	0.09	2.20	3.96	3.45	1.62	0.19	4.34
50th perc.	64.93	0.69	14.85	6.14	0.10	2.44	4.22	3.57	1.73	0.21	5.38
60th perc.	65.98	0.79	15.08	6.77	0.11	2.69	4.47	3.66	1.90	0.25	6.70
70th perc.	67.01	0.91	15.36	7.55	0.12	2.98	4.77	3.76	2.14	0.29	8.34
80th perc.	68.11	1.08	15.71	8.67	0.14	3.49	5.12	3.87	2.56	0.37	10.72
90th perc.	69.58	1.42	16.30	10.64	0.17	4.52	5.73	4.02	3.14	0.49	15.29
95th perc.	70.69	1.82	16.91	13.05	0.21	6.06	6.91	4.16	3.51	0.64	19.94
98th perc.	71.84	2.37	17.82	15.31	0.26	9.95	9.51	4.31	3.89	0.87	25.99
99th perc.	72.62	2.75	18.57	17.21	0.33	15.17	10.33	4.45	4.18	1.11	31.08

	As	Au	Ba	Br	Ce	Co	Cr	Cs	Cu	Eu	Ga
Number	6326	6326	6421	6280	6326	6326	6422	6326	6366	6071	5023
Conc. unit	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Max.	1100	850	5500	660	2071	150	24770	19	825	77	97
Min.	0	0	0	0	4	0	0	0	0	0	0
Mean	5.29	2.60	563.17	34.38	127.87	22.06	140.41	1.52	40.67	2.08	19.37
Std. Dev.	23.81	18.35	244.17	48.91	131.80	14.86	396.43	2.38	42.05	1.91	6.79
10th perc.	0	0	356	0	44	9	23	0	10	1.0	13
20th perc.	0	0	425	4	58	12	39	0	14	1.2	15
30th perc.	0	0	466	8	68	14	57	0	18	1.3	17
40th perc.	0	0	500	12	80	16	75	0	23	1.4	18
50th perc.	0	0	538	18	92	18	93	0	27	1.6	18
60th perc.	0	0	580	26	110	21	110	0	34	1.8	19
70th perc.	3	0	625	36	130	24	130	2	43	2.0	21
80th perc.	5	0	684	53	168	30	158	3	57	2.6	22
90th perc.	11	7	788	84	231	40	221	5	87	3.6	25
95th perc.	23	10	905	120	320	53	329	6	124	4.7	30
98th perc.	49	17	1095	190	496	67	660	8	166	6.9	39
99th perc.	80	29	1268	250	651	74	1500	10	204	8.6	48

	Hf	La	Lu	Mo	Nb	Nd	Ni	Rb	Sb	Sc	Sm
Number	6326	6326	6071	6326	5698	6071	6505	6515	6326	6326	6280
Conc. unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Max.	480	1431	6.35	95	902	1000	1504	329	36.40	61	171
Min.	0	2.6	0	0	0	0	0	0	0	0	0.4
Mean	17.25	77.28	0.45	1.26	23.15	54.42	59.26	62.55	0.22	15.63	9.15
Std. Dev.	17.83	84.66	0.40	4.51	50.35	54.21	71.73	39.46	0.74	6.84	8.46
10th perc.	7	27	0.19	0	4	19	18	26	0	9	3.6
20th perc.	9	34	0.23	0	5	24	24	33	0	11	4.4
30th perc.	10	40	0.27	0	6	28	29	38	0	12	5.1
40th perc.	12	47	0.31	0	7	34	35	44	0	13	5.9
50th perc.	13	55	0.35	0	10	40	41	52	0	14	6.8
60th perc.	15	65	0.40	0	14	46	48	62	0	16	7.9
70th perc.	18	78	0.46	0	20	57	58	74	0.3	17	9.5
80th perc.	22	99	0.55	0	27	71	76	93	0.4	19	12.0
90th perc.	29	137	0.73	5.00	44	100	110	116	0.6	23	16.0
95th perc.	40	190	0.99	8.75	69	140	152	136	0.9	28	22.0
98th perc.	61	314	1.60	15.00	148	210	249	164	1.5	39	33.0
99th perc.	85	452	2.24	21.00	264	290	400	184	1.9	44	45.2

	Sr	Ta	Tb	Th	U	V	W	Y	Yb	Zn	Zr
Number	6505	6326	6326	6327	6573	5319	6326	6339	6071	6505	5905
Conc. unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Max.	2091	49	22	270	1400	1030	220	542	60	1786	9241
Min.	35	0	0	0	0	0	0	0	0	0	4
Mean	323.69	0.75	0.81	12.49	15.12	105.46	0.51	33.53	3.37	92.26	496.72
Std. Dev.	132.17	2.44	1.38	14.43	43.55	65.91	4.97	33.71	3.36	80.87	513.35
10th perc.	179	0	0	3.4	0.0	56	0	15	1.5	38	209
20th perc.	218	0	0	4.6	1.2	66	0	17	1.7	48	254
30th perc.	253	0	0	5.7	1.8	73	0	19	2.0	57	296
40th perc.	286	0	0	6.7	2.7	80	0	21	2.2	66	336
50th perc.	314	0	0	8.0	4.0	88	0	24	2.5	75	379
60th perc.	342	0	0.8	9.7	6.0	97	0	29	2.9	86	432
70th perc.	369	0	1.1	12.0	9.7	109	0	34	3.4	100	498
80th perc.	401	1	1.4	16.0	16.4	127	0	41	4.1	119	600
90th perc.	468	2	1.9	26.0	34.9	168	0	56	5.5	155	811
95th perc.	543	3	2.7	37.0	60.7	223	0	75	7.5	199	1130
98th perc.	631	6	4.5	56.0	112.6	334	7	128	12.7	276	1873
99th perc.	712	12	6.7	71.0	180.3	400	12	185	18.0	362	2585

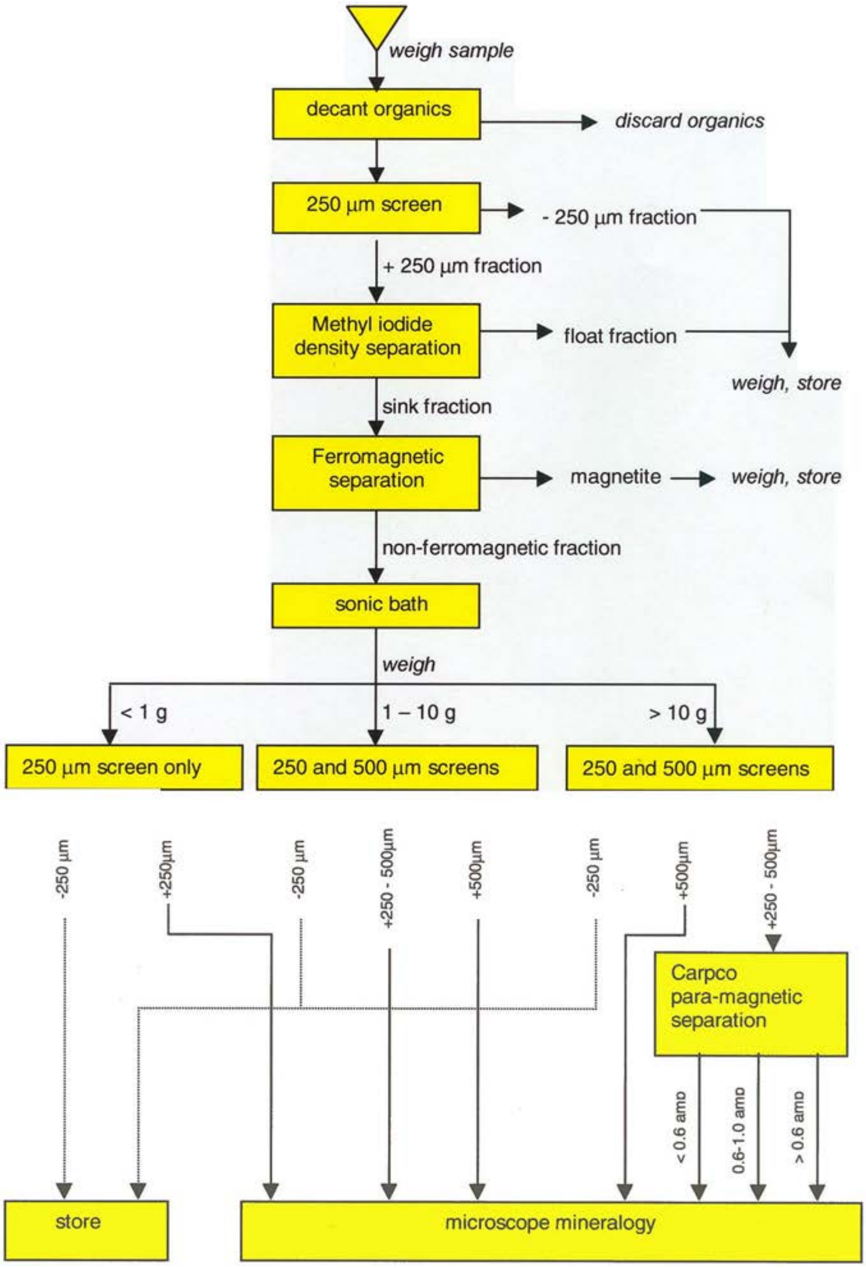
l.o.i.: *loss on ignition (a measure of volatile content).* Conc. unit: *unit of concentration*. Min.: *Minimum*. Max.: *Maximum*. Std. Dev.: *Standard deviation*. perc.: *percentile*

Table 1. *Statistical parameters for stream sediment analytical data in West and South Greenland.*

Appendix 1

Treatment of stream sediment samples for investigation of kimberlite indicator minerals.

Mineral separation procedure at Overburden Drilling Management Ltd.:



Appendix 2

A test of the influence of semi-variogram models on a grid produced by kriging.

The kriging method is recommended for gridding of irregularly spaced data points, such as element concentrations measured in stream sediment samples. The kriging procedure uses a model of the spatial variation within the data set. The spatial variation is illustrated by the semi-variogram. The semi-variograms of the elements of the atlas data are very irregular, which is expected because of the elongated shape of the data area, and because of the great variation range of data reflecting a diversity of rock assemblages. A gridded image provides a homogenised display of irregularly distributed data points that facilitate the appreciation of large-scale geochemical features. On the other hand, it is desired to reflect relatively small-scale geochemical variations and avoid too much smoothing of the patterns. It was decided, therefore, to choose the parameters of the semi-variogram model (nugget, range and slope) so that a good match was obtained in the first part (left-hand side) of the semi-variogram, i.e. to delimit the range of influence to between 30 and 40 km. The importance of this choice has been tested on the semi-variogram for Hf, see Fig. A2.1 and A2.2.

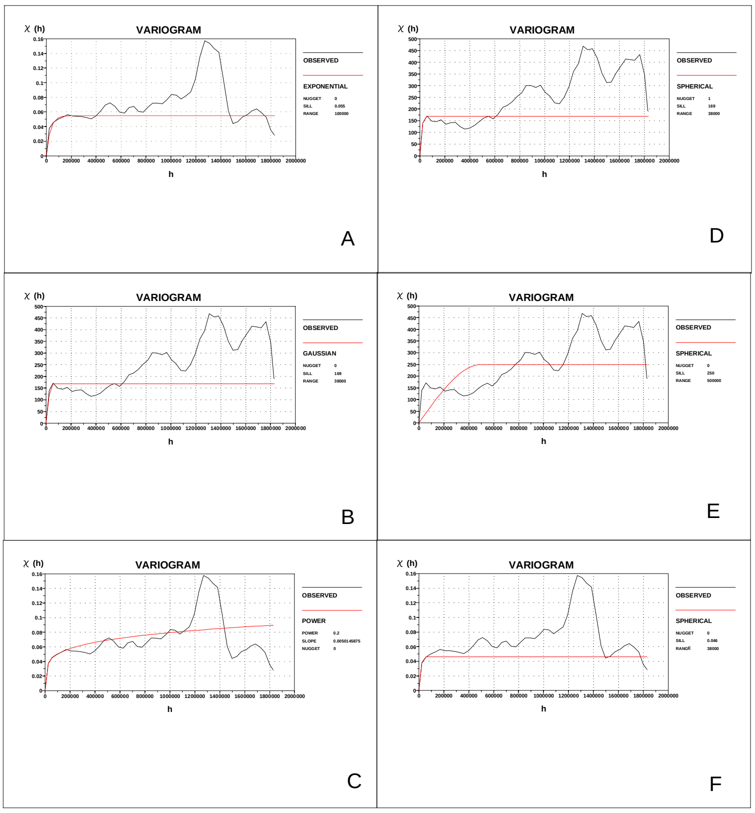


Figure A2.1: *Semi-variograms of Hf for the atlas area. Four different models (red curves) are applied and fitted to the semi-variograms (A to D). D to F illustrate three versions of the* *spherical model. In A, C and F the variance (Y-axis) is logarithmic. Grids produced by kriging using these models are shown in Fig. A2.2.*

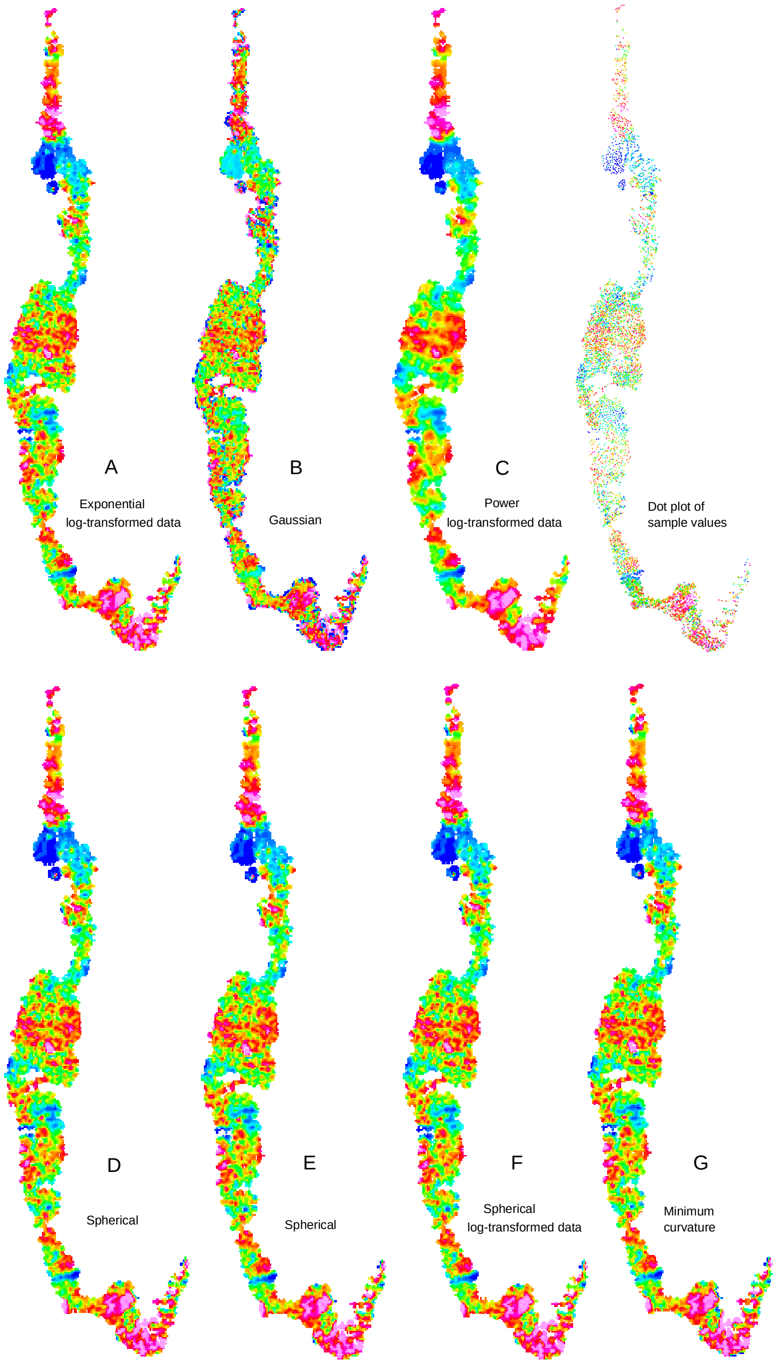


Figure A2.2: *Grids of hafnium in stream sediment. Different gridding methods and semi-variogram models. A to F is produced by kriging with semi-variogram models shown in Fig. A2.1. G is produced by the minimum curvature method (RANGRID-program in Geosoft)*

The grids produced confirm that the spherical model is optimal for displaying the irregular distribution of Hf. The test also shows that the Hf variation is so pronounced that it does not matter whether the range of influence is set to c. 40 km (D in Fig. A2.1), thus matching the first part of the semi-variogram, or to 500 km as in E of Fig. A2.1. Neither does it matter that the model is fitted to a logarithmic version of the semi-variogram (F in Fig. A2.1).

The Gaussian model gives the poorest grid representation, in agreement with the observation, that the shape of the Gaussian model could not be fitted properly to the actual semi-variogram. The power model, on the contrary, was adjusted to represent the logarithmic semi-variogram (C in Fig. A2.1) up to a range of 1100 km. This resulted in a grid that features a clear pattern with less resolution than the grid based on the spherical model. For some purposes this may be preferred.

The non-kriging gridding method, minimum curvature (RANGRID program) produces a grid almost indistinguishable from those based on 'spherical kriging'. Again this is taken to reflect the strong variation in the data set.

In conclusion, the test showed that the choice of model matters, but for the element chosen, the effect of varying the range and slope of a spherical model on the appearance of the grid is inappreciable. It is assumed that the outcome of similar tests for other elements would be comparable with that for Hf, because most other elements show equally strong regional variation.

Appendix 3

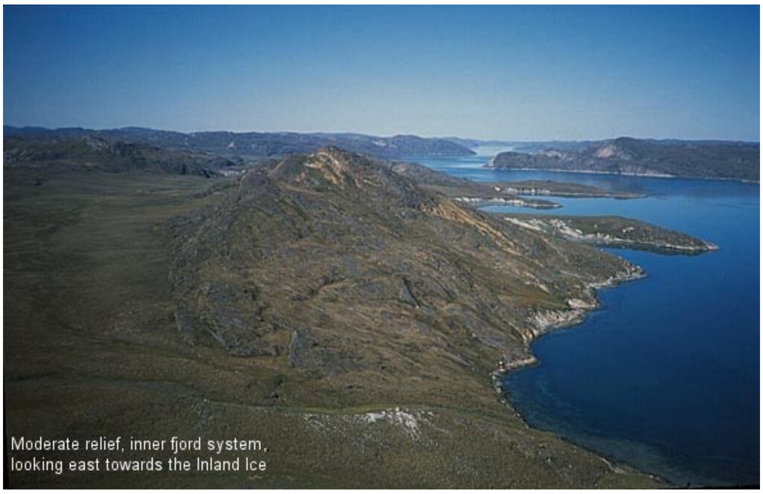
Prints of photographs stored in the directory 'Report/Photos' on the CD.

1

North of Karrat island

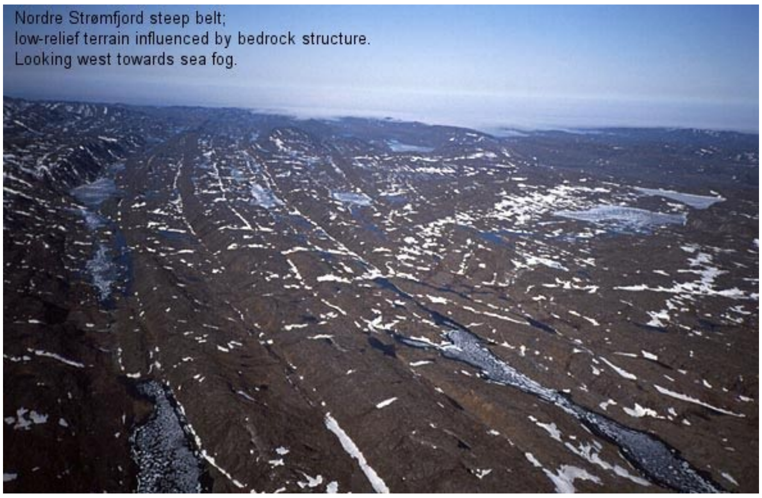
2

Northern Disko



3

Inner Nordre Strømfjord



4

Outer Nordre Strømfjord

5

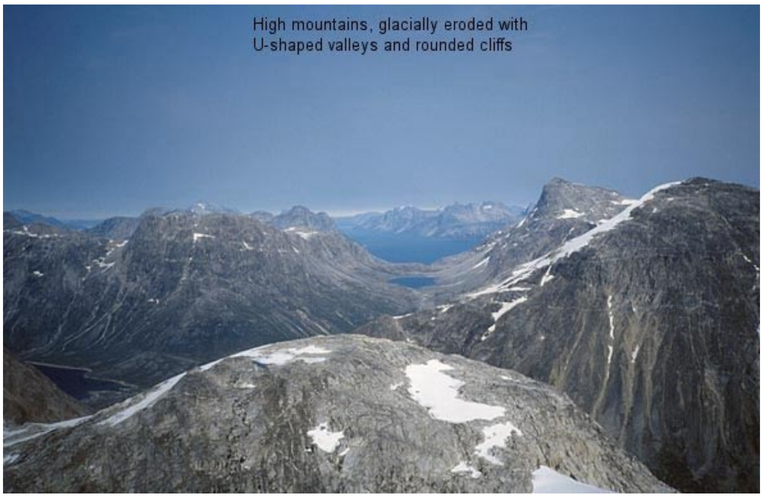
Nordre Isortoq, Isortuarsuk

6

East of Sisimiut

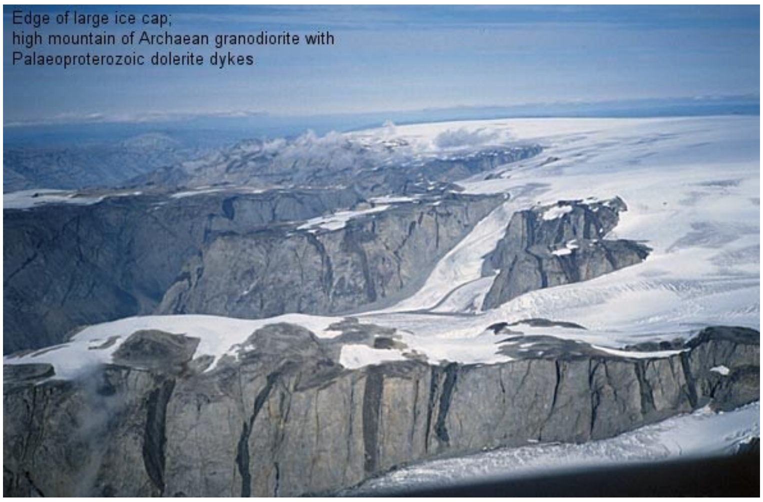
7

Isortoqelven, north of Kangerlussuaq (airport)



8

South of Itilleq, Kangerlussuaq (fjord)



9

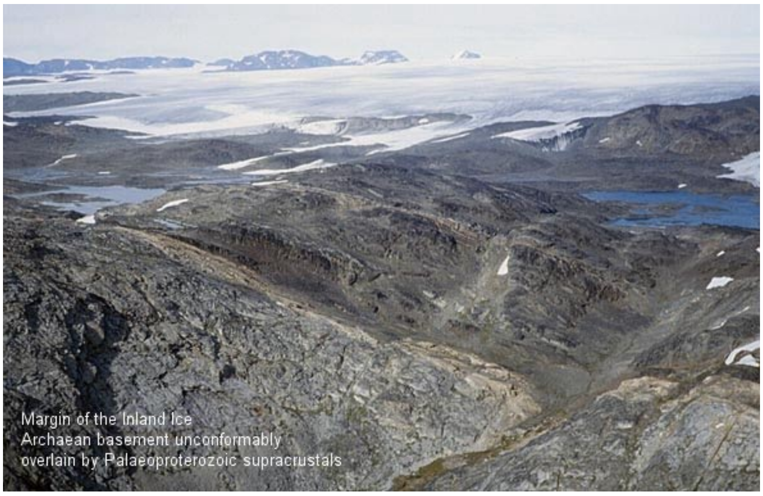
Sukkertoppen Iskappe

10

Godthåbsfjord

11

Sermeq



12

Grænseland

13

Inner Igaliku Fjord

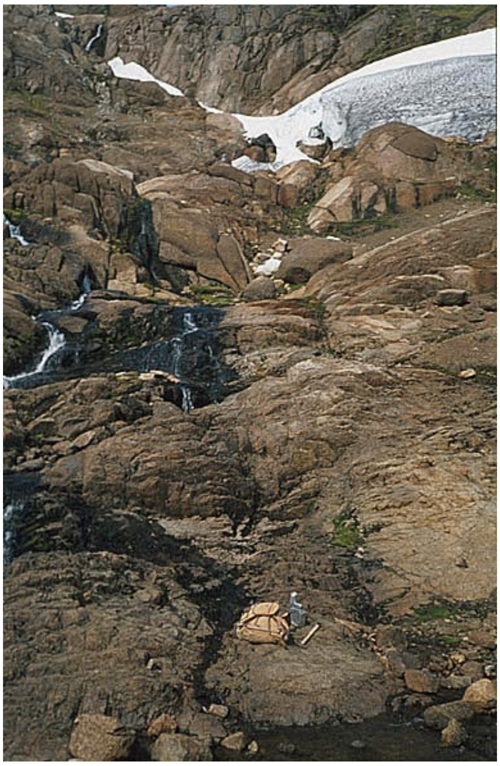
North of
Narsarsuak
Airport

14

15

Prins Christian Sund

16



17

18

19

Examples of sampled streams

20

21

22

Photos 20 and 21: sampled streams. Photo 22: sun-drying sample bags

List of printed maps

Single element distribution maps:

- SiO_2
- TiO_2
- Al_2O_3
- Fe_2O_3
- MnO
- MgO
- CaO
- Na_2O
- K_2O
- P_2O_5
- As
- Au
- Ba
- Br
- Ce
- Co
- Cr
- Cs
- Cu
- Eu
- Ga
- Hf
- La
- Lu
- Mo
- Nb
- Nd
- Ni
- Rb
- Sb
- Sc
- Sm
- Sr
- Ta
- Tb
- Th
- U
- V
- W
- Y
- Yb
- Zn
- Zr

Loss on ignition map

Gamma radiation map

Maximum autocorrelation factor map

Maps of kimberlite indicator minerals:

- Chromite
- Clinopyroxene
- Eclogitic garnet
- Ilmenite
- Pyrope

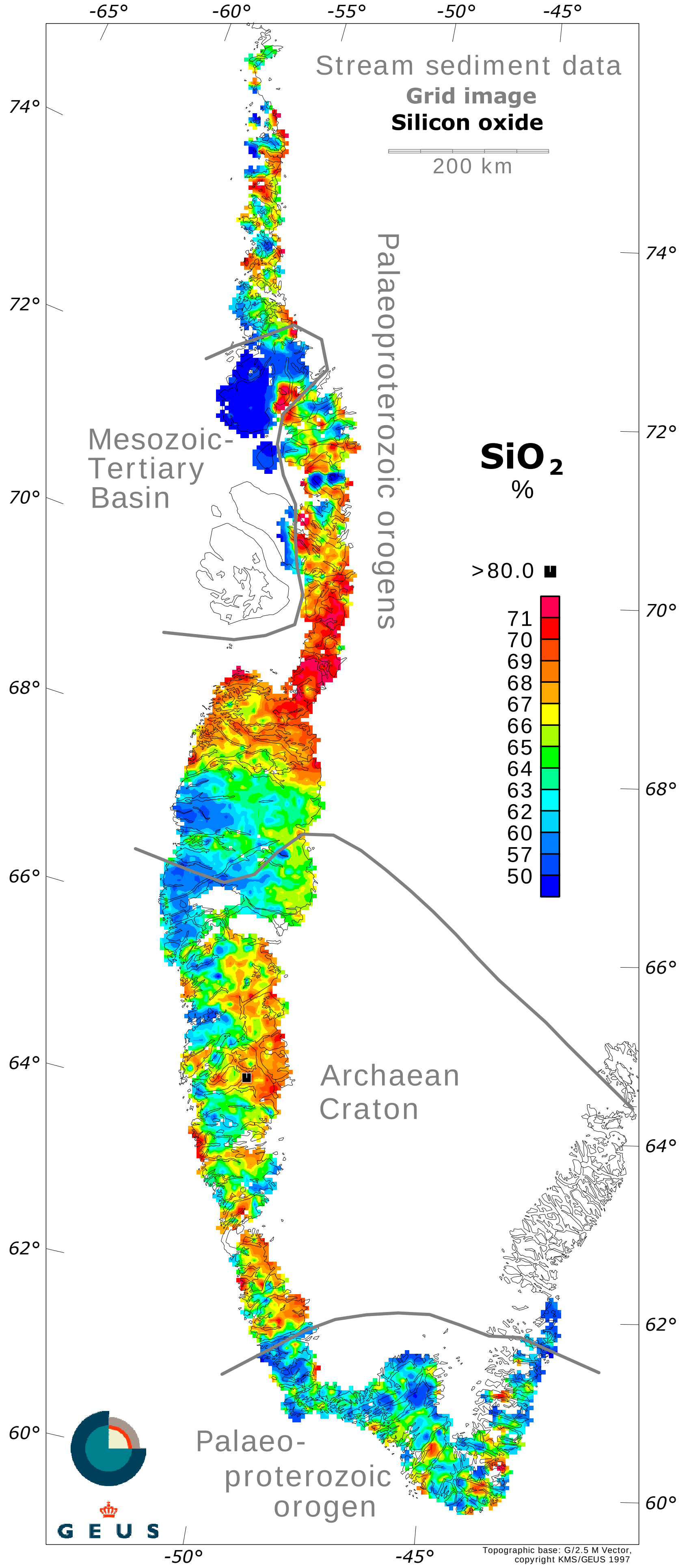
Geological map

Aeromagnetic map

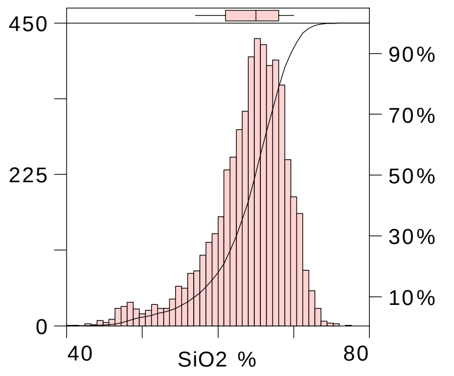
Map of place names

Geochemical atlas of Greenland

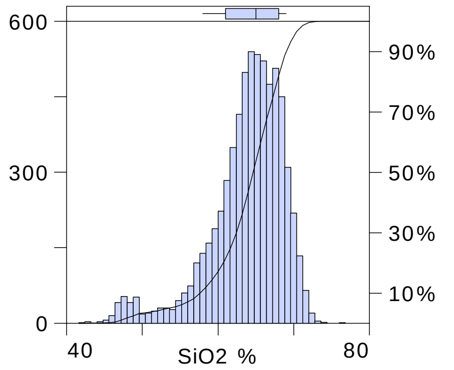
West and South Greenland



Sample values



Grid cell values



Statistics

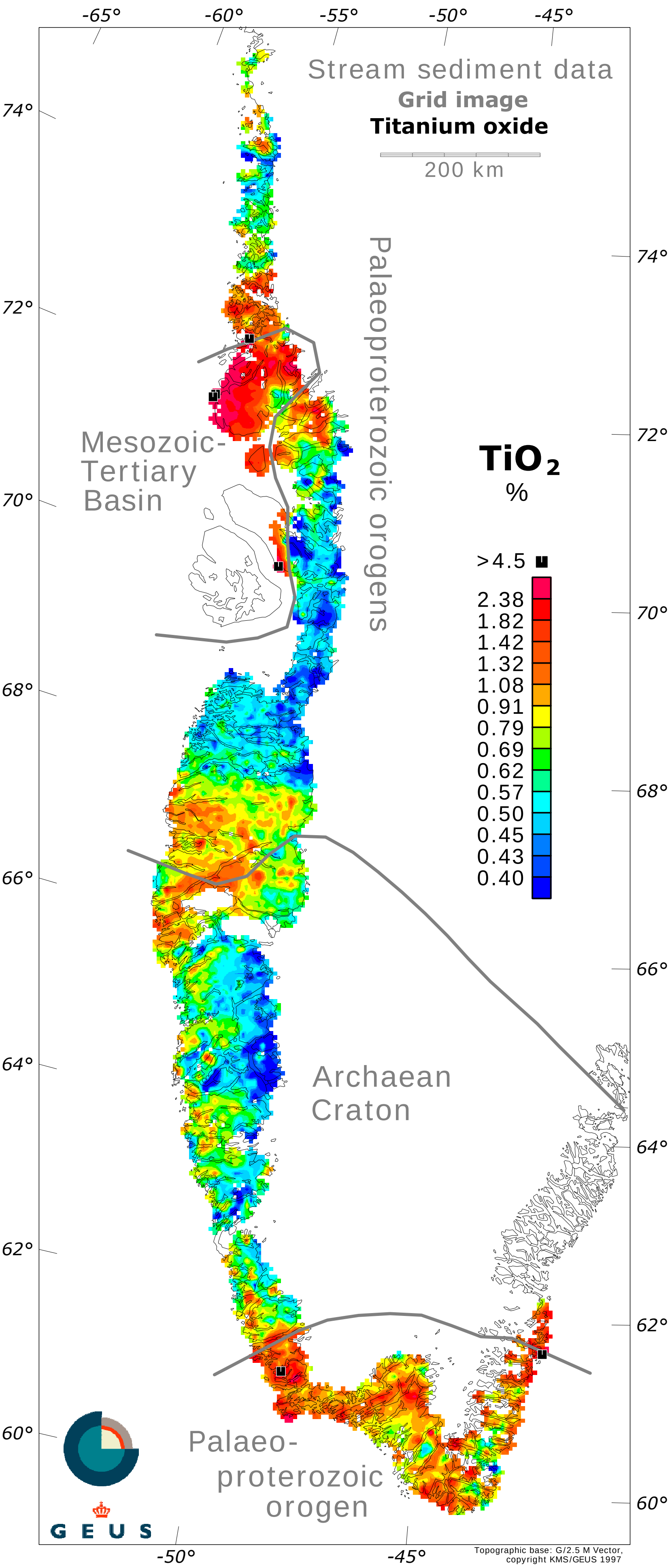
SiO2 %	Samples	Cells
Number	5398	6706
Maximum	82.66	76.72
Minimum	8.24	30.10
Mean	63.84	63.76
Std. dev.	5.83	5.06
10th perc.	56.95	57.62
20th perc.	60.54	60.65
30th perc.	62.40	62.40
40th perc.	63.83	63.63
50th perc.	64.93	64.63
60th perc.	65.98	65.65
70th perc.	67.01	66.70
80th perc.	68.11	67.75
90th perc.	69.58	69.00
95th perc.	70.69	69.98
98th perc.	71.84	70.87
99th perc.	72.62	71.41

Upper crustal mean: 66

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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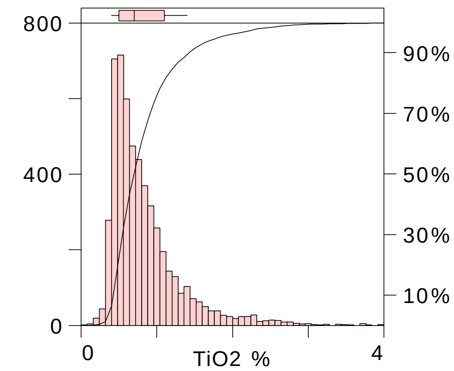

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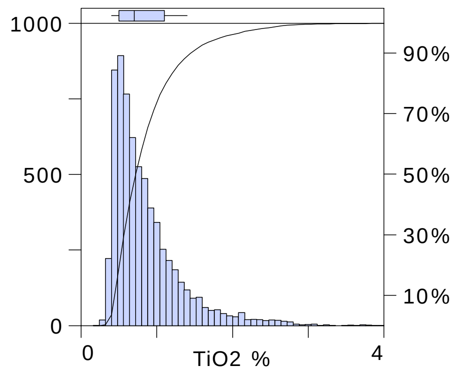


Statistics

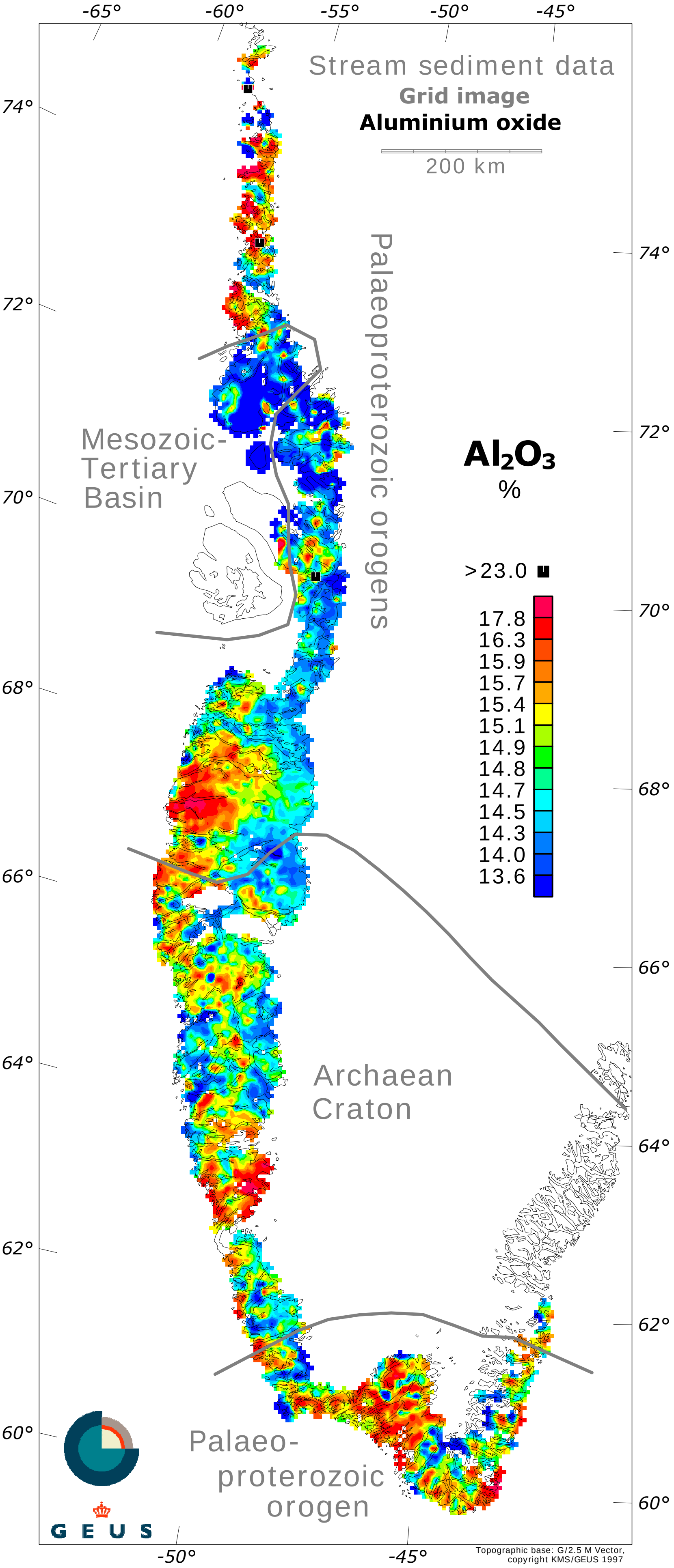
TiO2 %	Samples	Cells
Number	5398	6706
Maximum	9.90	4.86
Minimum	0.05	0.21
Mean	0.84	0.86
Std. dev.	0.52	0.50
10th perc.	0.43	0.44
20th perc.	0.48	0.50
30th perc.	0.54	0.56
40th perc.	0.61	0.63
50th perc.	0.69	0.72
60th perc.	0.79	0.82
70th perc.	0.91	0.95
80th perc.	1.08	1.12
90th perc.	1.42	1.45
95th perc.	1.82	1.83
98th perc.	2.37	2.37
99th perc.	2.75	2.69

Upper crustal mean: 0.5

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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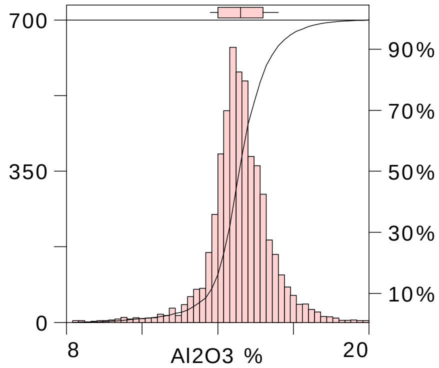

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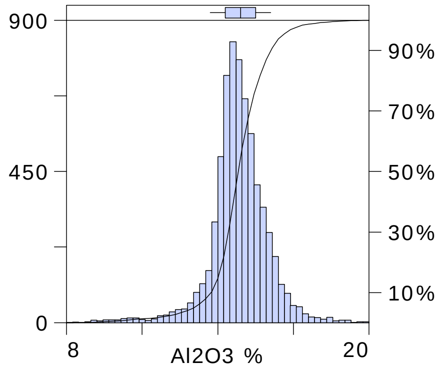


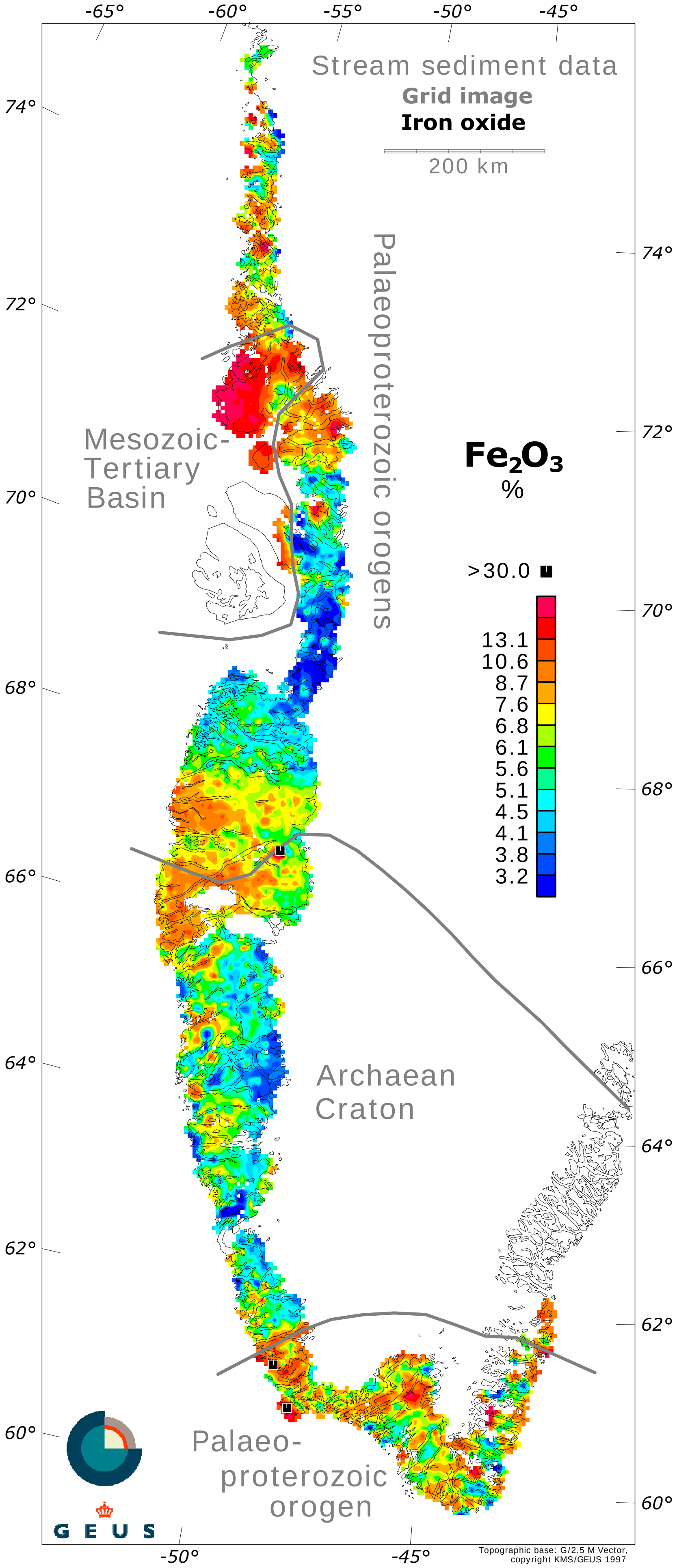
Statistics

Al2O3 %	Samples	Cells
Number	5398	6706
Maximum	31.00	21.59
Minimum	0.45	5.76
Mean	14.86	14.82
Std. dev.	1.50	1.20
10th perc.	13.65	13.72
20th perc.	14.14	14.18
30th perc.	14.42	14.42
40th perc.	14.63	14.60
50th perc.	14.85	14.81
60th perc.	15.08	15.02
70th perc.	15.36	15.27
80th perc.	15.71	15.61
90th perc.	16.30	16.10
95th perc.	16.91	16.53
98th perc.	17.82	17.26
99th perc.	18.57	17.93

Upper crustal mean: 15.2
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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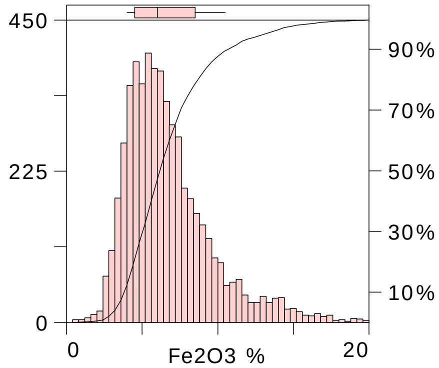

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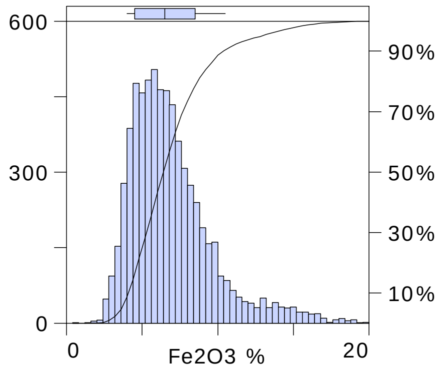


Statistics

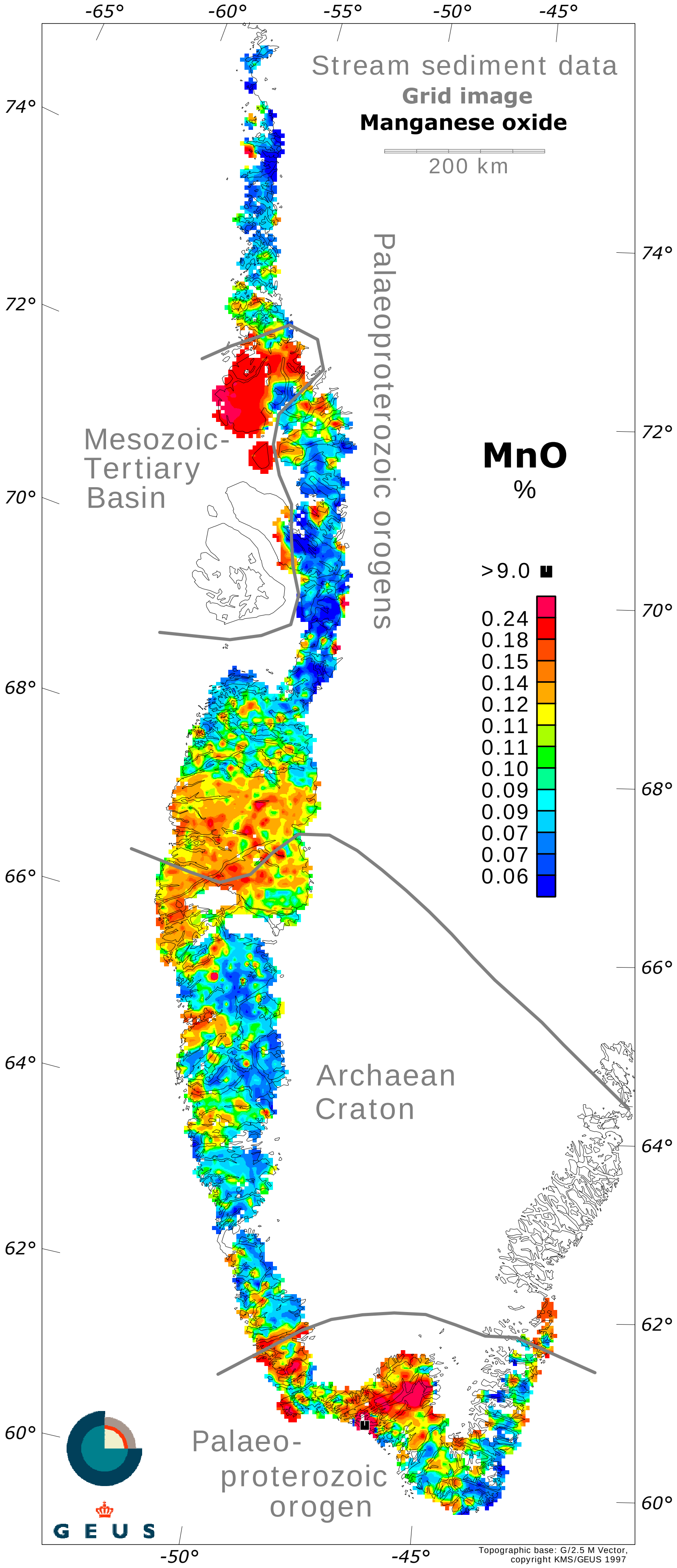
Fe2O3 %	Samples	Cells
Number	5398	6706
Maximum	44.83	24.87
Minimum	0.47	0.71
Mean	6.82	6.95
Std. dev.	3.11	2.81
10th perc.	3.84	4.10
20th perc.	4.45	4.71
30th perc.	5.05	5.29
40th perc.	5.59	5.83
50th perc.	6.14	6.40
60th perc.	6.77	6.99
70th perc.	7.55	7.68
80th perc.	8.67	8.66
90th perc.	10.64	10.37
95th perc.	13.05	12.92
98th perc.	15.31	15.19
99th perc.	17.21	16.50

Upper crustal mean: 4.5

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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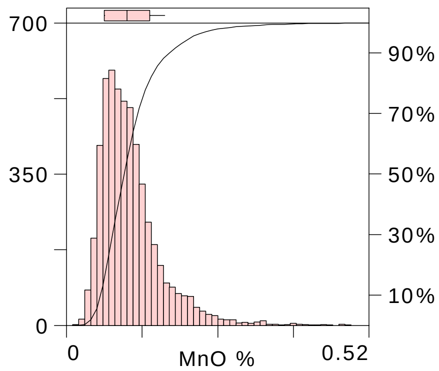

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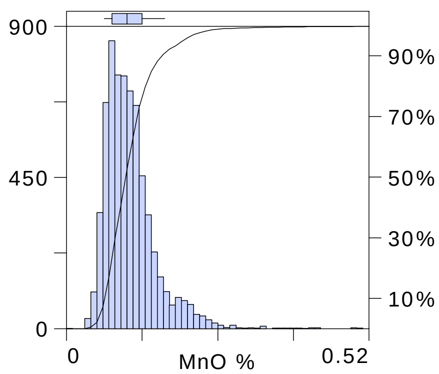


Statistics

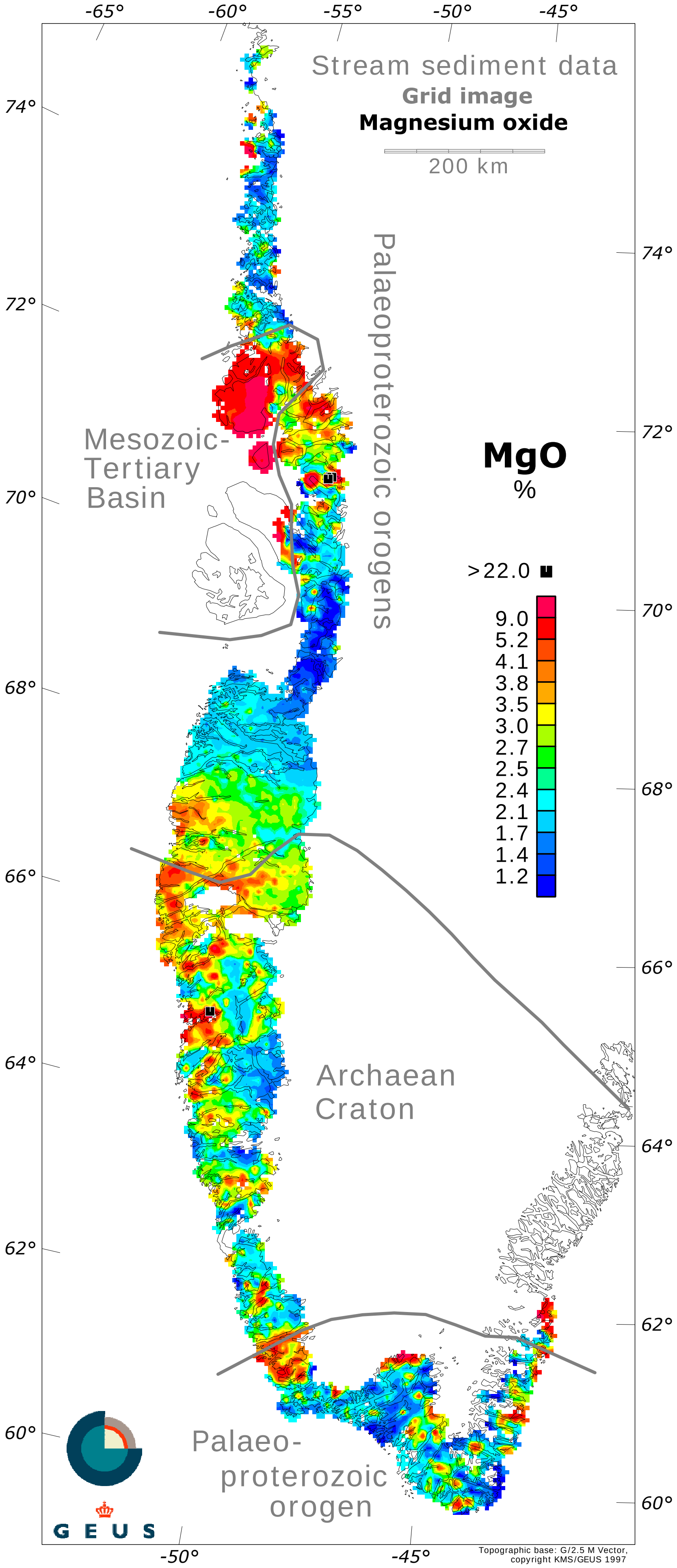
MnO %	Samples	Cells
Number	5398	6706
Maximum	9.22	6.18
Minimum	0.02	0.00
Mean	0.11	0.11
Std. dev.	0.14	0.14
10th perc.	0.06	0.07
20th perc.	0.07	0.08
30th perc.	0.08	0.08
40th perc.	0.09	0.09
50th perc.	0.10	0.10
60th perc.	0.11	0.11
70th perc.	0.12	0.12
80th perc.	0.14	0.14
90th perc.	0.17	0.16
95th perc.	0.21	0.20
98th perc.	0.26	0.24
99th perc.	0.33	0.28

Upper crustal mean: 0.08

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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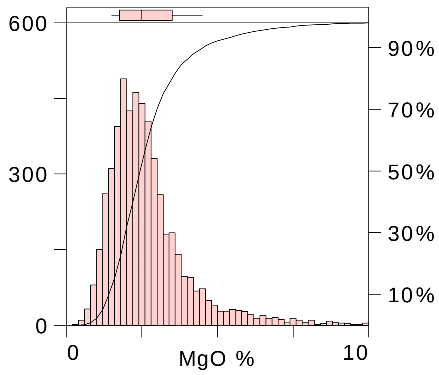

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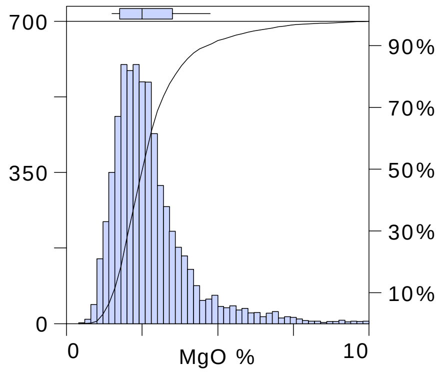


Statistics

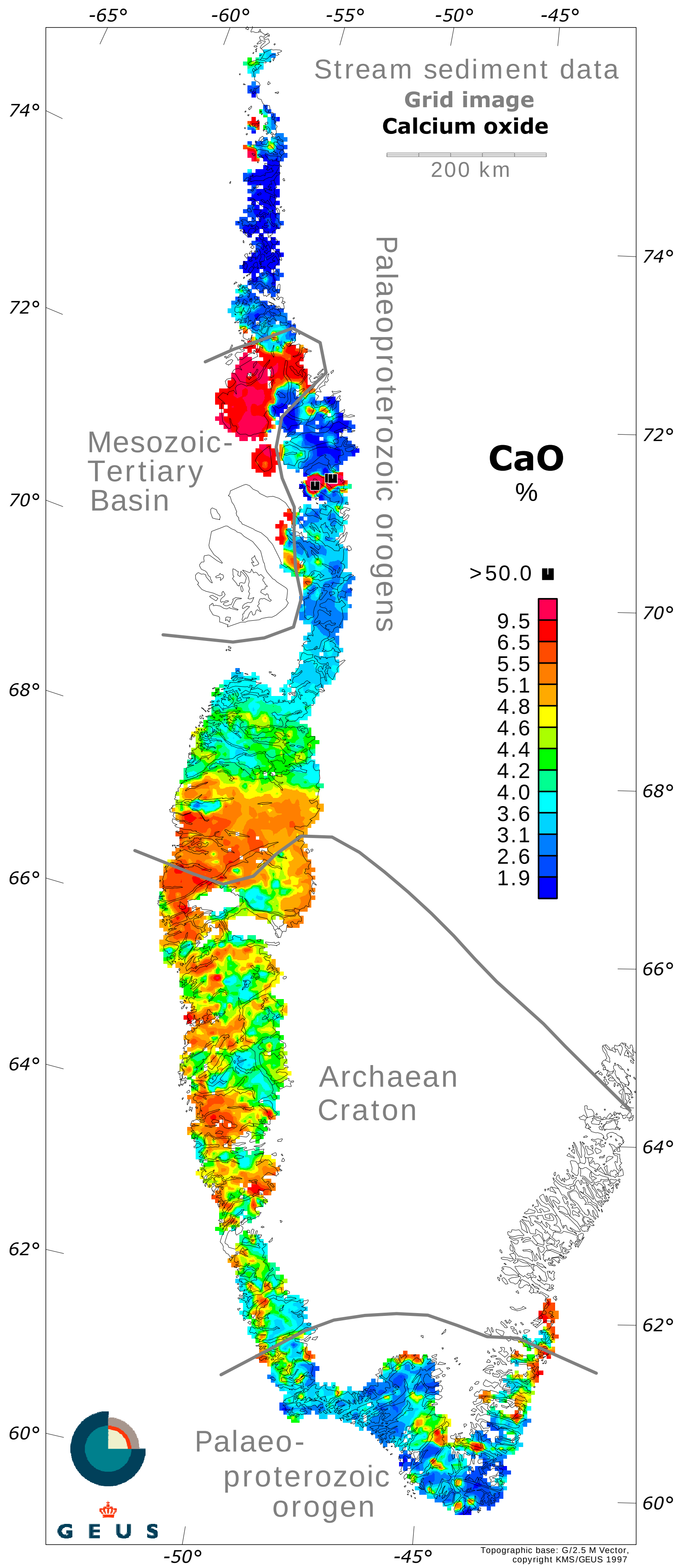
MgO %	Samples	Cells
Number	5398	6706
Maximum	28.65	18.98
Minimum	0.30	0.42
Mean	2.93	3.00
Std. dev.	2.23	2.09
10th perc.	1.41	1.53
20th perc.	1.72	1.83
30th perc.	1.95	2.05
40th perc.	2.20	2.27
50th perc.	2.44	2.50
60th perc.	2.69	2.75
70th perc.	2.98	3.05
80th perc.	3.49	3.54
90th perc.	4.52	4.64
95th perc.	6.06	6.30
98th perc.	9.95	10.28
99th perc.	15.17	14.34

Upper crustal mean: 2.2

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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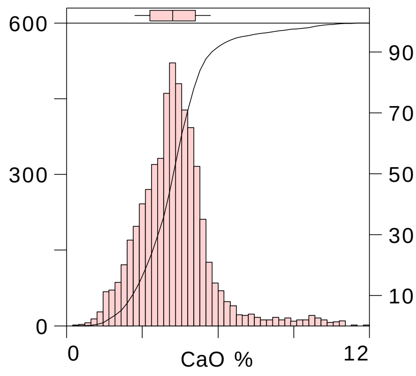

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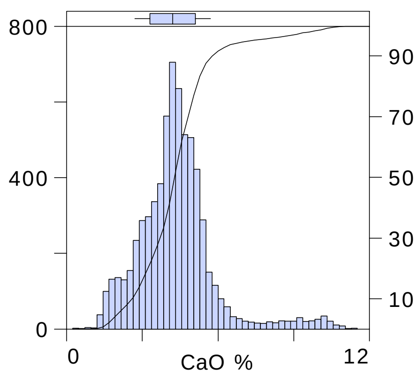


Statistics

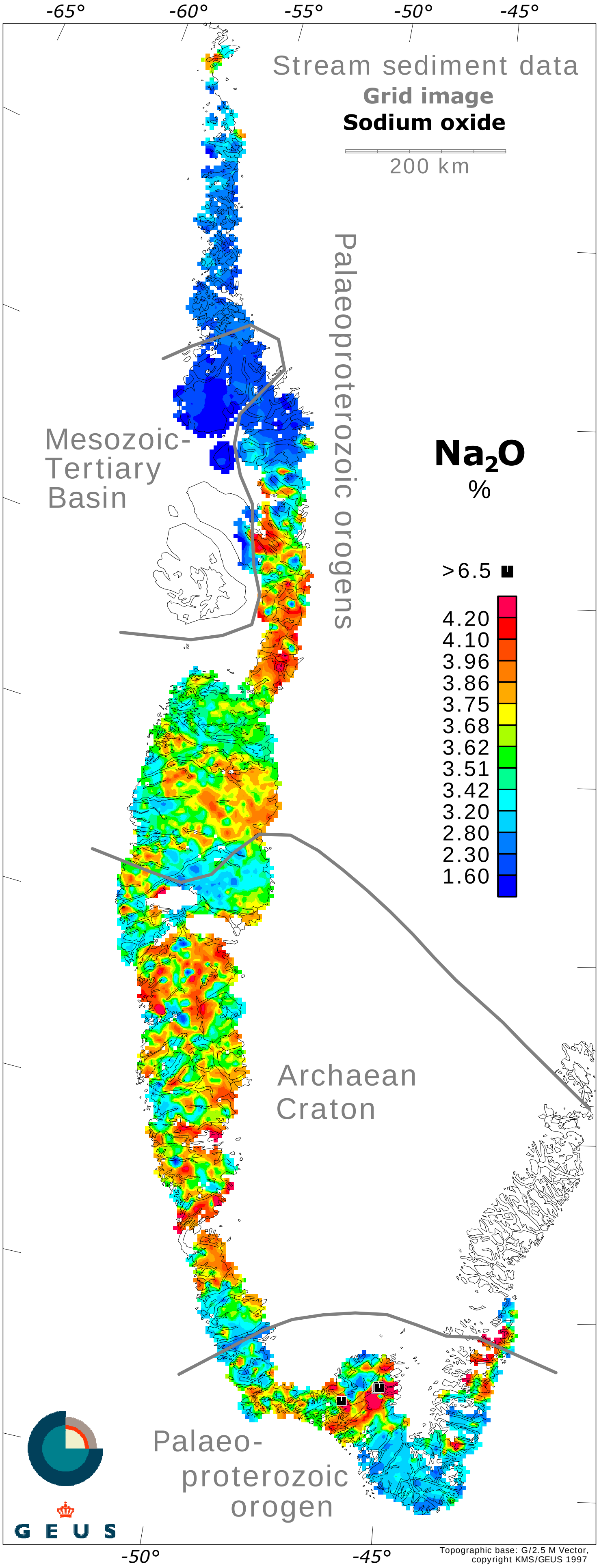
CaO %	Samples	Cells
Number	5398	6706
Maximum	78.28	40.53
Minimum	0.35	-1.23
Mean	4.44	4.40
Std. dev.	2.99	1.89
10th perc.	2.61	2.61
20th perc.	3.17	3.22
30th perc.	3.61	3.71
40th perc.	3.96	4.03
50th perc.	4.22	4.27
60th perc.	4.47	4.51
70th perc.	4.77	4.81
80th perc.	5.12	5.14
90th perc.	5.73	5.78
95th perc.	6.91	7.30
98th perc.	9.51	9.70
99th perc.	10.33	10.26

Upper crustal mean: 4.2

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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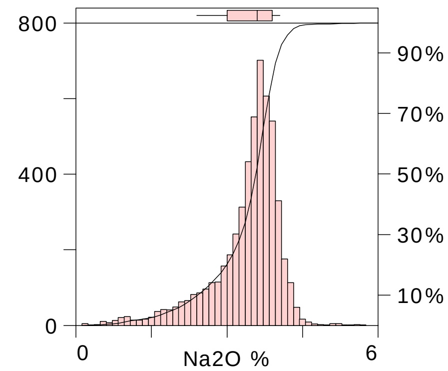
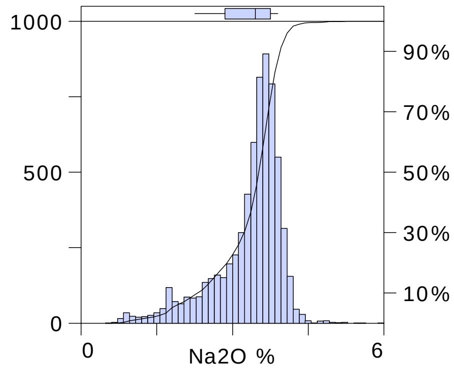


Grid cell values



Statistics

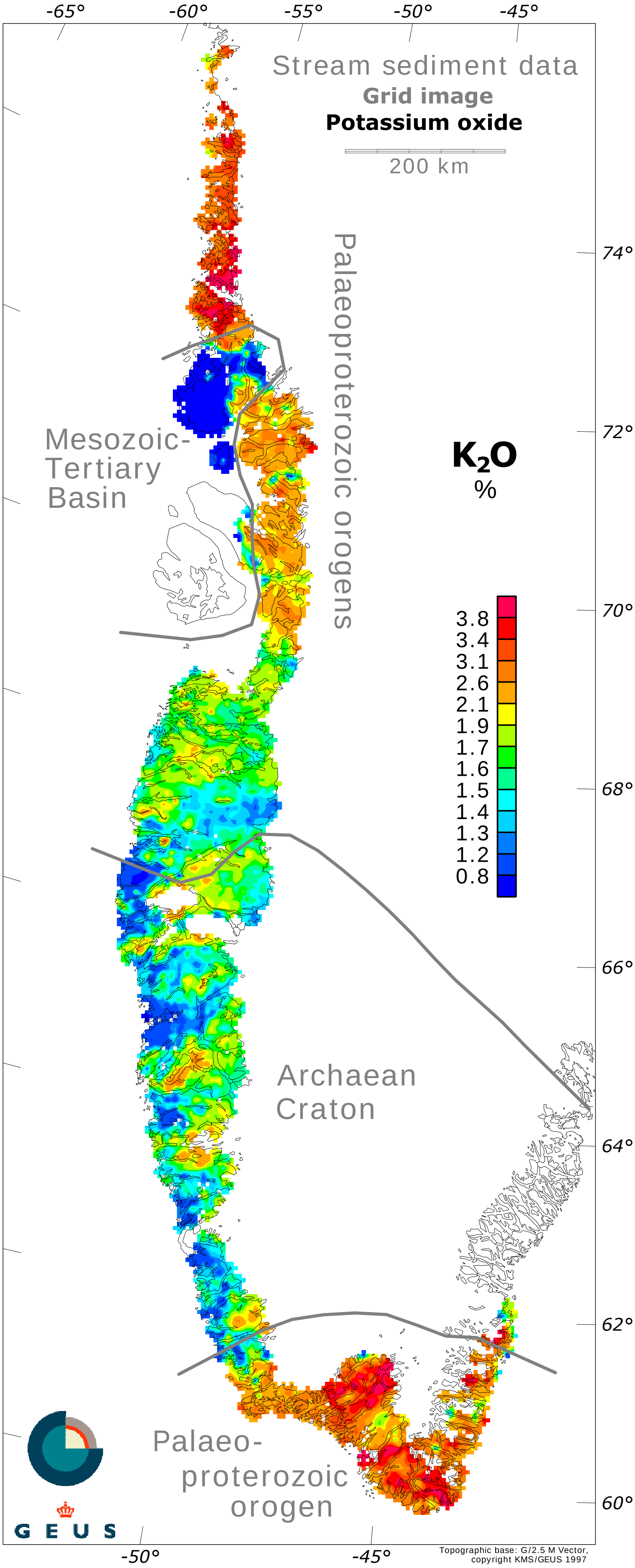
Na2O %	Samples	Cells
Number	5398	6706
Maximum	6.89	6.34
Minimum	0.12	0.59
Mean	3.39	3.32
Std. dev.	0.71	0.68
10th perc.	2.41	2.32
20th perc.	2.98	2.89
30th perc.	3.27	3.22
40th perc.	3.45	3.40
50th perc.	3.57	3.52
60th perc.	3.66	3.62
70th perc.	3.76	3.71
80th perc.	3.87	3.80
90th perc.	4.02	3.93
95th perc.	4.16	4.05
98th perc.	4.31	4.17
99th perc.	4.45	4.31

Upper crustal mean: 3.9

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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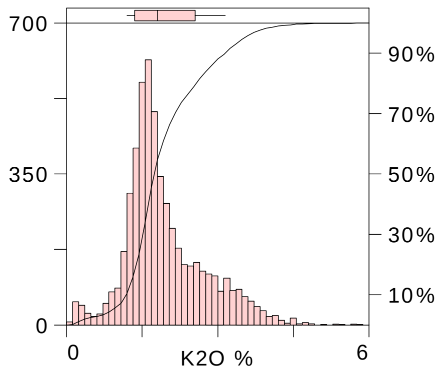
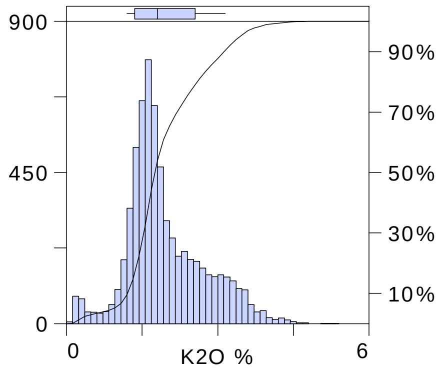


Grid cell values



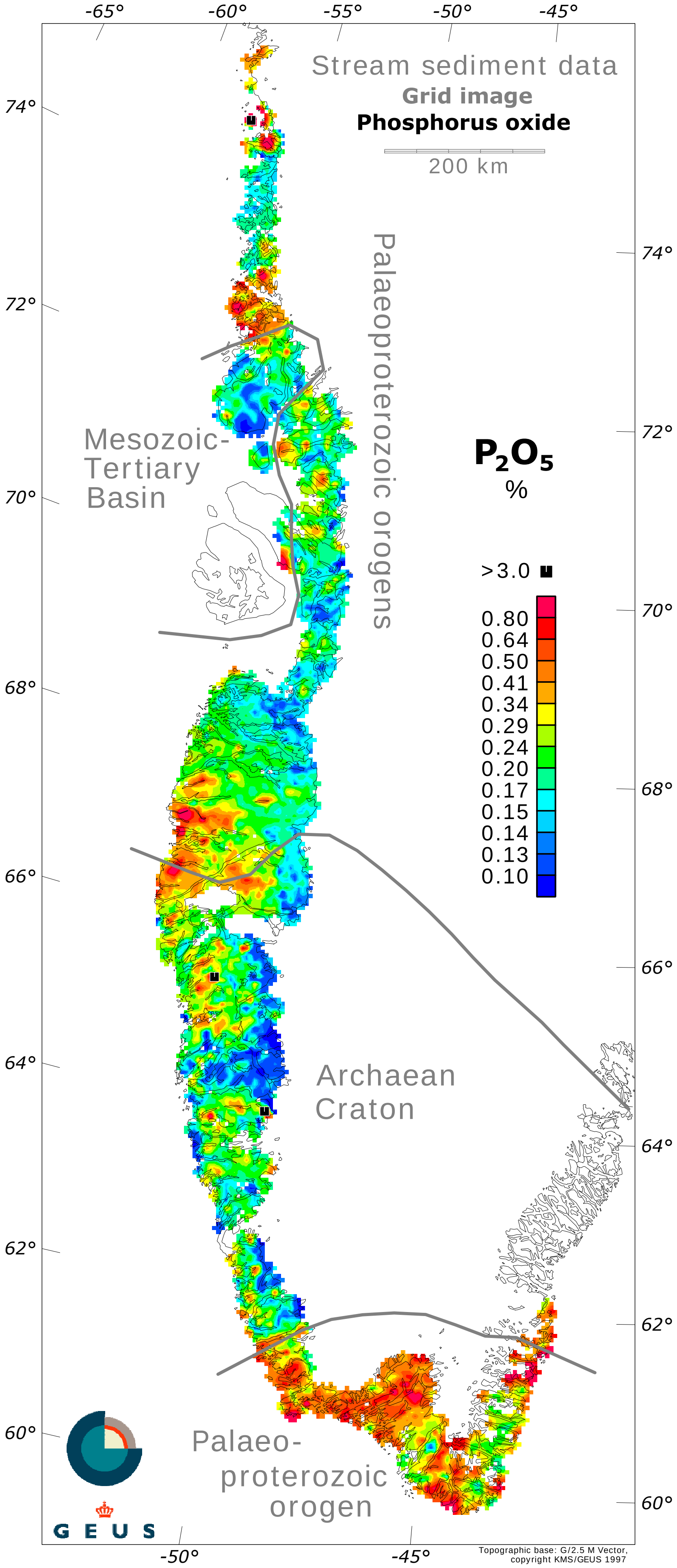
Statistics

K2O %	Samples	Cells
Number	5398	6706
Maximum	5.79	5.36
Minimum	0.07	0.08
Mean	1.94	1.95
Std. dev.	0.80	0.78
10th perc.	1.19	1.21
20th perc.	1.39	1.40
30th perc.	1.51	1.53
40th perc.	1.62	1.64
50th perc.	1.73	1.75
60th perc.	1.90	1.90
70th perc.	2.14	2.19
80th perc.	2.56	2.60
90th perc.	3.14	3.12
95th perc.	3.51	3.44
98th perc.	3.89	3.77
99th perc.	4.18	3.99

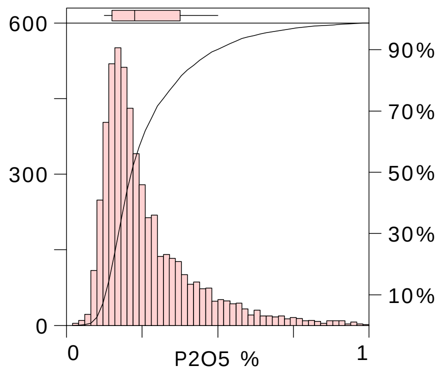
Upper crustal mean: 3.4
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

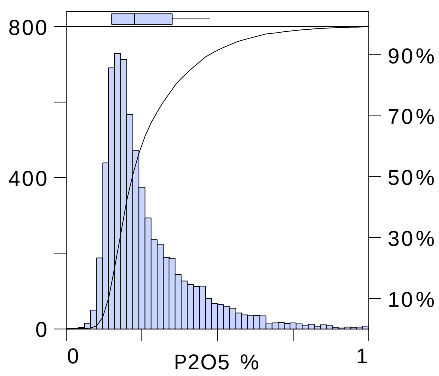
West and South Greenland



Sample values



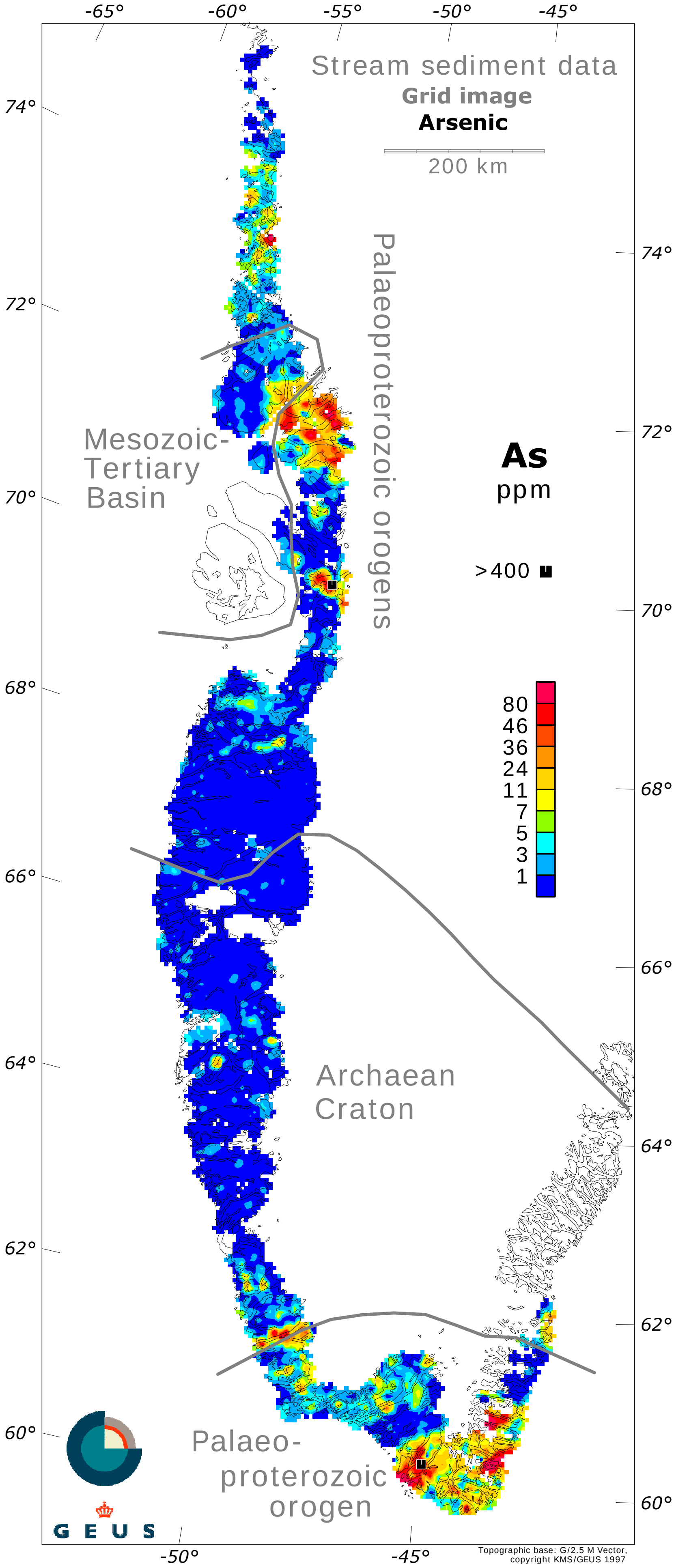
Grid cell values



Statistics

P2O5 %	Samples	Cells
Number	5398	6706
Maximum	5.29	4.14
Minimum	0.02	0.01
Mean	0.28	0.27
Std. dev.	0.23	0.18
10th perc.	0.13	0.14
20th perc.	0.15	0.16
30th perc.	0.17	0.18
40th perc.	0.19	0.20
50th perc.	0.21	0.22
60th perc.	0.25	0.25
70th perc.	0.29	0.29
80th perc.	0.37	0.36
90th perc.	0.49	0.47
95th perc.	0.64	0.59
98th perc.	0.87	0.75
99th perc.	1.11	0.92

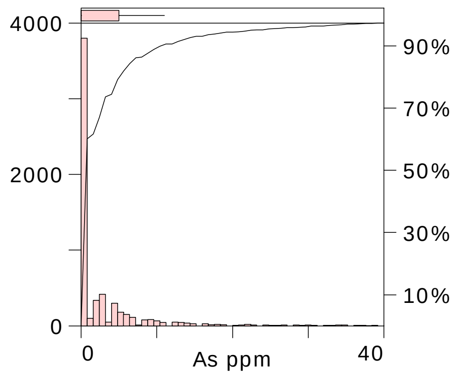
Upper crustal mean: 0.17
(Taylor & McLennan 1985)



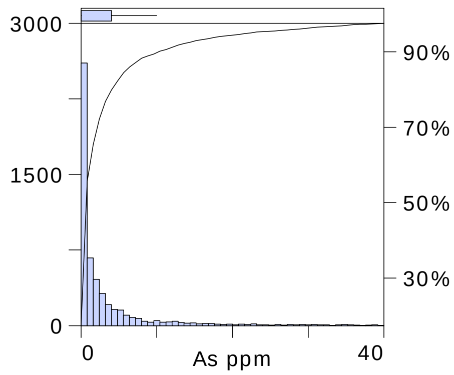
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



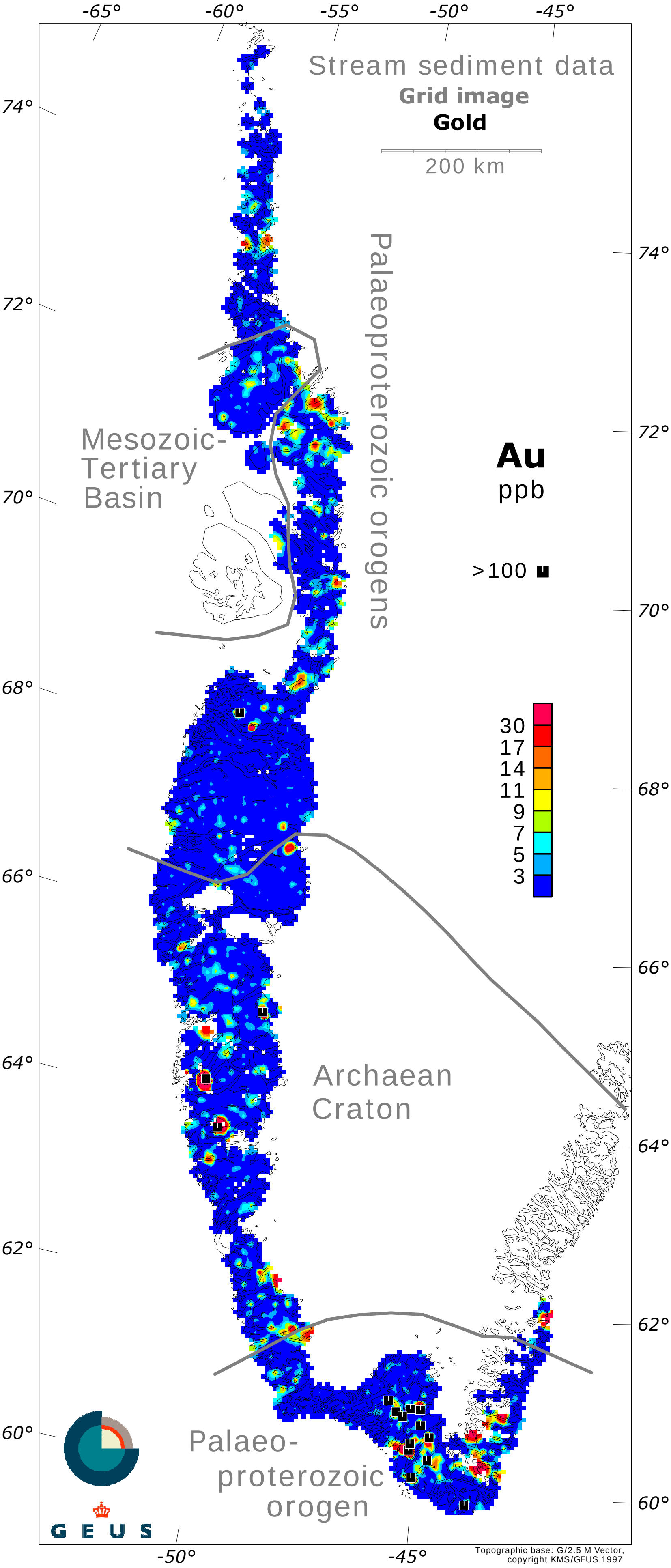
Statistics

As ppm	Samples	Cells
Number	6326	6815
Maximum	1100	257.1
Minimum	0	-6.1
Mean	5.29	4.40
Std. dev.	23.81	13.27
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0.1
50th perc.	0	0.5
60th perc.	0	1.1
70th perc.	3	2.1
80th perc.	5	4.0
90th perc.	11	10.2
95th perc.	23	22.3
98th perc.	49	44.8
99th perc.	80	61.7

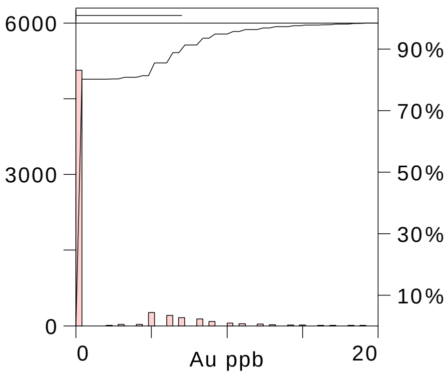
Upper crustal mean: 1.5
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

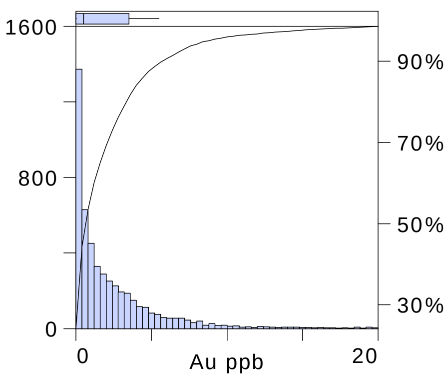
West and South Greenland



Sample values



Grid cell values

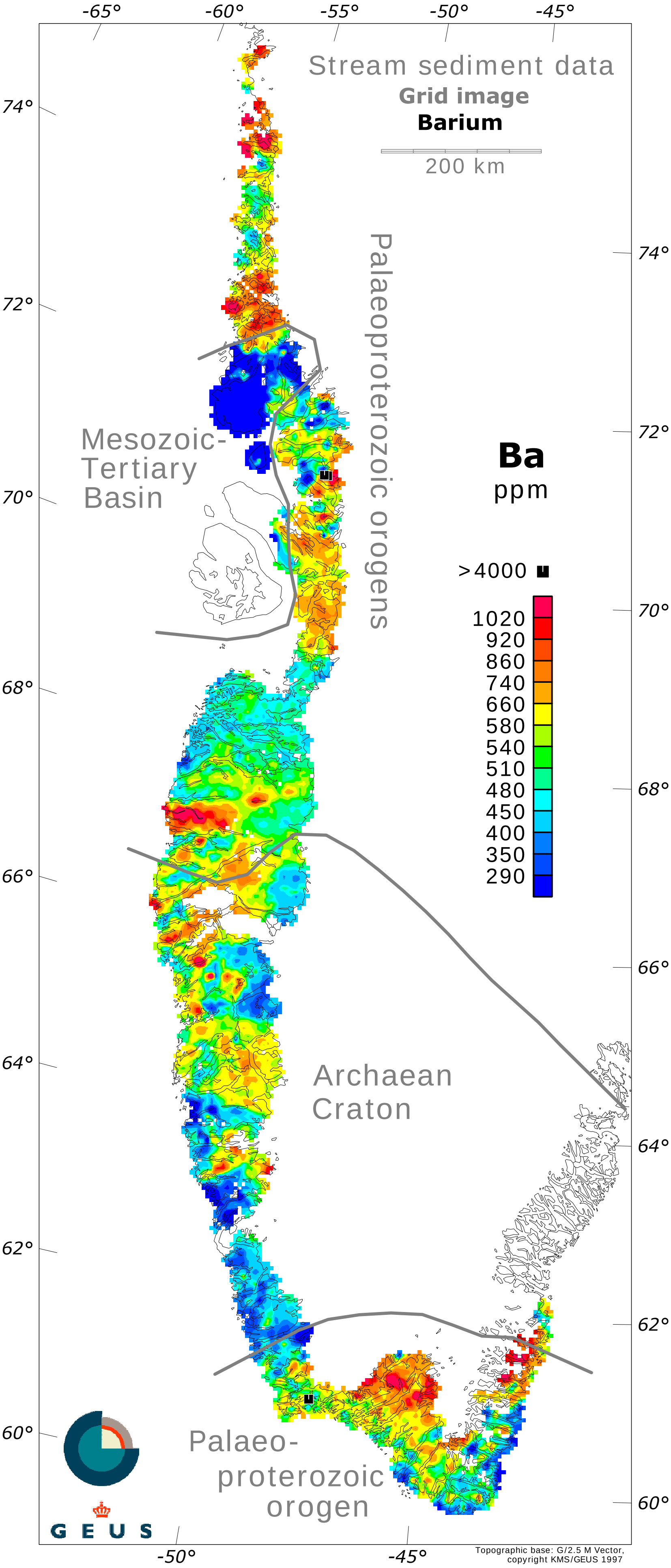


Statistics

Au ppb	Samples	Cells
Number	6326	6815
Maximum	850	316.2
Minimum	0	-38.8
Mean	2.60	2.45
Std. dev.	18.35	9.64
10th perc.	0	-0.2
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0.3
50th perc.	0	0.6
60th perc.	0	1.2
70th perc.	0	2.1
80th perc.	0	3.3
90th perc.	7	5.7
95th perc.	10	8.7
98th perc.	17	16.7
99th perc.	29	26.9

Upper crustal mean: 1.8

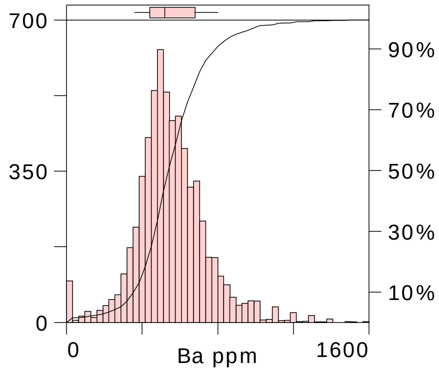
(Taylor & McLennan 1985)



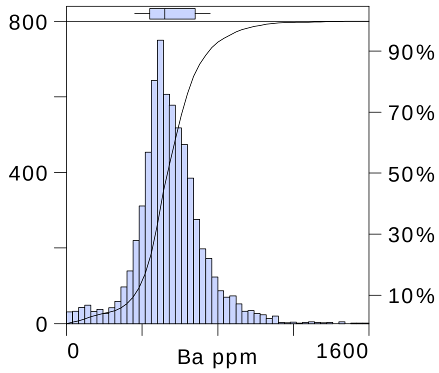
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



Statistics

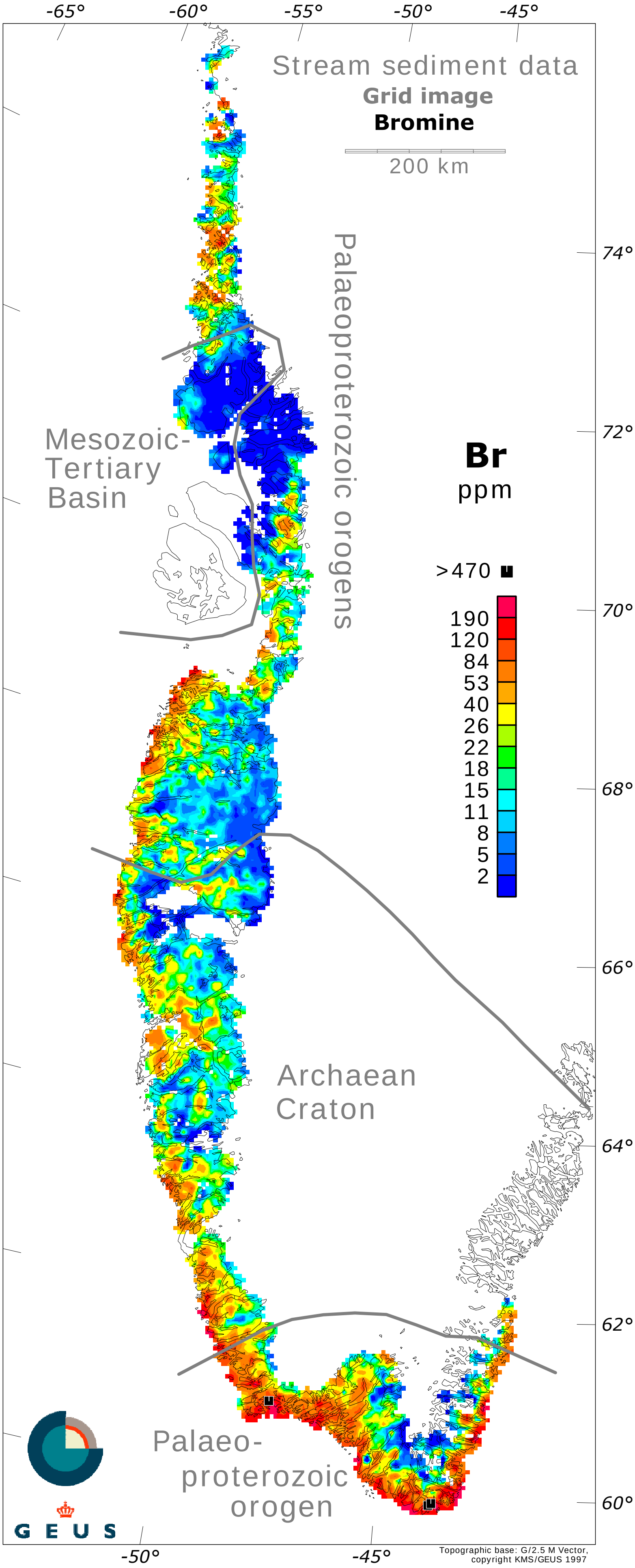
Ba ppm	Samples	Cells
Number	6421	6821
Maximum	5500	2954.1
Minimum	0	-45.2
Mean	563.17	545.72
Std. dev.	244.17	191.51
10th perc.	356	359
20th perc.	425	431
30th perc.	466	471
40th perc.	500	499
50th perc.	538	532
60th perc.	580	571
70th perc.	625	612
80th perc.	684	663
90th perc.	788	751
95th perc.	905	855
98th perc.	1095	986
99th perc.	1268	1084

Upper crustal mean: 550

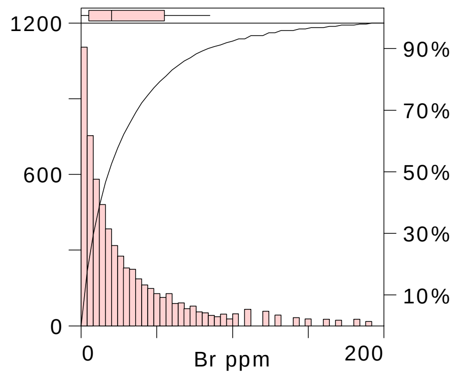
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

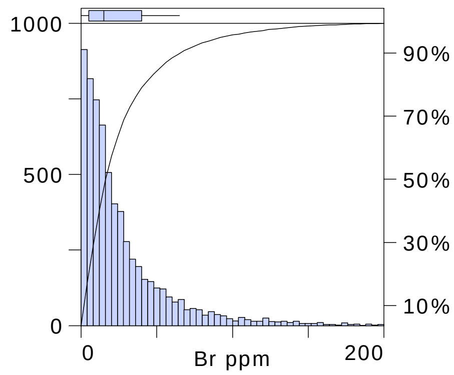
West and South Greenland



Sample values



Grid cell values



Statistics

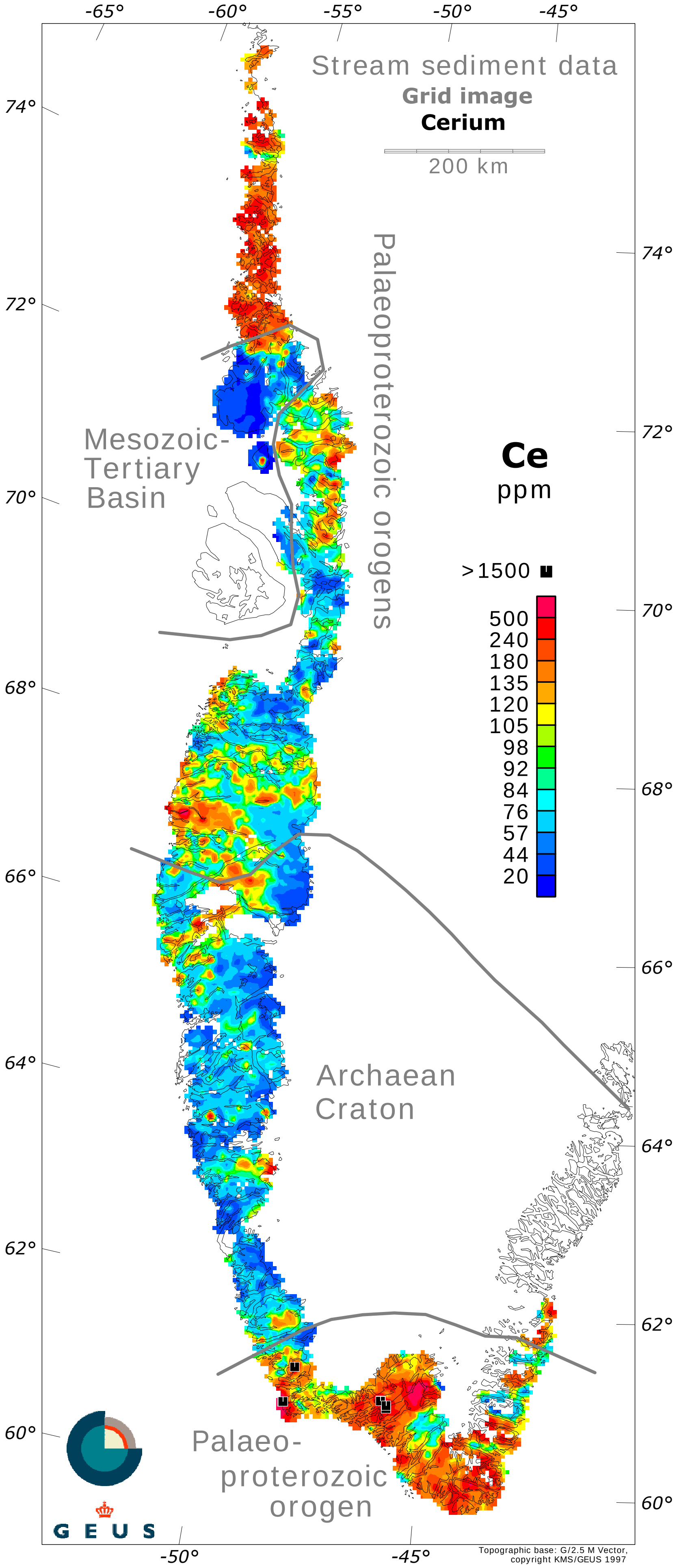
Br ppm	Samples	Cells
Number	6280	6788
Maximum	660	350.0
Minimum	0	-14.7
Mean	34.38	27.26
Std. dev.	48.91	33.95
10th perc.	0	1.4
20th perc.	4	4.9
30th perc.	8	8.3
40th perc.	12	11.9
50th perc.	18	16.1
60th perc.	26	21.7
70th perc.	36	28.9
80th perc.	53	41.6
90th perc.	84	65.2
95th perc.	120	92.2
98th perc.	190	135.6
99th perc.	250	169.0

Upper crustal mean: not given

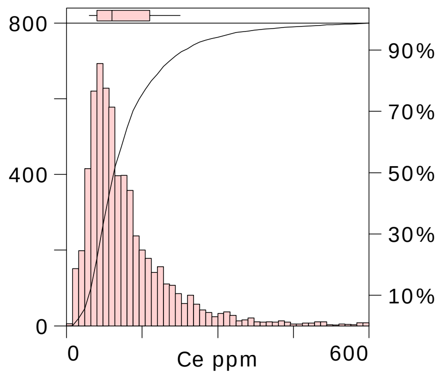
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

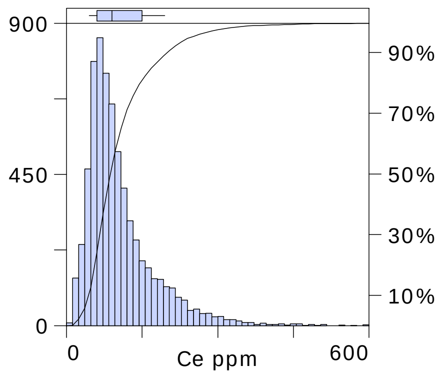
West and South Greenland



Sample values



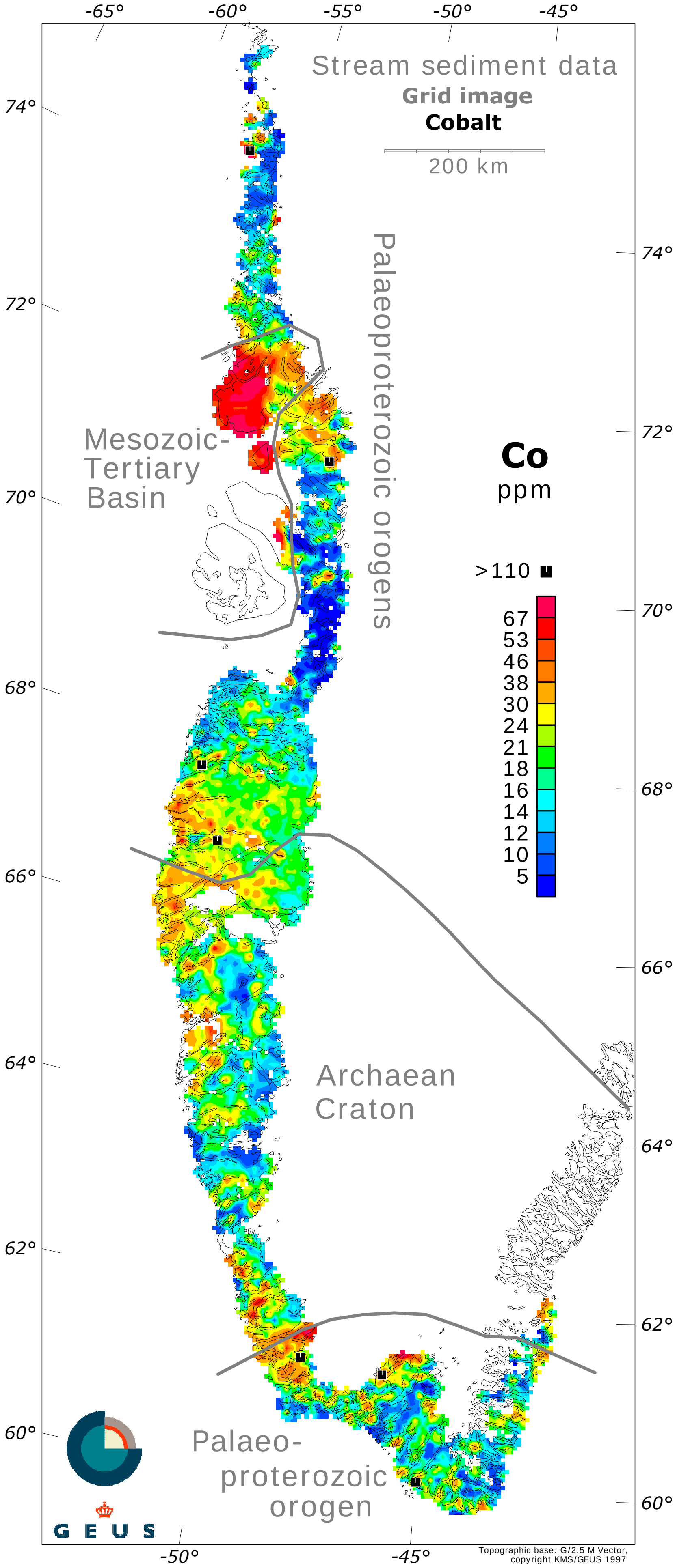
Grid cell values



Statistics

Ce ppm	Samples	Cells
Number	6326	6815
Maximum	2071	1301.3
Minimum	4	-18.7
Mean	127.87	108.64
Std. dev.	131.80	83.64
10th perc.	44	45
20th perc.	58	56
30th perc.	68	65
40th perc.	80	75
50th perc.	92	86
60th perc.	110	100
70th perc.	130	118
80th perc.	168	146
90th perc.	231	200
95th perc.	320	246
98th perc.	496	320
99th perc.	651	404

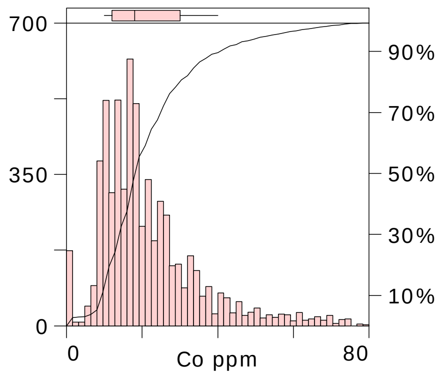
Upper crustal mean: 64
(Taylor & McLennan 1985)



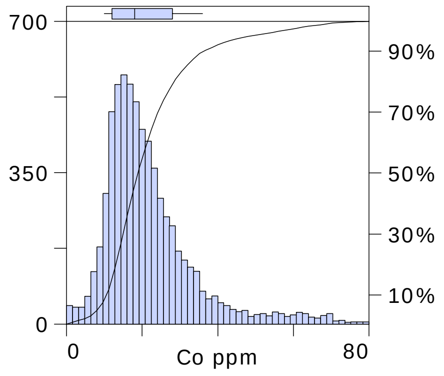
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

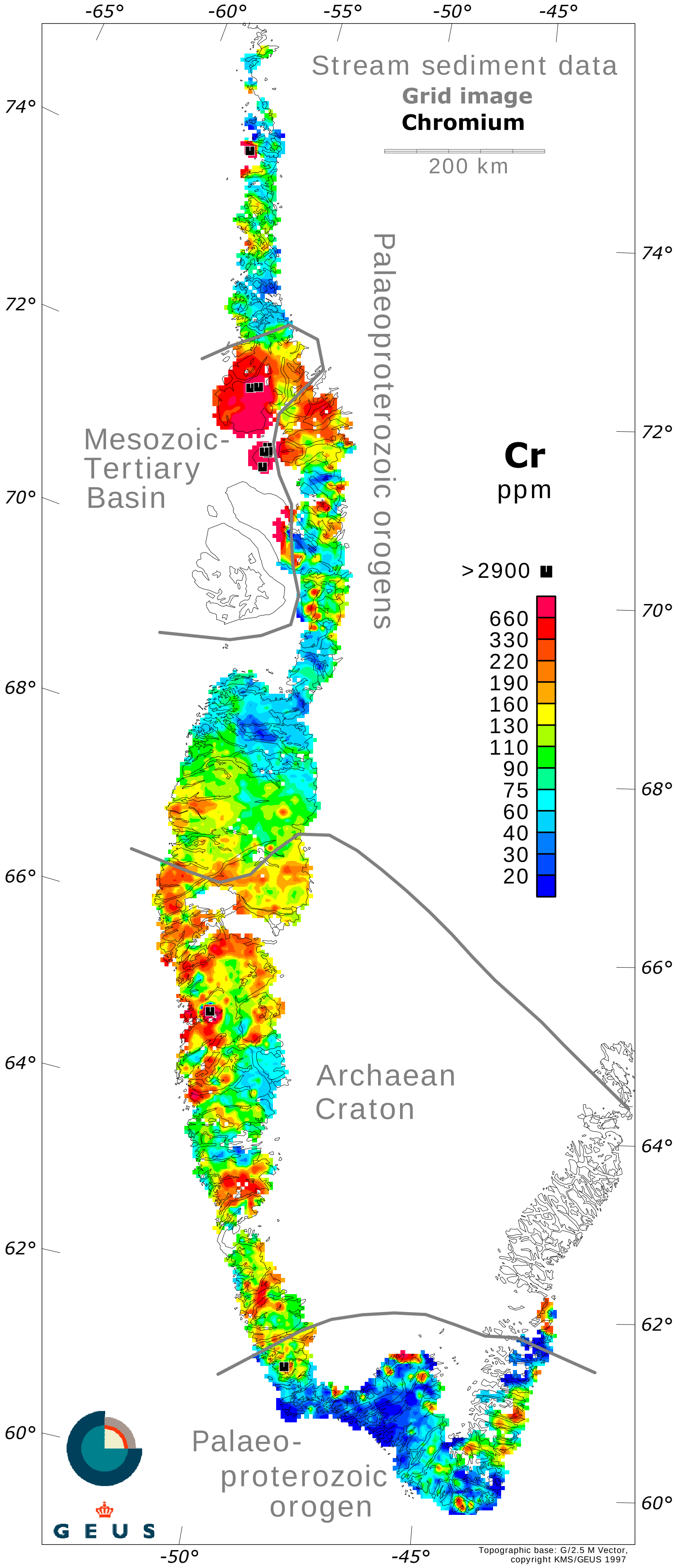


Statistics

Co ppm	Samples	Cells
Number	6326	6815
Maximum	150	127.1
Minimum	0	-1.5
Mean	22.06	21.91
Std. dev.	14.86	12.87
10th perc.	9	11
20th perc.	12	13
30th perc.	14	15
40th perc.	16	17
50th perc.	18	19
60th perc.	21	21
70th perc.	24	24
80th perc.	30	28
90th perc.	40	36
95th perc.	53	49
98th perc.	67	63
99th perc.	74	69

Upper crustal mean: 10

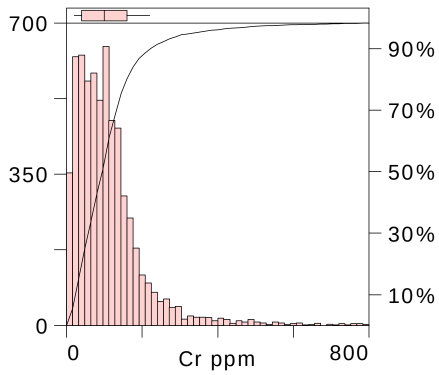
(Taylor & McLennan 1985)



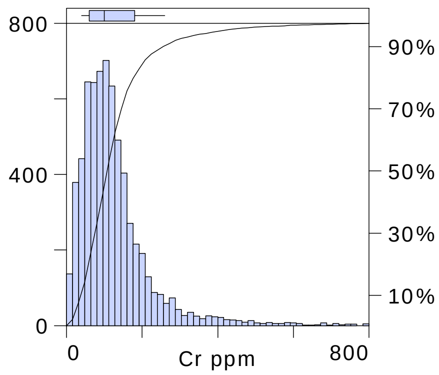
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

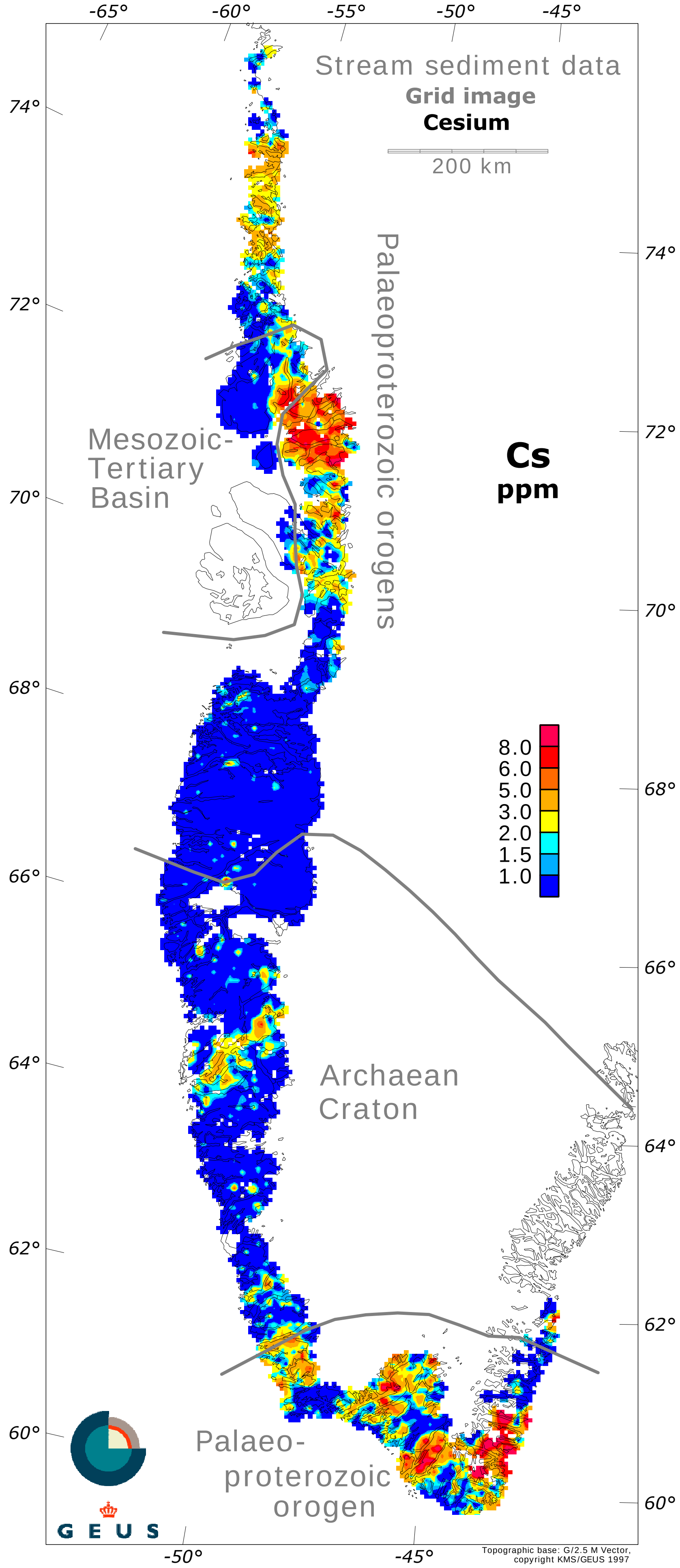


Statistics

Cr ppm	Samples	Cells
Number	6422	6821
Maximum	24770	10494.5
Minimum	0	-63.4
Mean	140.41	167.07
Std. dev.	396.43	319.12
10th perc.	23	38
20th perc.	39	58
30th perc.	57	75
40th perc.	75	91
50th perc.	93	107
60th perc.	110	123
70th perc.	130	144
80th perc.	158	178
90th perc.	221	254
95th perc.	329	402
98th perc.	660	1122
99th perc.	1500	1773

Upper crustal mean: 35

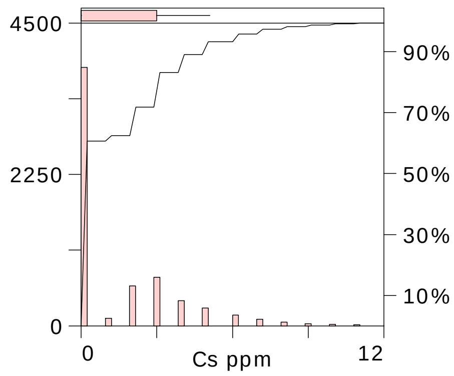
(Taylor & McLennan 1985)



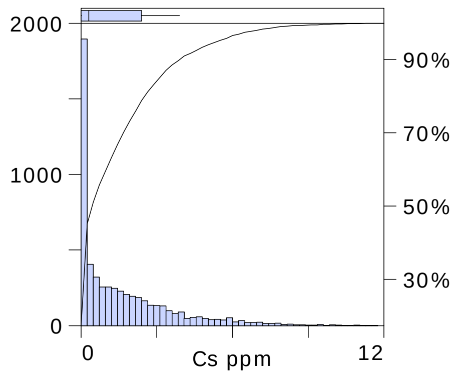
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

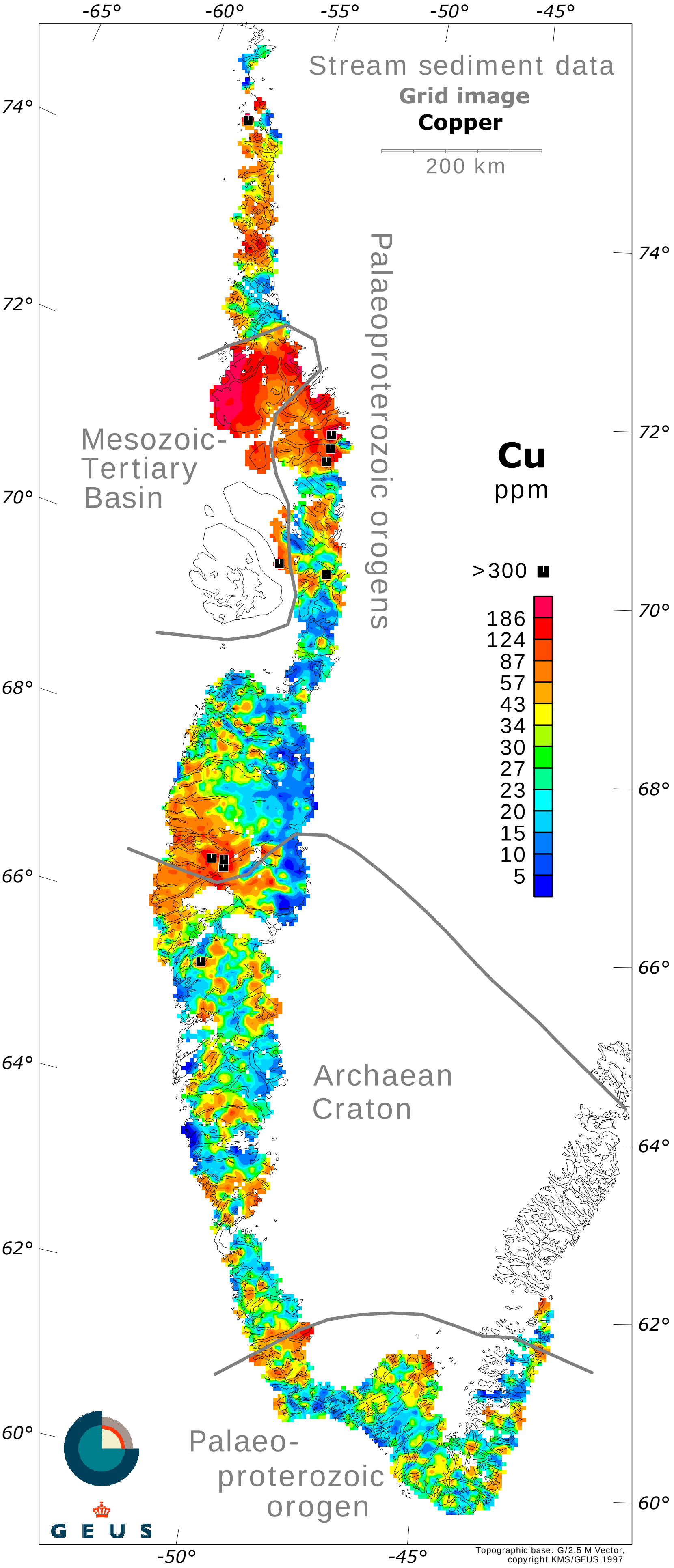


Statistics

Cs ppm	Samples	Cells
Number	6326	6815
Maximum	19	17.1
Minimum	0	-0.6
Mean	1.52	1.32
Std. dev.	2.38	1.89
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0.1
50th perc.	0	0.4
60th perc.	0	1.0
70th perc.	2	1.7
80th perc.	3	2.5
90th perc.	5	3.9
95th perc.	6	5.4
98th perc.	8	6.9
99th perc.	10	7.9

Upper crustal mean: 3.7

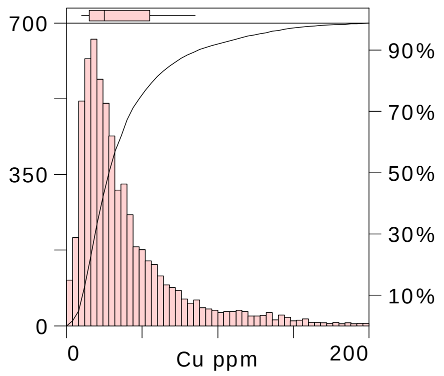
(Taylor & McLennan 1985)



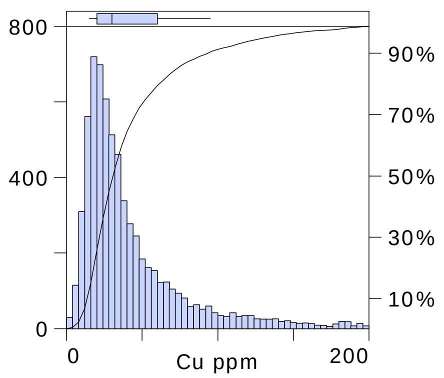
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

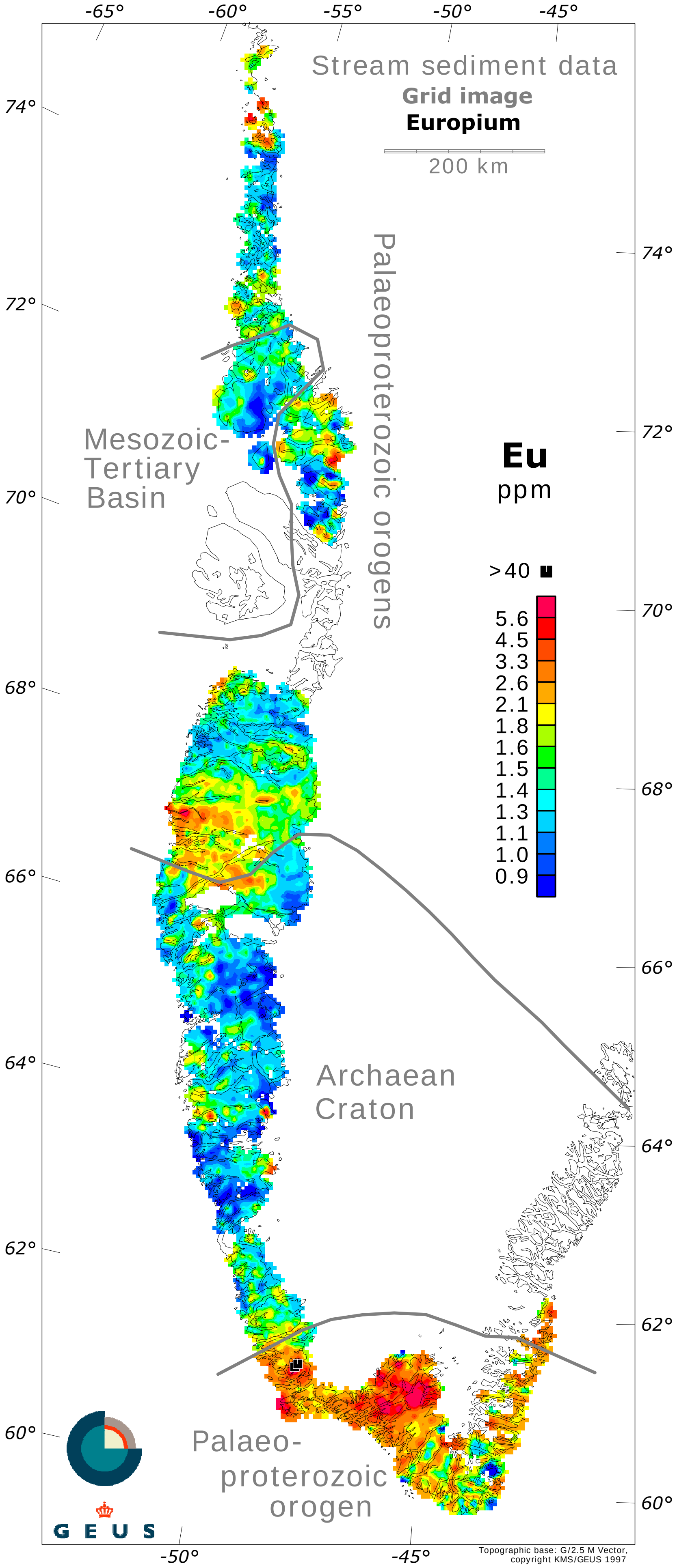


Statistics

Cu ppm	Samples	Cells
Number	6366	6772
Maximum	825	581.6
Minimum	0	-1.1
Mean	40.67	44.10
Std. dev.	42.05	40.41
10th perc.	10	14
20th perc.	14	18
30th perc.	18	22
40th perc.	23	26
50th perc.	27	31
60th perc.	34	36
70th perc.	43	46
80th perc.	57	61
90th perc.	87	93
95th perc.	124	130
98th perc.	166	183
99th perc.	204	205

Upper crustal mean: 25

(Taylor & McLennan 1985)

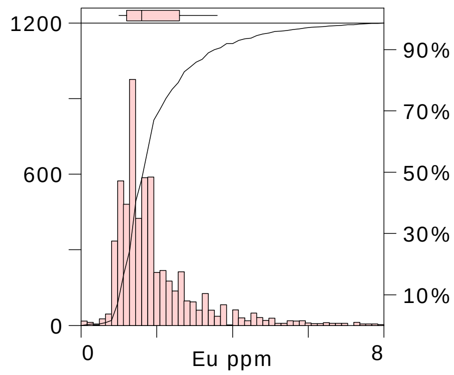


G E U S

Geochemical atlas of Greenland

West and South Greenland

Sample values



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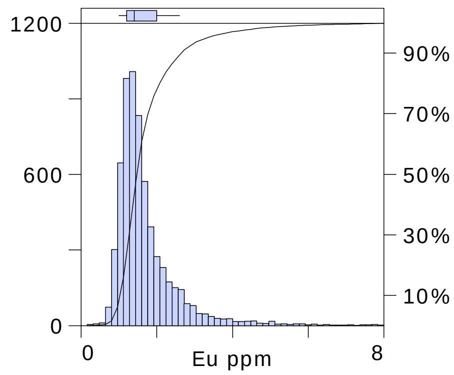


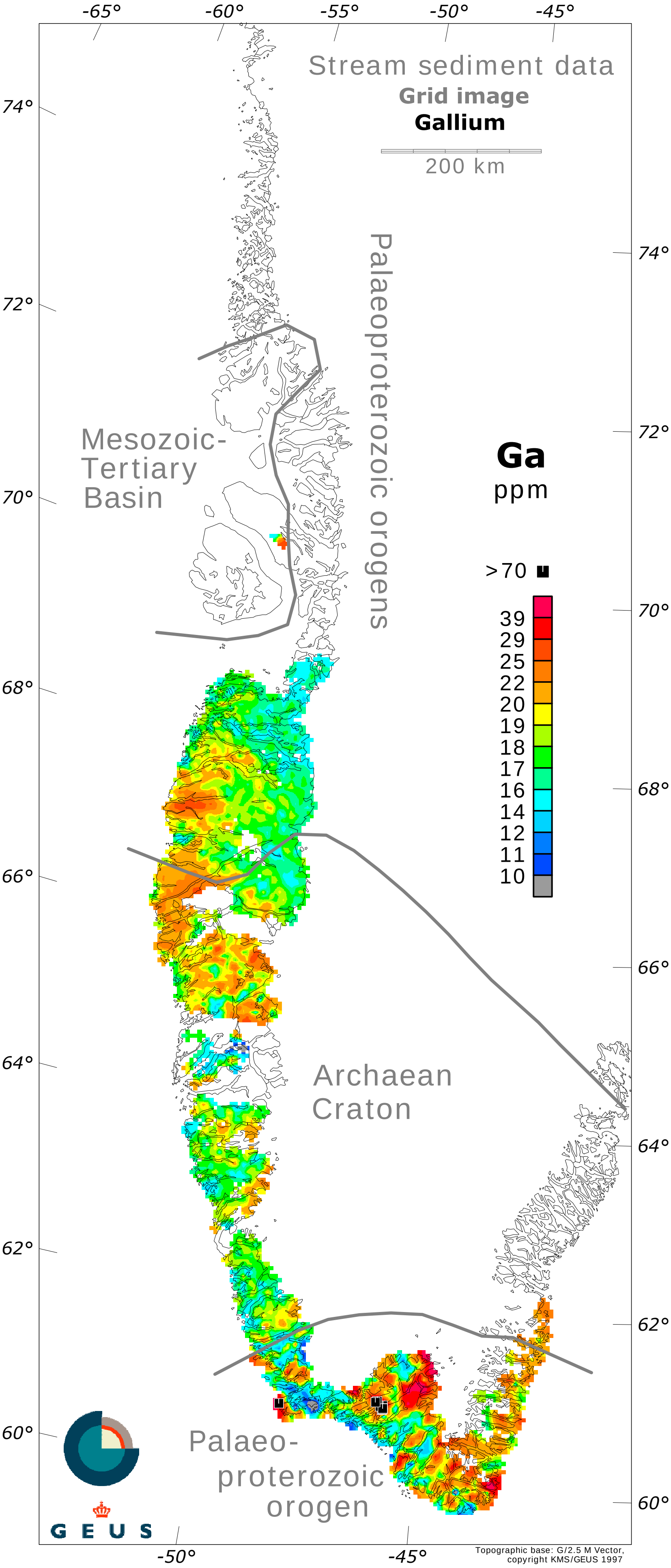
Statistics

Eu ppm	Samples	Cells
Number	6071	6374
Maximum	77	17.4
Minimum	0	0.2
Mean	2.08	1.72
Std. dev.	1.91	0.94
10th perc.	1.0	1.02
20th perc.	1.2	1.17
30th perc.	1.3	1.26
40th perc.	1.4	1.37
50th perc.	1.6	1.47
60th perc.	1.8	1.59
70th perc.	2.0	1.77
80th perc.	2.6	2.08
90th perc.	3.6	2.64
95th perc.	4.7	3.33
98th perc.	6.9	4.55
99th perc.	8.6	5.67

Upper crustal mean: 0.88
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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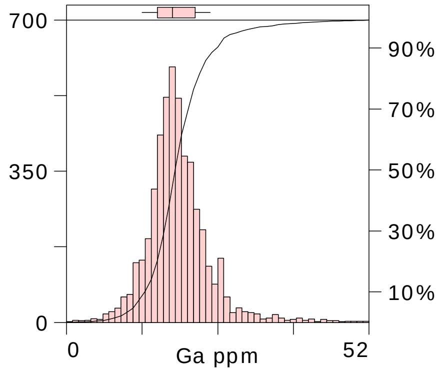

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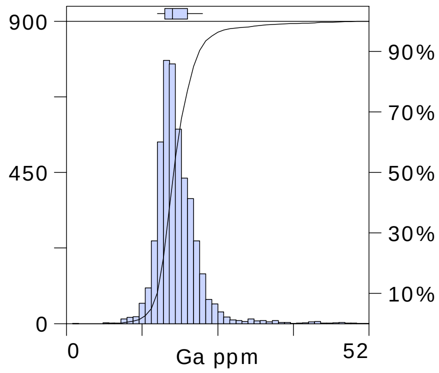


Statistics

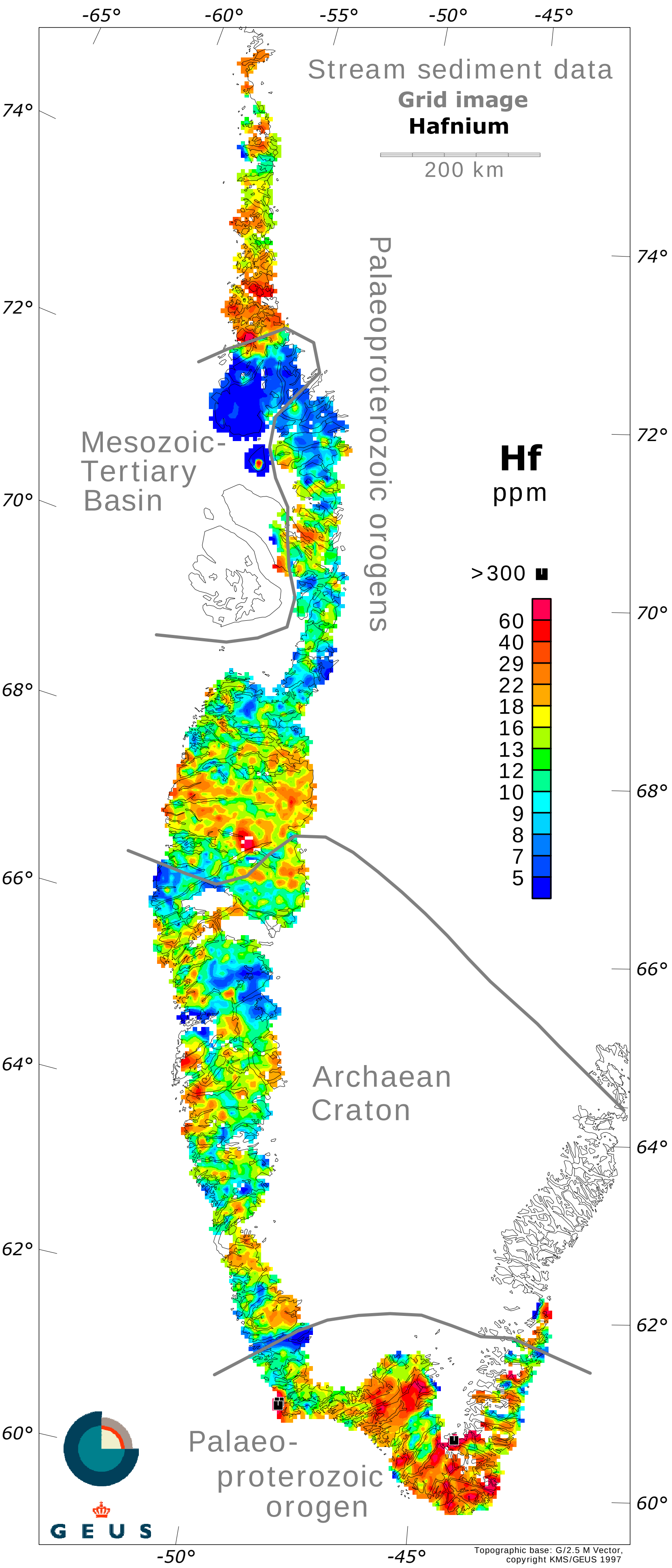
Ga ppm	Samples	Cells
Number	5023	4651
Maximum	97	57.6
Minimum	0	2.0
Mean	19.37	19.06
Std. dev.	6.79	4.08
10th perc.	13	15.6
20th perc.	15	16.5
30th perc.	17	17.2
40th perc.	18	17.8
50th perc.	18	18.3
60th perc.	19	19.1
70th perc.	21	20.0
80th perc.	22	21.2
90th perc.	25	22.8
95th perc.	30	24.9
98th perc.	39	30.4
99th perc.	48	35.9

Upper crustal mean: 17

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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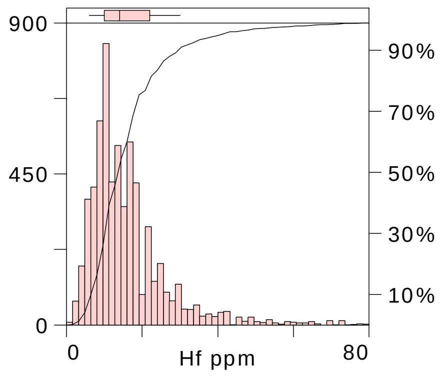
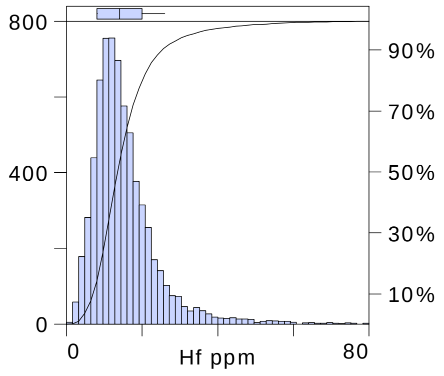


Grid cell values



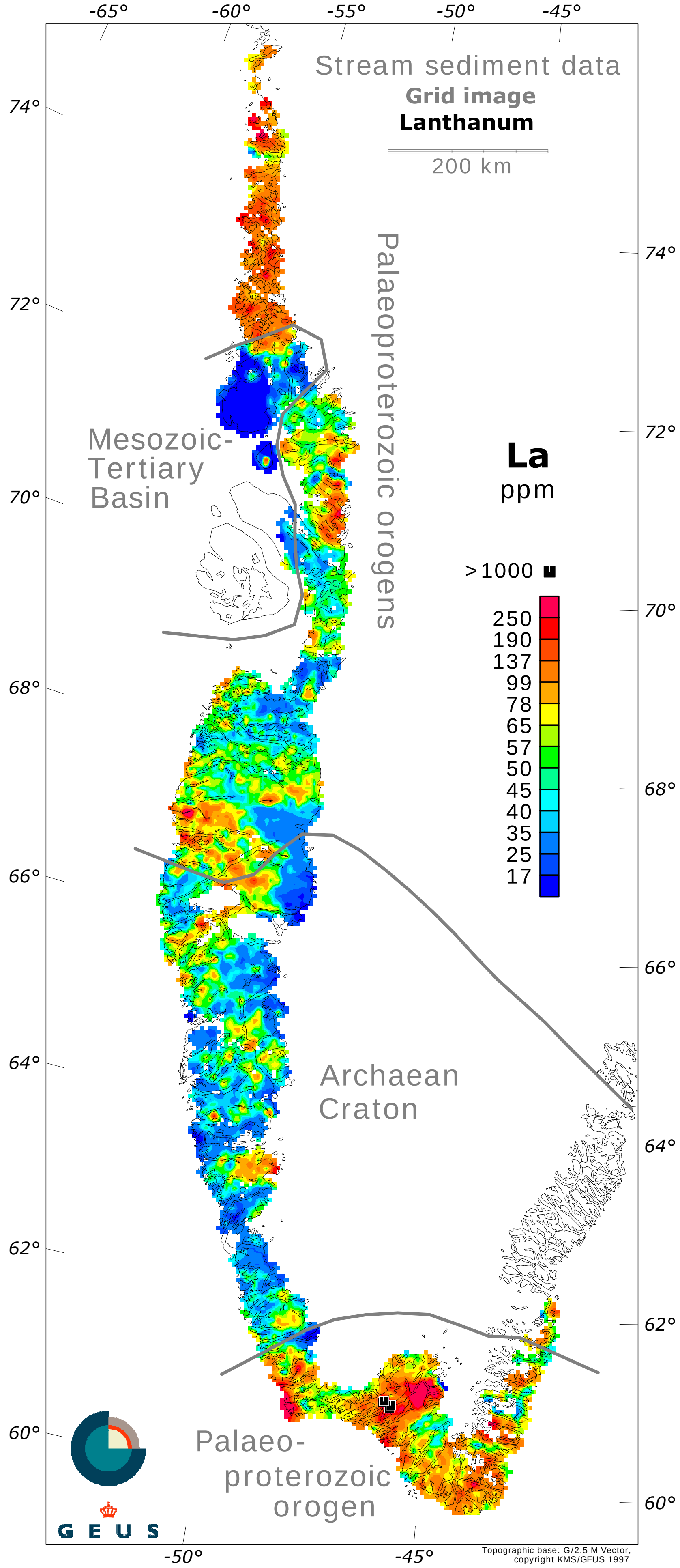
Statistics

Hf ppm	Samples	Cells
Number	6326	6815
Maximum	480	281.1
Minimum	0	-4.7
Mean	17.25	15.86
Std. dev.	17.83	12.67
10th perc.	7	7.0
20th perc.	9	9.0
30th perc.	10	10.5
40th perc.	12	11.9
50th perc.	13	13.4
60th perc.	15	15.1
70th perc.	18	17.1
80th perc.	22	20.0
90th perc.	29	25.2
95th perc.	40	32.8
98th perc.	61	46.5
99th perc.	85	59.6

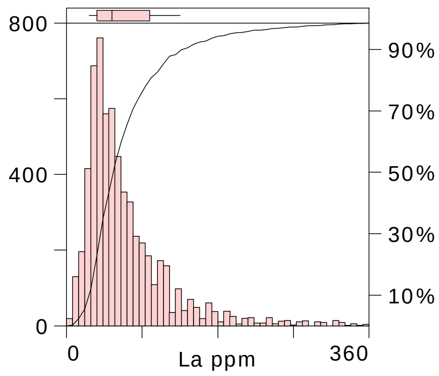
Upper crustal mean: 5.8
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

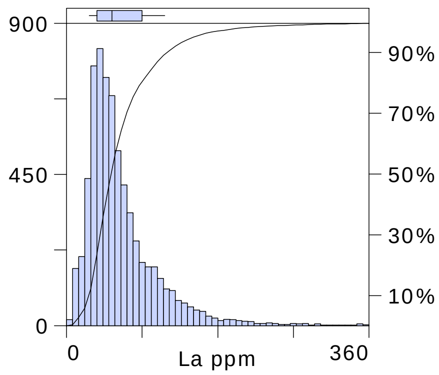
West and South Greenland



Sample values



Grid cell values



Statistics

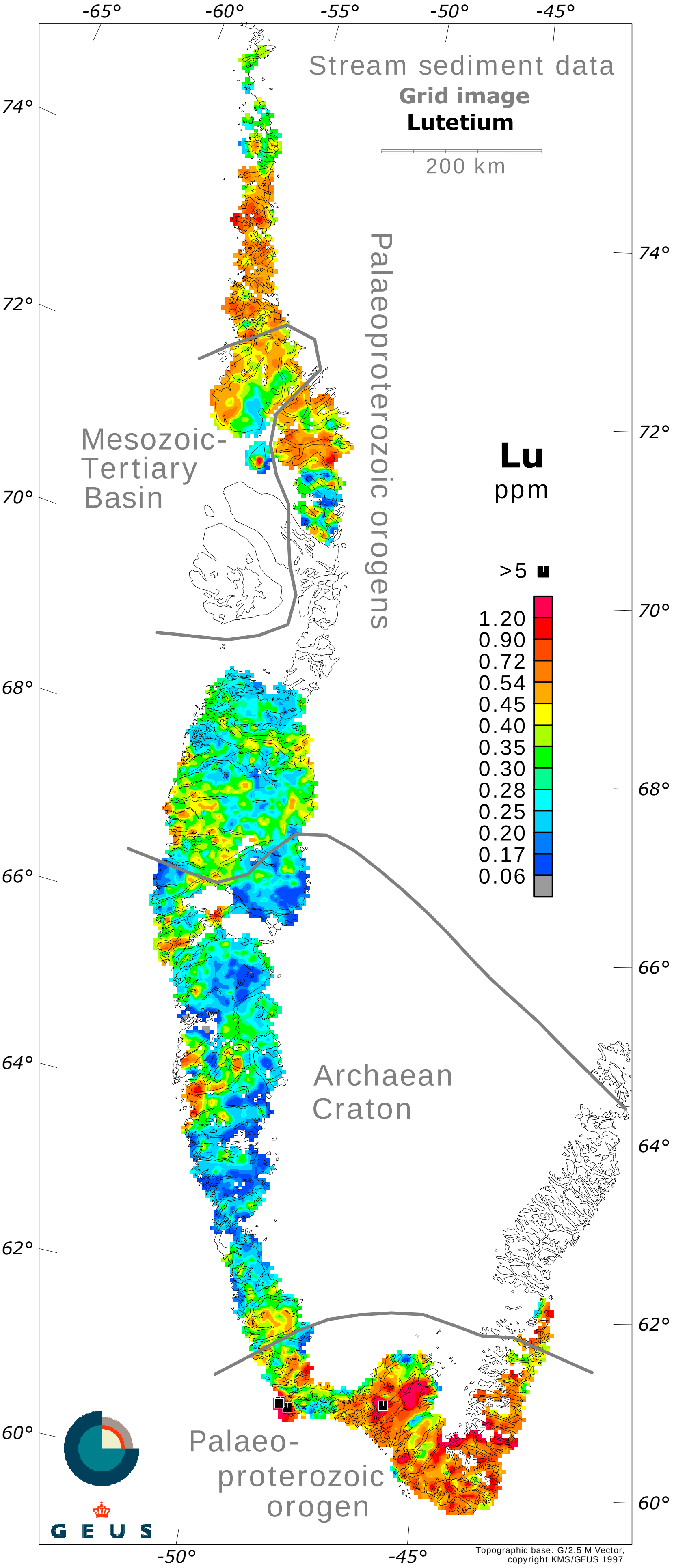
La ppm	Samples	Cells
Number	6326	6815
Maximum	1431	640.0
Minimum	2.6	-12.4
Mean	77.28	66.20
Std. dev.	84.66	51.80
10th perc.	27	27
20th perc.	34	34
30th perc.	40	40
40th perc.	47	46
50th perc.	55	53
60th perc.	65	61
70th perc.	78	72
80th perc.	99	89
90th perc.	137	119
95th perc.	190	151
98th perc.	314	205
99th perc.	452	270

Upper crustal mean: 30

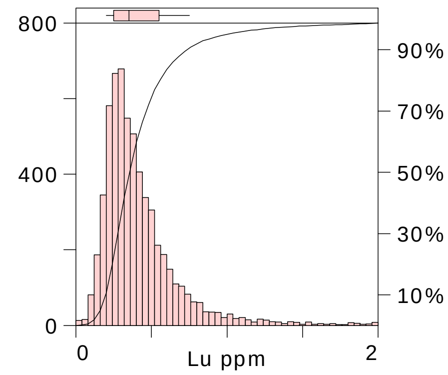
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

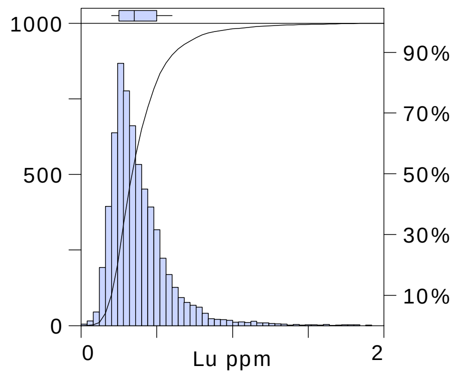
West and South Greenland



Sample values



Grid cell values



Statistics

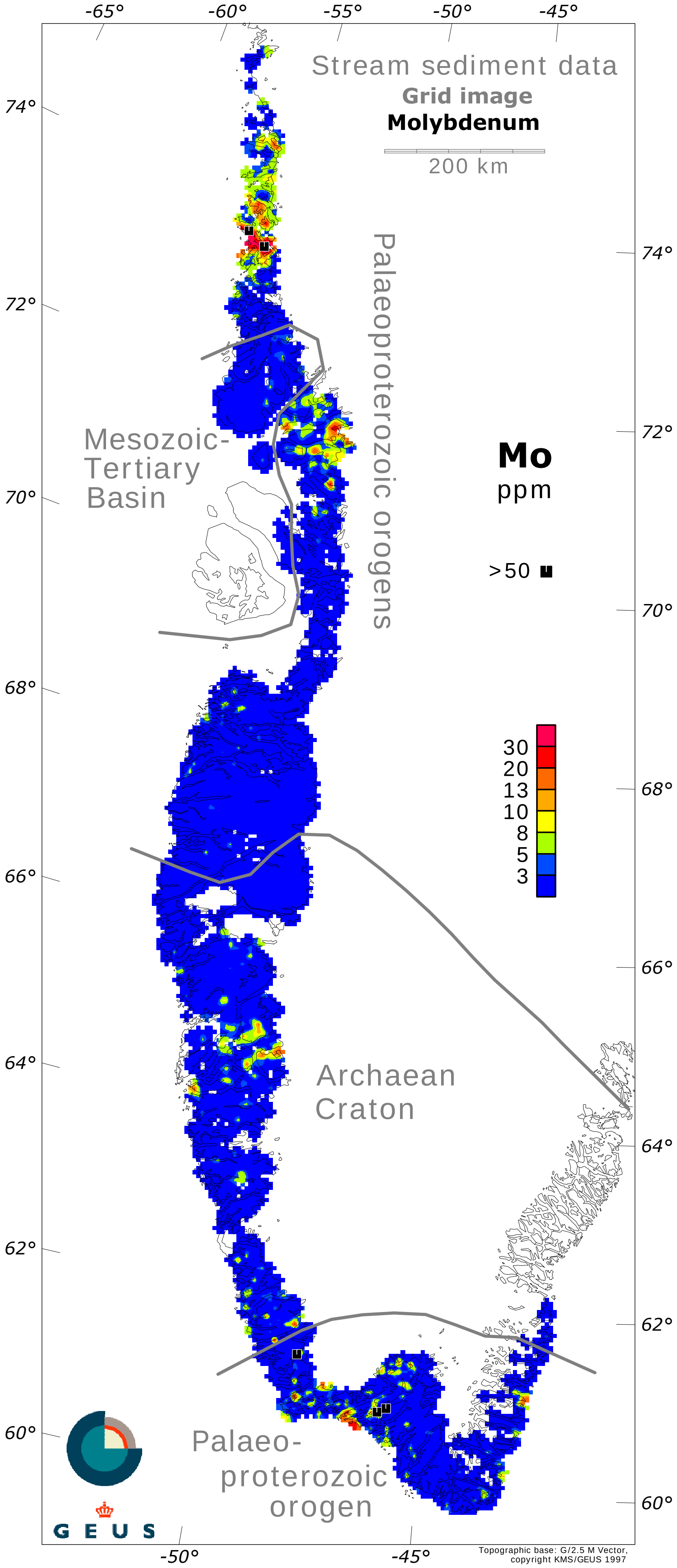
Lu ppm	Samples	Cells
Number	6071	6374
Maximum	6.35	4.0
Minimum	0	0.0
Mean	0.45	0.39
Std. dev.	0.40	0.25
10th perc.	0.19	0.20
20th perc.	0.23	0.24
30th perc.	0.27	0.27
40th perc.	0.31	0.30
50th perc.	0.35	0.33
60th perc.	0.40	0.38
70th perc.	0.46	0.43
80th perc.	0.55	0.49
90th perc.	0.73	0.62
95th perc.	0.99	0.77
98th perc.	1.60	1.06
99th perc.	2.24	1.34

Upper crustal mean: 0.32

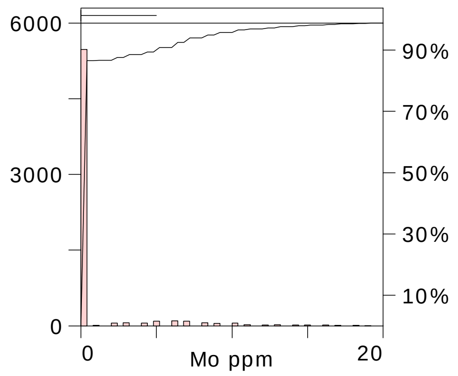
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

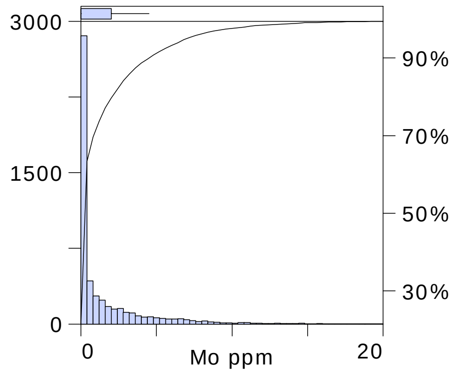
West and South Greenland



Sample values



Grid cell values



Statistics

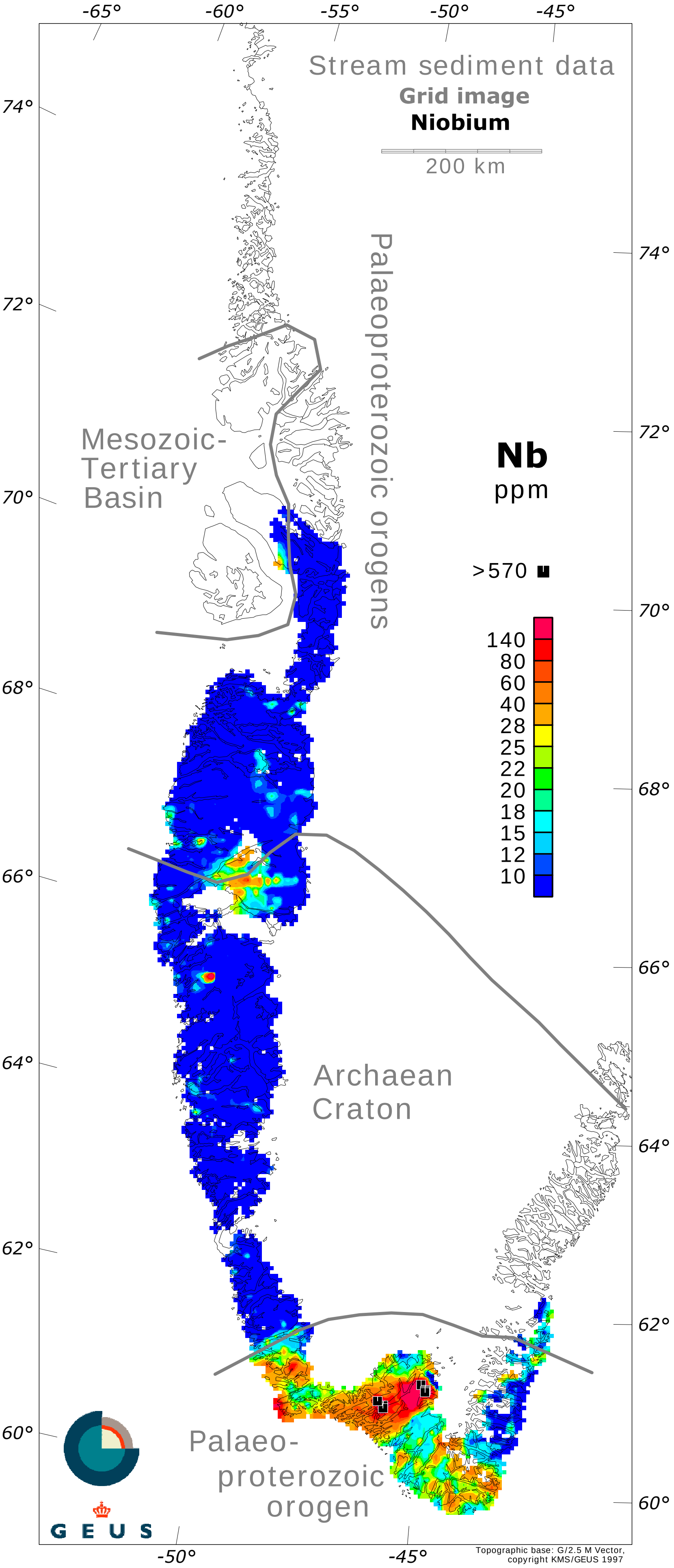
Mo ppm	Samples	Cells
Number	6326	6815
Maximum	95	69.3
Minimum	0	-2.4
Mean	1.26	1.38
Std. dev.	4.51	3.59
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0
50th perc.	0	0
60th perc.	0	0.2
70th perc.	0	0.8
80th perc.	0	2.0
90th perc.	5.00	4.5
95th perc.	8.75	7.0
98th perc.	15.00	10.8
99th perc.	21.00	14.6

Upper crustal mean: 1.5

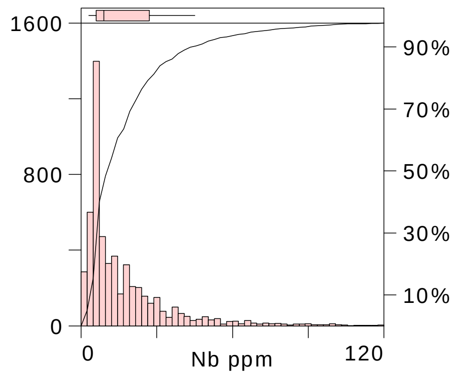
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

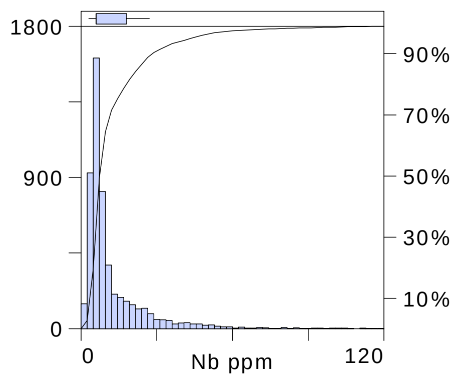
West and South Greenland



Sample values



Grid cell values



Statistics

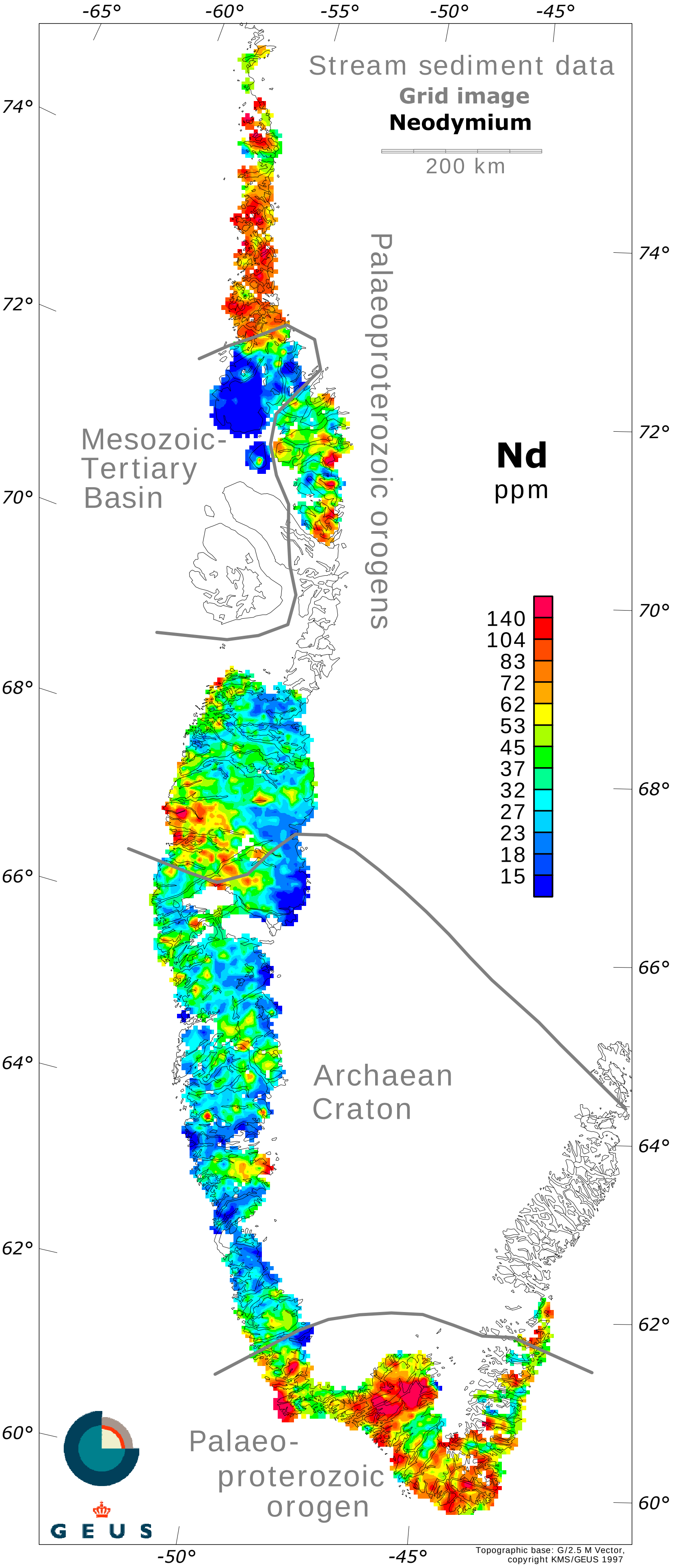
Nb ppm	Samples	Cells
Number	5698	5443
Maximum	902	602.0
Minimum	0	-19.2
Mean	23.15	14.83
Std. dev.	50.35	30.58
10th perc.	4	3.9
20th perc.	5	4.8
30th perc.	6	5.5
40th perc.	7	6.3
50th perc.	10	7.3
60th perc.	14	8.7
70th perc.	20	11.3
80th perc.	27	17.7
90th perc.	44	28.1
95th perc.	69	43.1
98th perc.	148	73.2
99th perc.	264	127.3

Upper crustal mean: 25

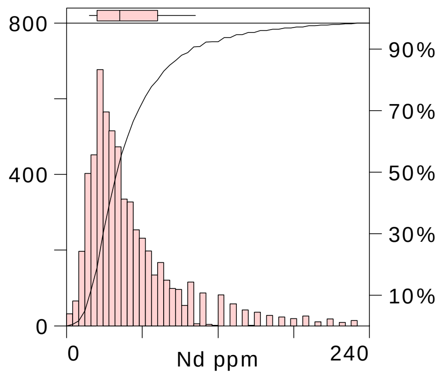
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

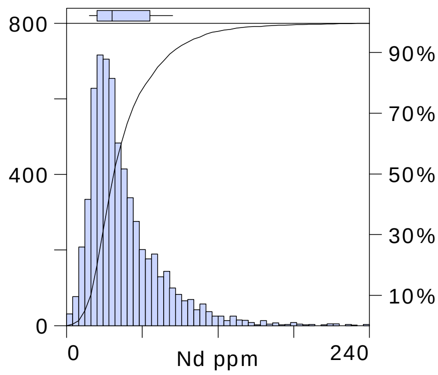
West and South Greenland



Sample values



Grid cell values



Statistics

Nd ppm	Samples	Cells
Number	6071	6374
Maximum	1000	386.4
Minimum	0	0.0
Mean	54.42	46.14
Std. dev.	54.21	33.05
10th perc.	19	19
20th perc.	24	24
30th perc.	28	28
40th perc.	34	32
50th perc.	40	37
60th perc.	46	43
70th perc.	57	51
80th perc.	71	63
90th perc.	100	83
95th perc.	140	104
98th perc.	210	134
99th perc.	290	166

Upper crustal mean: 26

(Taylor & McLennan 1985)

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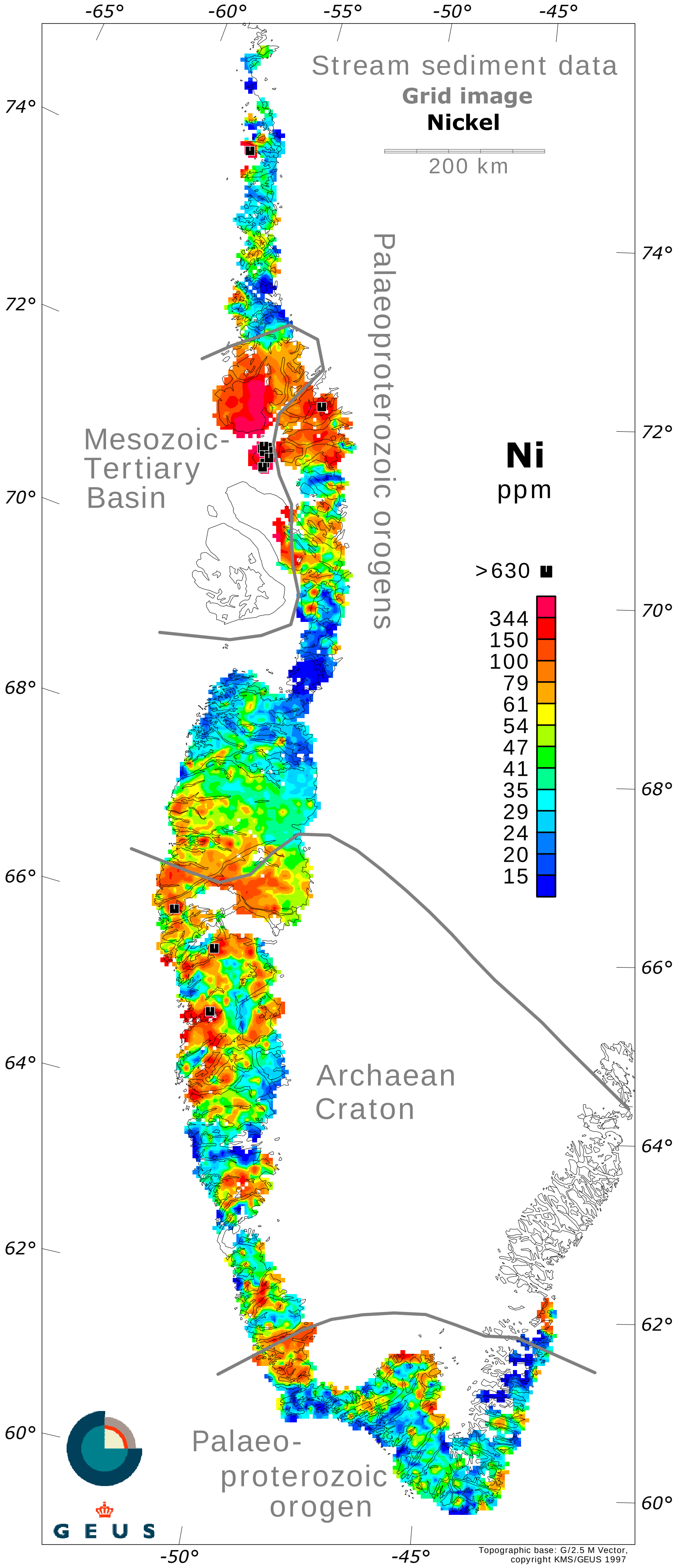
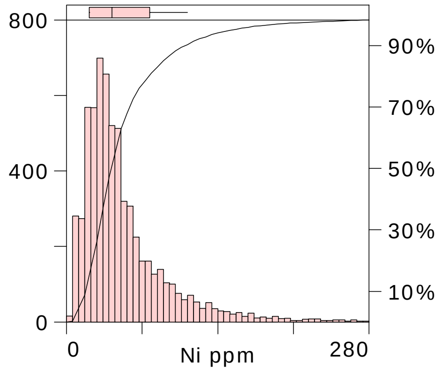


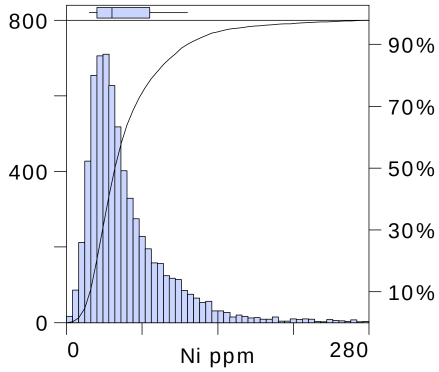
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

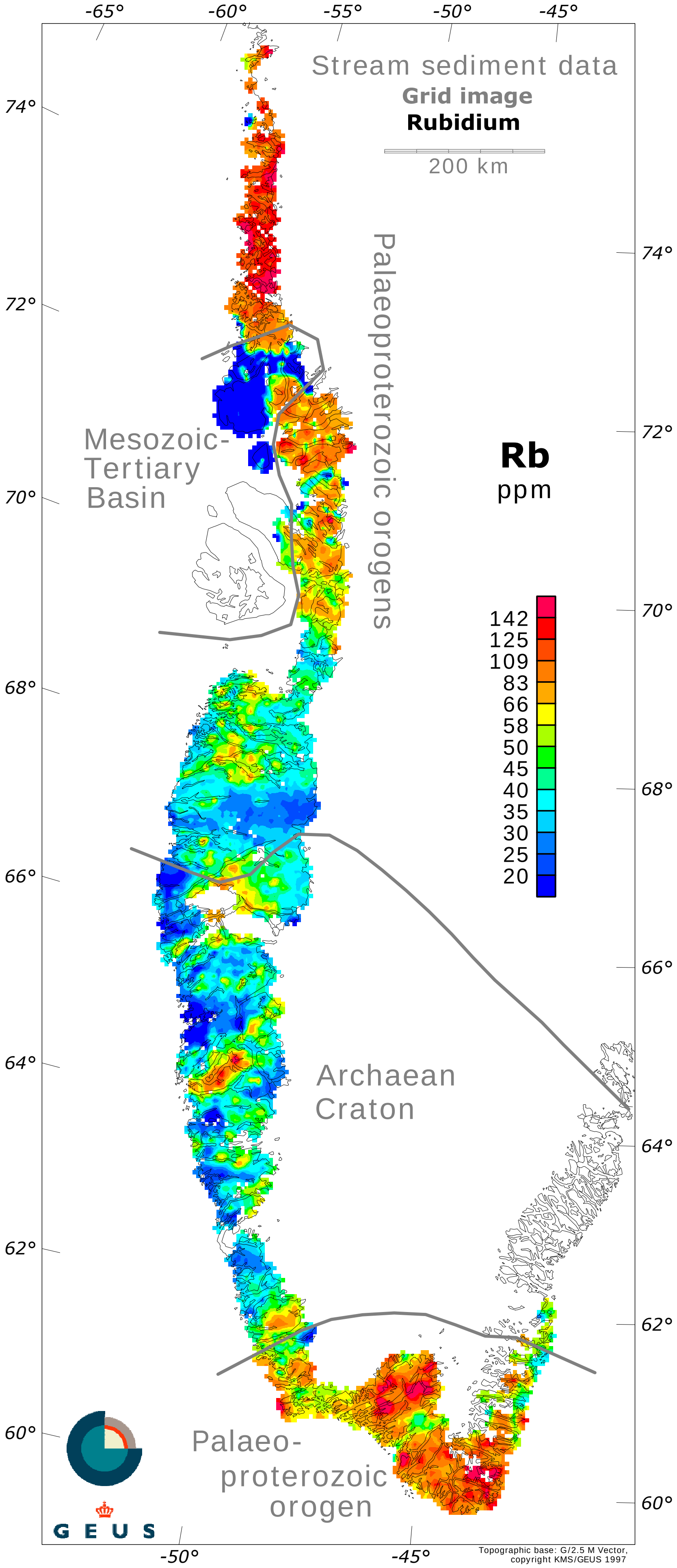


Statistics

Ni ppm	Samples	Cells
Number	6505	6824
Maximum	1504	1019.1
Minimum	0	-8.0
Mean	59.26	64.21
Std. dev.	71.73	74.07
10th perc.	18	22
20th perc.	24	28
30th perc.	29	33
40th perc.	35	38
50th perc.	41	45
60th perc.	48	52
70th perc.	58	63
80th perc.	76	80
90th perc.	110	112
95th perc.	152	151
98th perc.	249	303
99th perc.	400	471

Upper crustal mean: 20

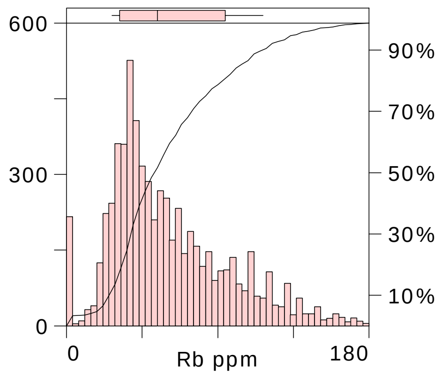
(Taylor & McLennan 1985)



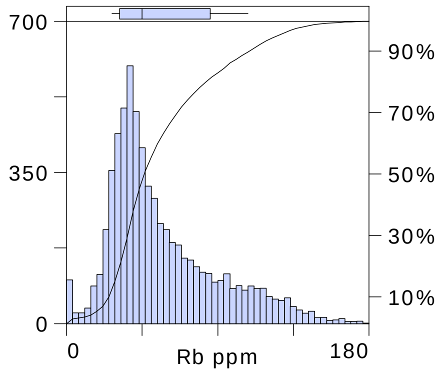
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values

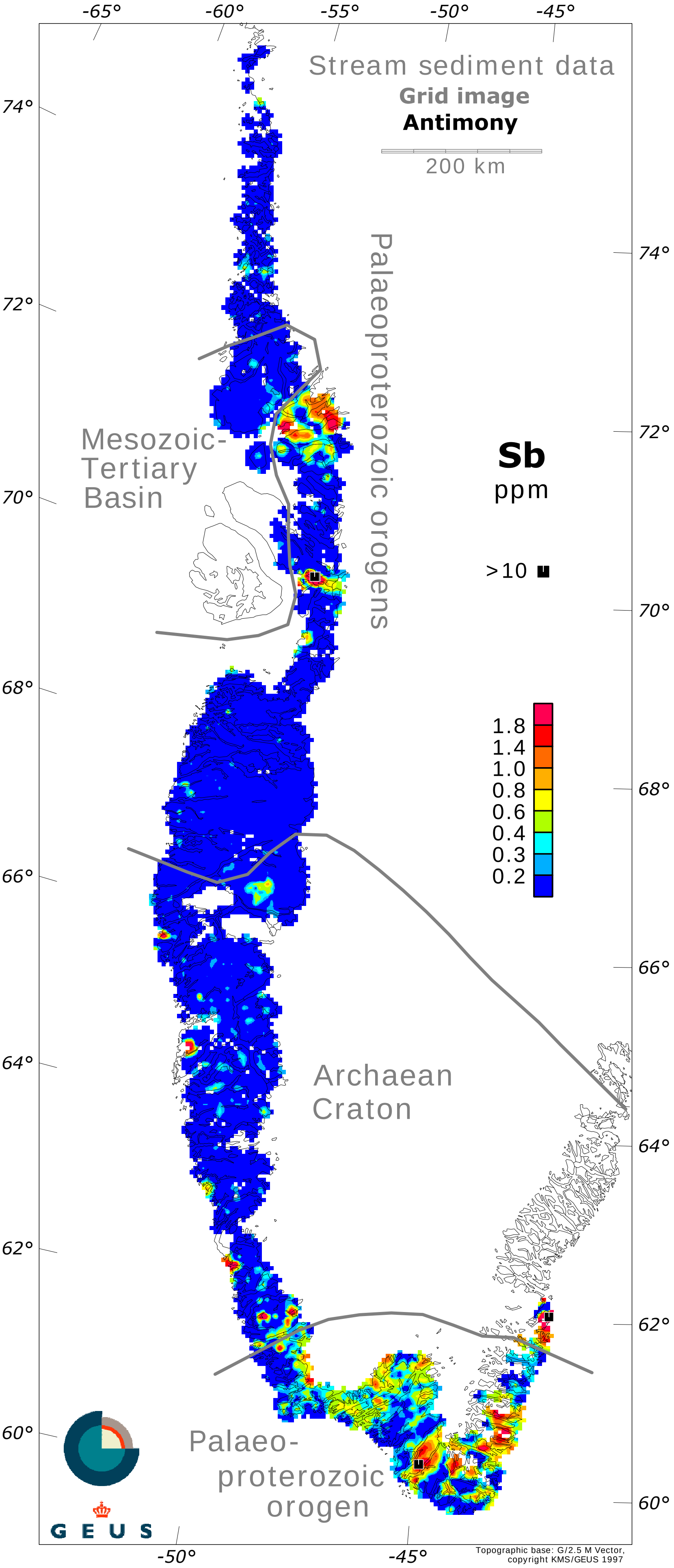


Statistics

Rb ppm	Samples	Cells
Number	6515	6836
Maximum	329	292.7
Minimum	0	-6.9
Mean	62.55	56.73
Std. dev.	39.46	33.93
10th perc.	26	25
20th perc.	33	32
30th perc.	38	36
40th perc.	44	41
50th perc.	52	46
60th perc.	62	54
70th perc.	74	66
80th perc.	93	83
90th perc.	116	109
95th perc.	136	125
98th perc.	164	142
99th perc.	184	154

Upper crustal mean: 112

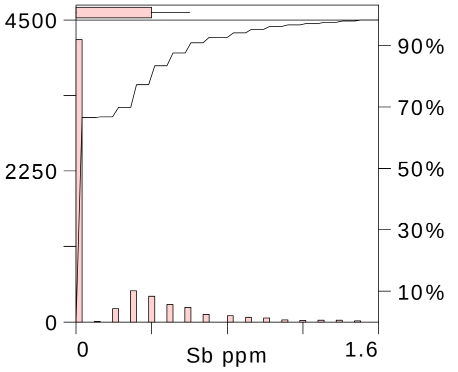
(Taylor & McLennan 1985)



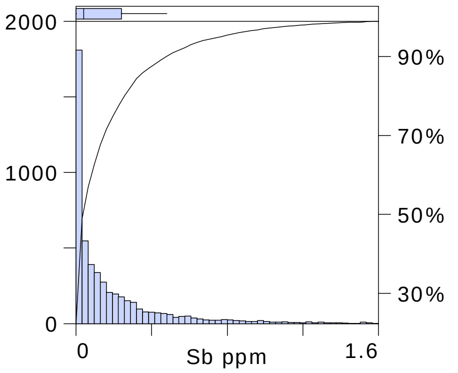
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



Statistics

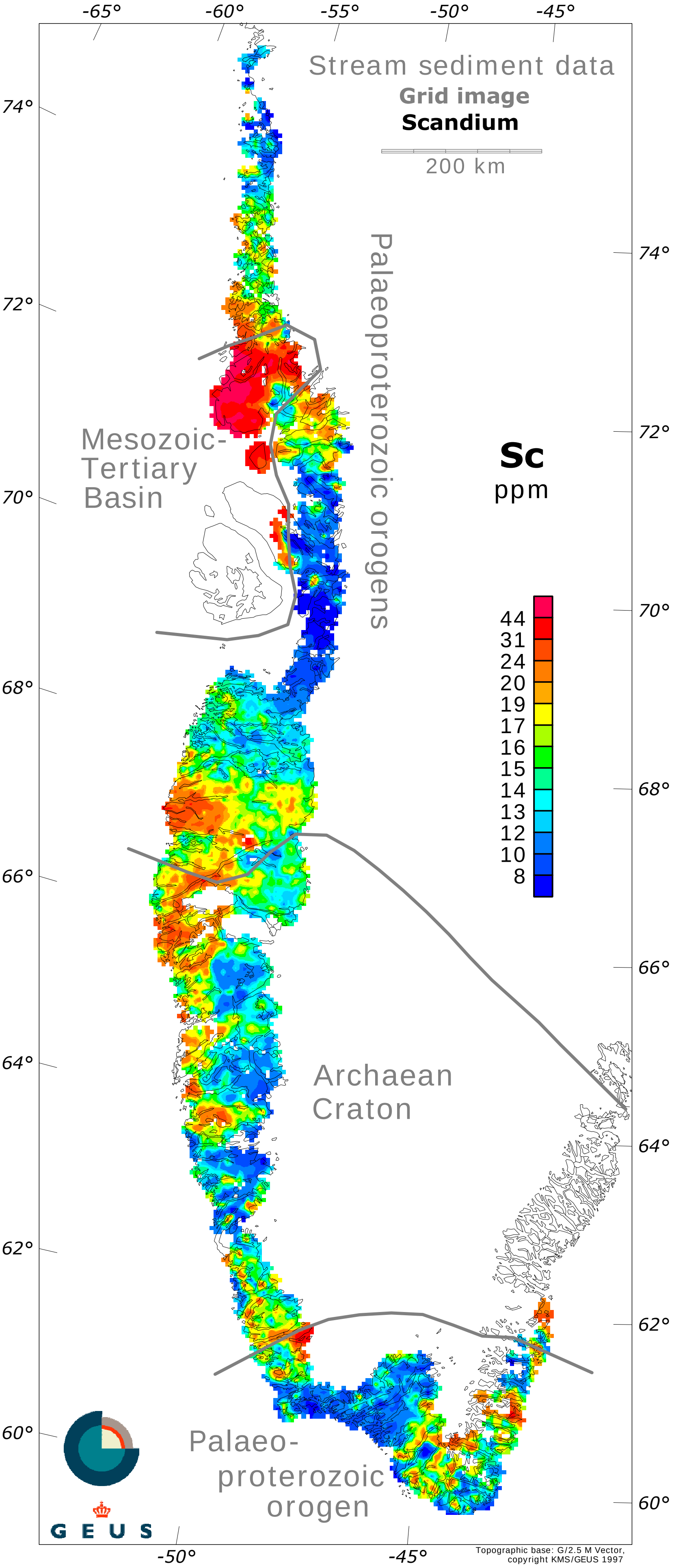
Sb ppm	Samples	Cells
Number	6326	6815
Maximum	36.40	12.1
Minimum	0	-0.4
Mean	0.22	0.17
Std. dev.	0.74	0.44
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0
50th perc.	0	0
60th perc.	0	0.1
70th perc.	0.3	0.1
80th perc.	0.4	0.3
90th perc.	0.6	0.5
95th perc.	0.9	0.8
98th perc.	1.5	1.2
99th perc.	1.9	1.6

Upper crustal mean: 0.2

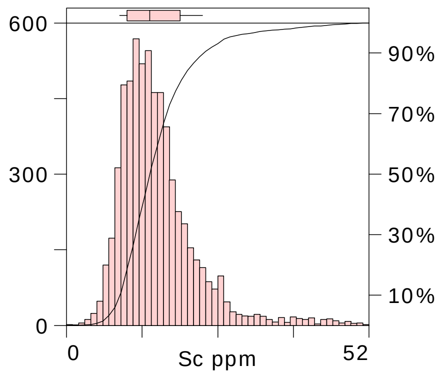
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

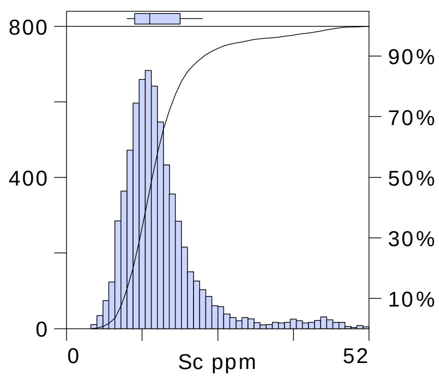
West and South Greenland



Sample values



Grid cell values



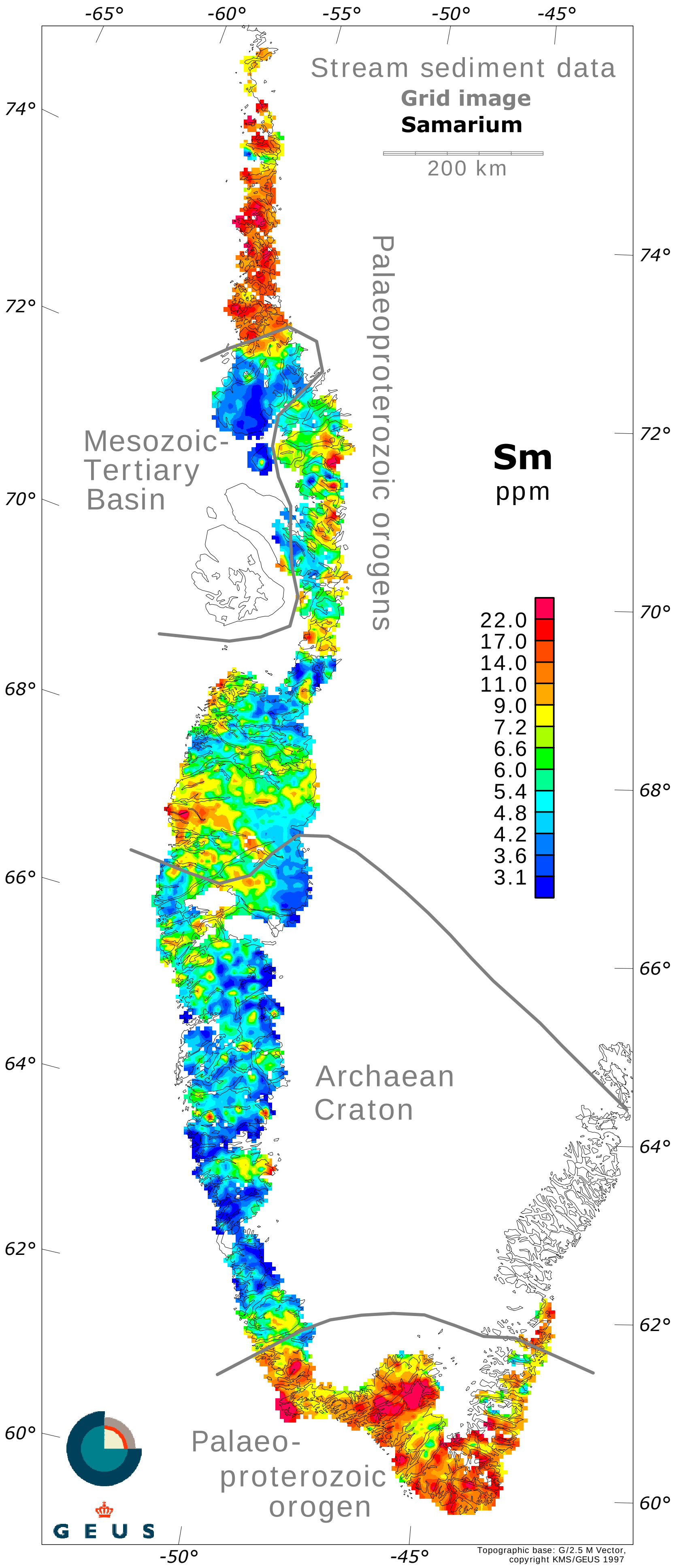
Statistics

Sc ppm	Samples	Cells
Number	6326	6815
Maximum	61	59.0
Minimum	0	4.3
Mean	15.63	16.33
Std. dev.	6.84	7.28
10th perc.	9	9.8
20th perc.	11	11.4
30th perc.	12	12.6
40th perc.	13	13.7
50th perc.	14	14.7
60th perc.	16	15.9
70th perc.	17	17.3
80th perc.	19	19.3
90th perc.	23	23.7
95th perc.	28	31.0
98th perc.	39	42.8
99th perc.	44	45.6

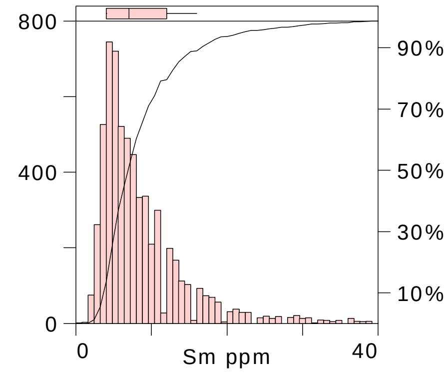
Upper crustal mean: 11
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

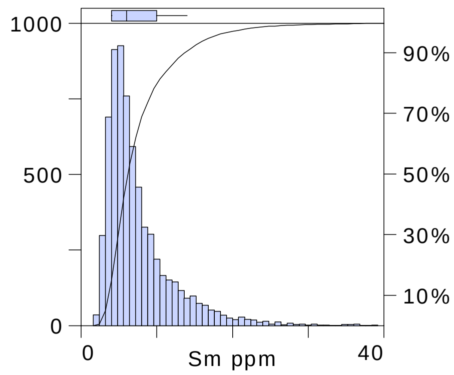
West and South Greenland



Sample values



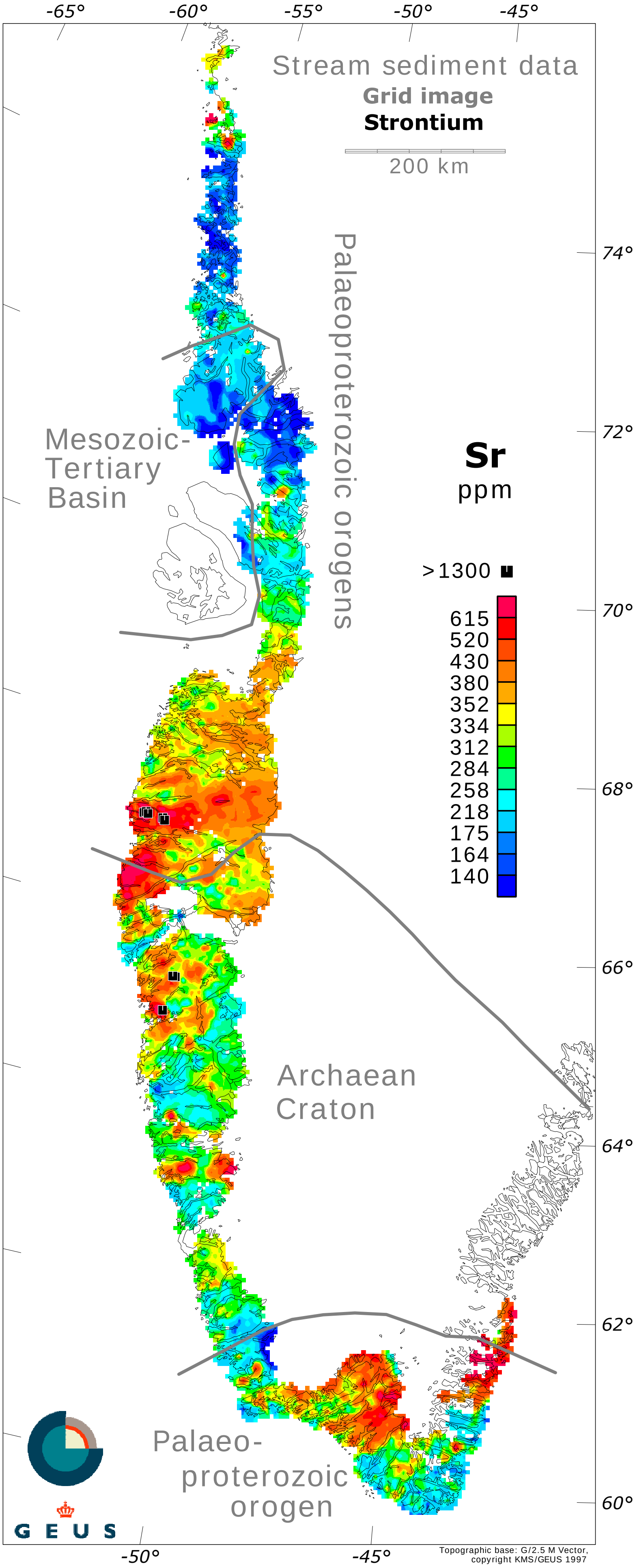
Grid cell values



Statistics

Sm ppm	Samples	Cells
Number	6280	6788
Maximum	171	64.1
Minimum	0.4	1.9
Mean	9.15	7.71
Std. dev.	8.46	5.24
10th perc.	3.6	3.7
20th perc.	4.4	4.3
30th perc.	5.1	4.9
40th perc.	5.9	5.5
50th perc.	6.8	6.1
60th perc.	7.9	7.0
70th perc.	9.5	8.2
80th perc.	12.0	10.0
90th perc.	16.0	13.7
95th perc.	22.0	17.0
98th perc.	33.0	22.2
99th perc.	45.2	27.2

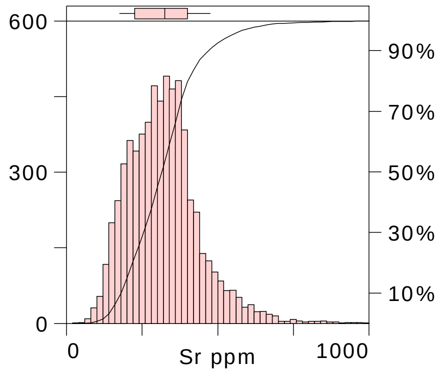
Upper crustal mean: 4.5
(Taylor & McLennan 1985)



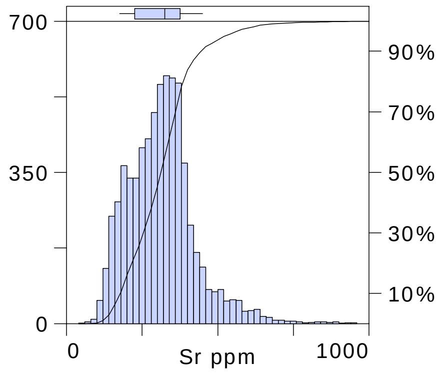
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



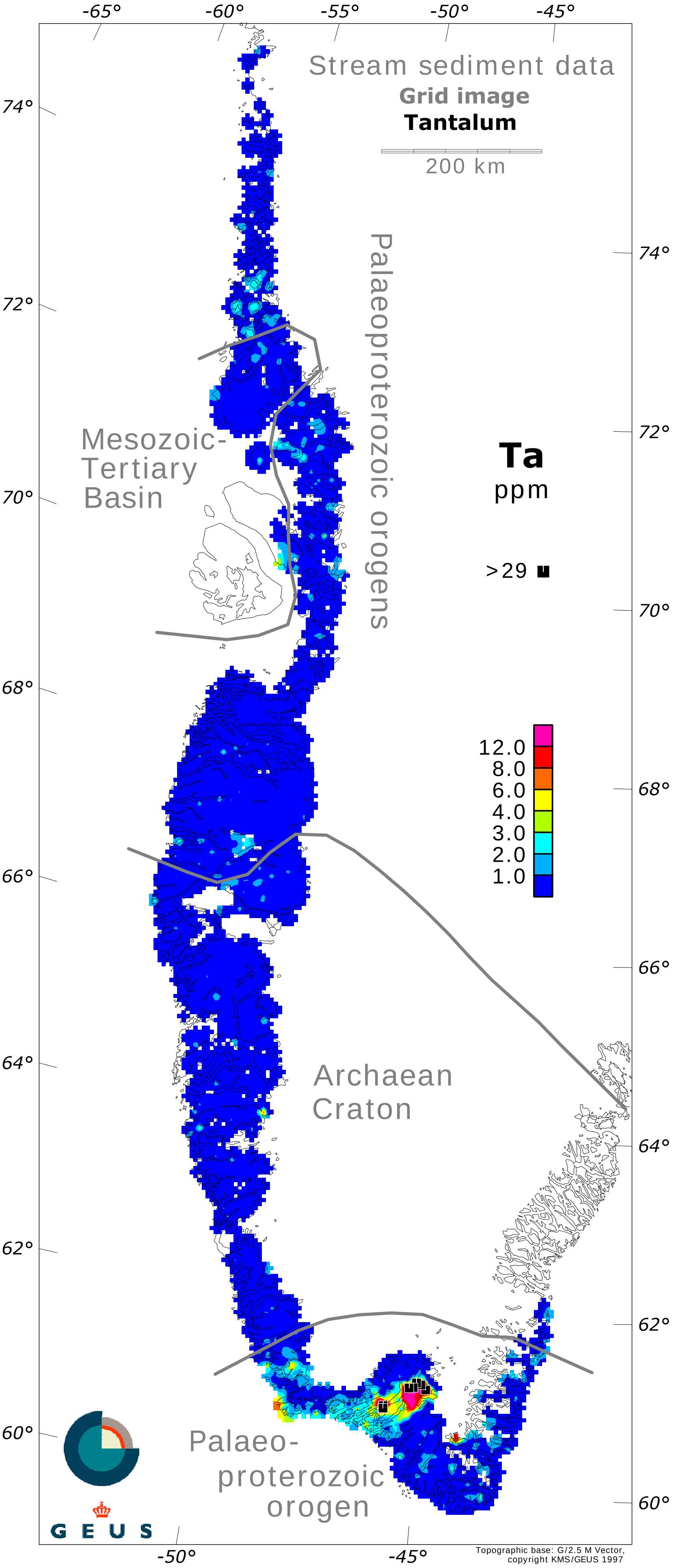
Statistics

Sr ppm	Samples	Cells
Number	6505	6824
Maximum	2091	1725.1
Minimum	35	51.0
Mean	323.69	316.02
Std. dev.	132.17	117.90
10th perc.	179	177
20th perc.	218	215
30th perc.	253	254
40th perc.	286	286
50th perc.	314	312
60th perc.	342	336
70th perc.	369	359
80th perc.	401	385
90th perc.	468	443
95th perc.	543	523
98th perc.	631	615
99th perc.	712	673

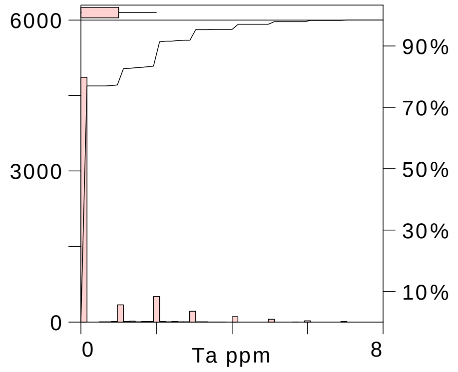
Upper crustal mean: 350
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

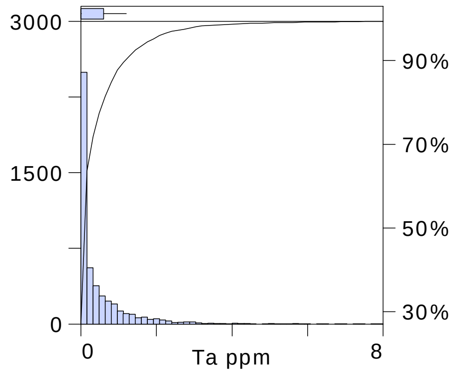
West and South Greenland



Sample values



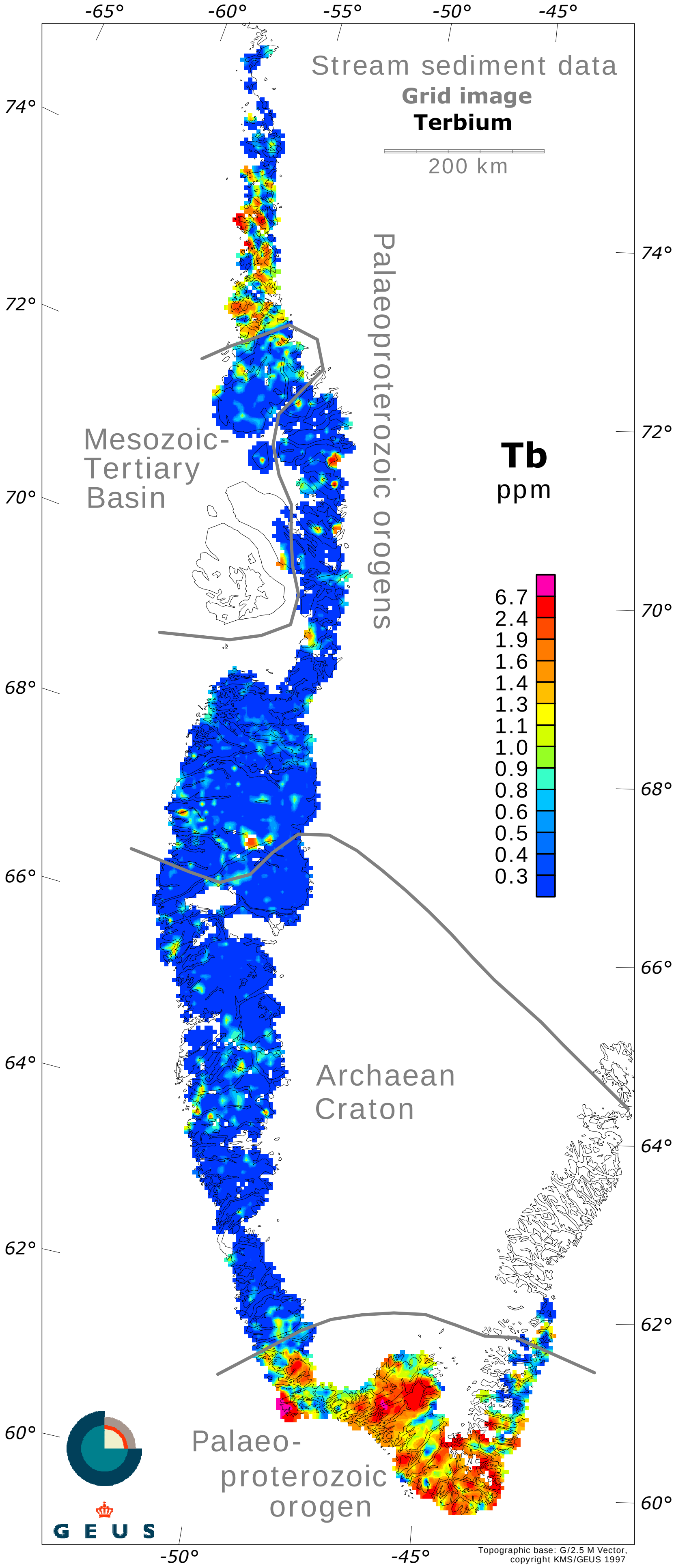
Grid cell values



Statistics

Ta ppm	Samples	Cells
Number	6326	6815
Maximum	49	27.9
Minimum	0	-2.8
Mean	0.75	0.43
Std. dev.	2.44	1.39
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0
50th perc.	0	0
60th perc.	0	0.1
70th perc.	0	0.3
80th perc.	1	0.6
90th perc.	2	1.2
95th perc.	3	1.9
98th perc.	6	3.0
99th perc.	12	5.0

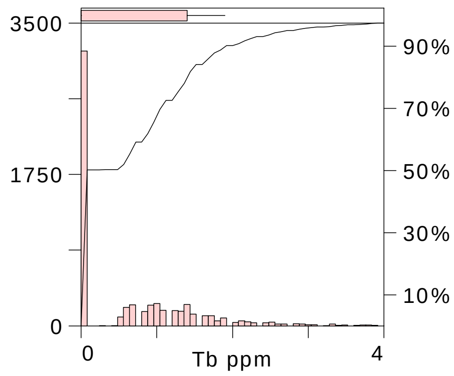
Upper crustal mean: 2.2
(Taylor & McLennan 1985)



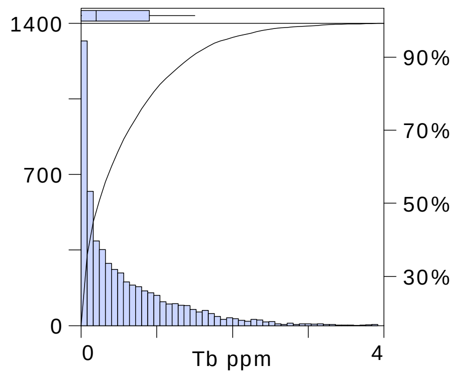
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



Statistics

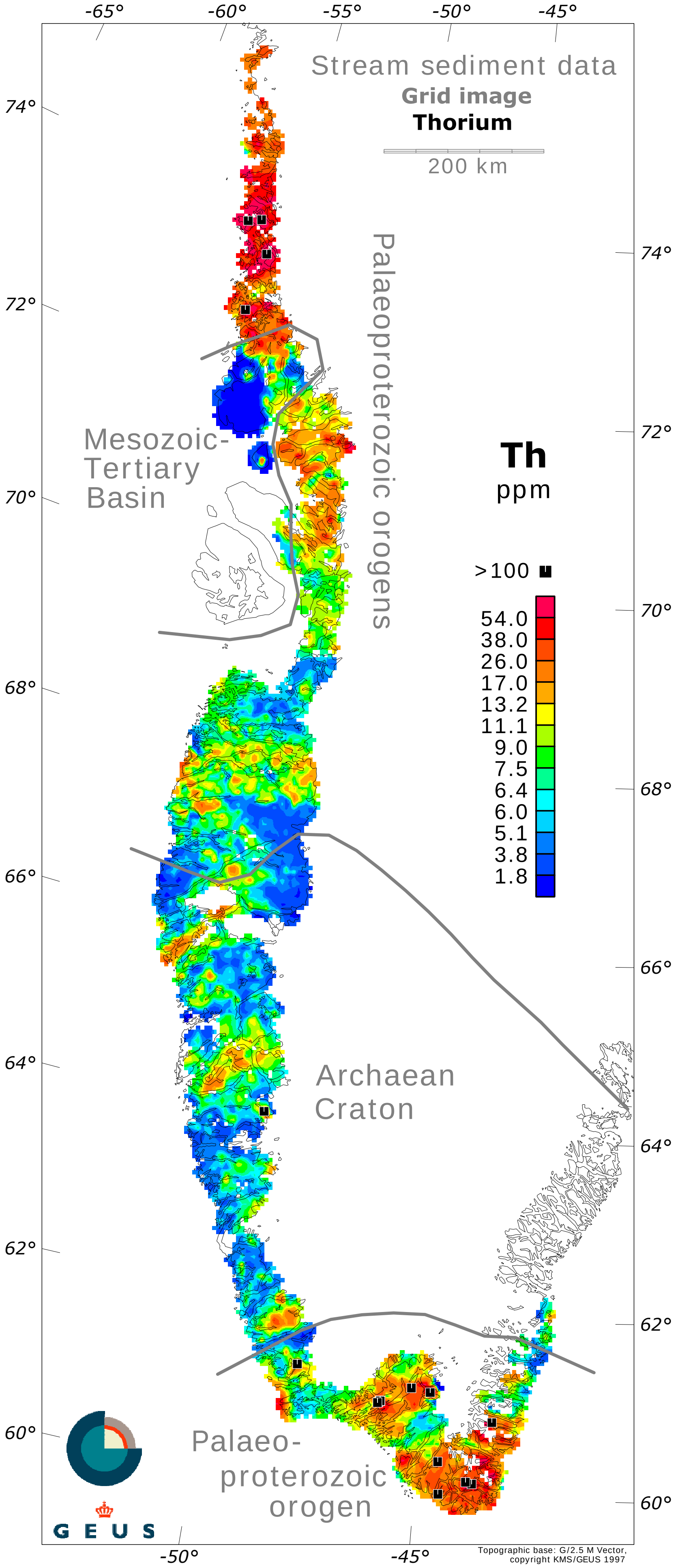
Tb ppm	Samples	Cells
Number	6326	6815
Maximum	22	11.2
Minimum	0	-0.4
Mean	0.81	0.53
Std. dev.	1.38	0.82
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0.1
50th perc.	0	0.2
60th perc.	0.8	0.4
70th perc.	1.1	0.6
80th perc.	1.4	0.9
90th perc.	1.9	1.5
95th perc.	2.7	1.9
98th perc.	4.5	2.6
99th perc.	6.7	3.4

Upper crustal mean: 0.64

(Taylor & McLennan 1985)

Geochemical atlas of Greenland

West and South Greenland



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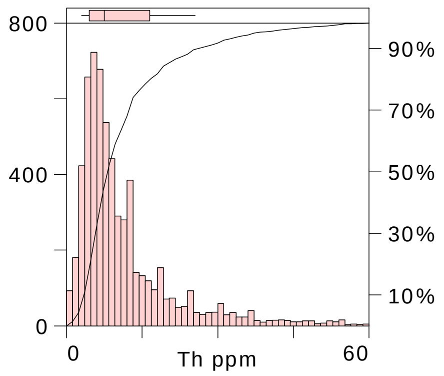
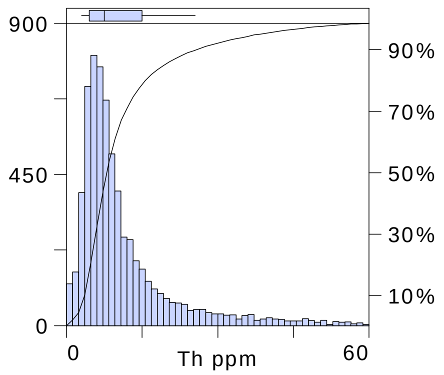


Grid cell values



Statistics

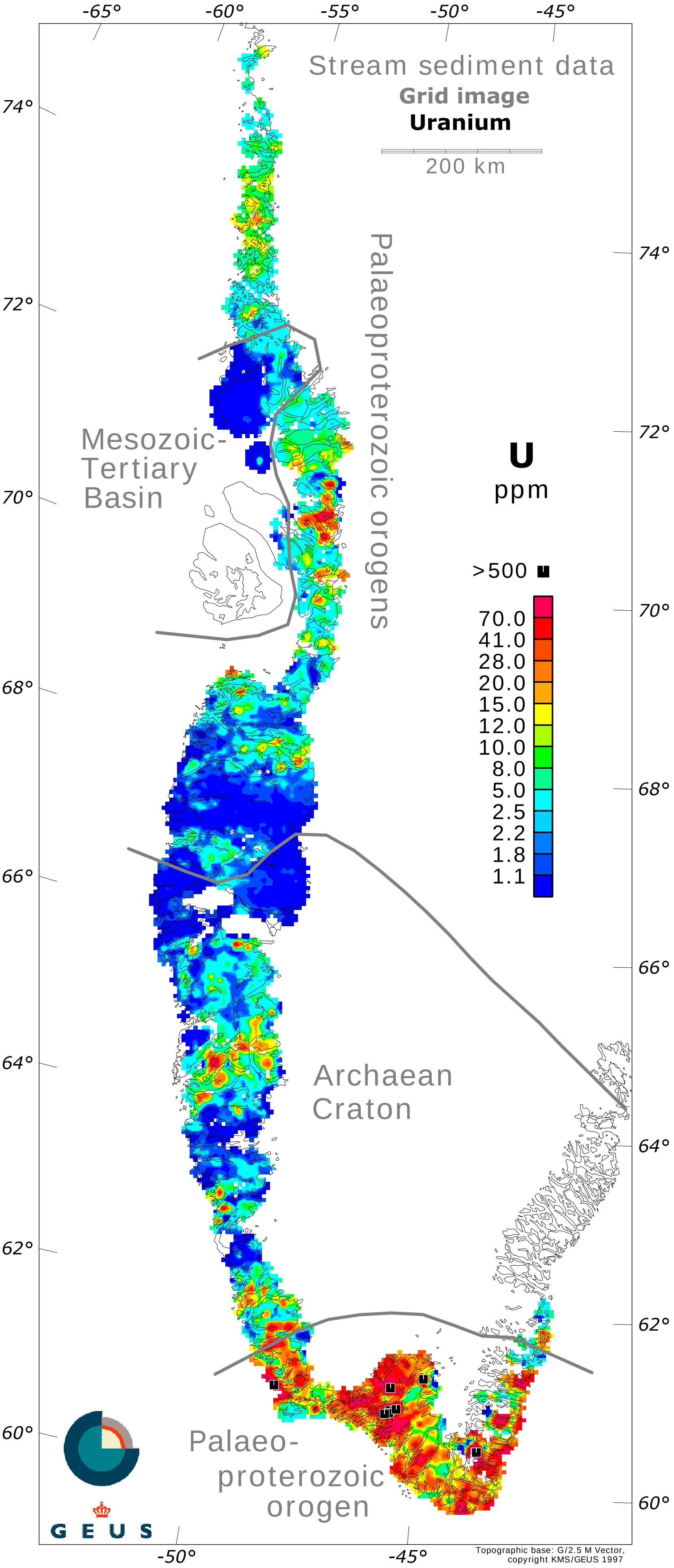
Th ppm	Samples	Cells
Number	6327	6815
Maximum	270	162.5
Minimum	0	-10.1
Mean	12.49	12.10
Std. dev.	14.43	12.87
10th perc.	3.4	3.6
20th perc.	4.6	4.7
30th perc.	5.7	5.8
40th perc.	6.7	6.7
50th perc.	8.0	8.0
60th perc.	9.7	9.4
70th perc.	12.0	11.7
80th perc.	16.0	15.6
90th perc.	26.0	25.6
95th perc.	37.0	38.0
98th perc.	56.0	53.8
99th perc.	71.0	65.0

Upper crustal mean: 10.7

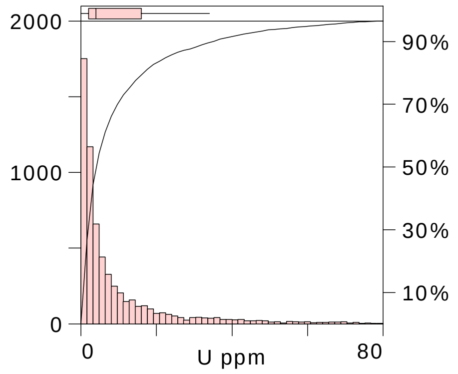
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

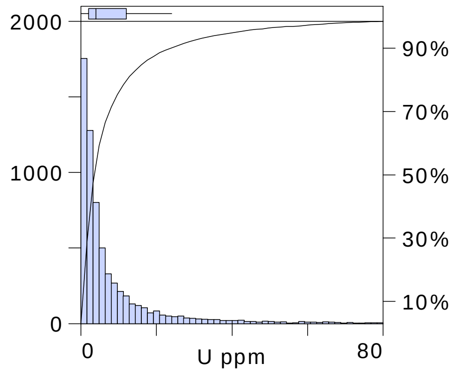
West and South Greenland



Sample values



Grid cell values



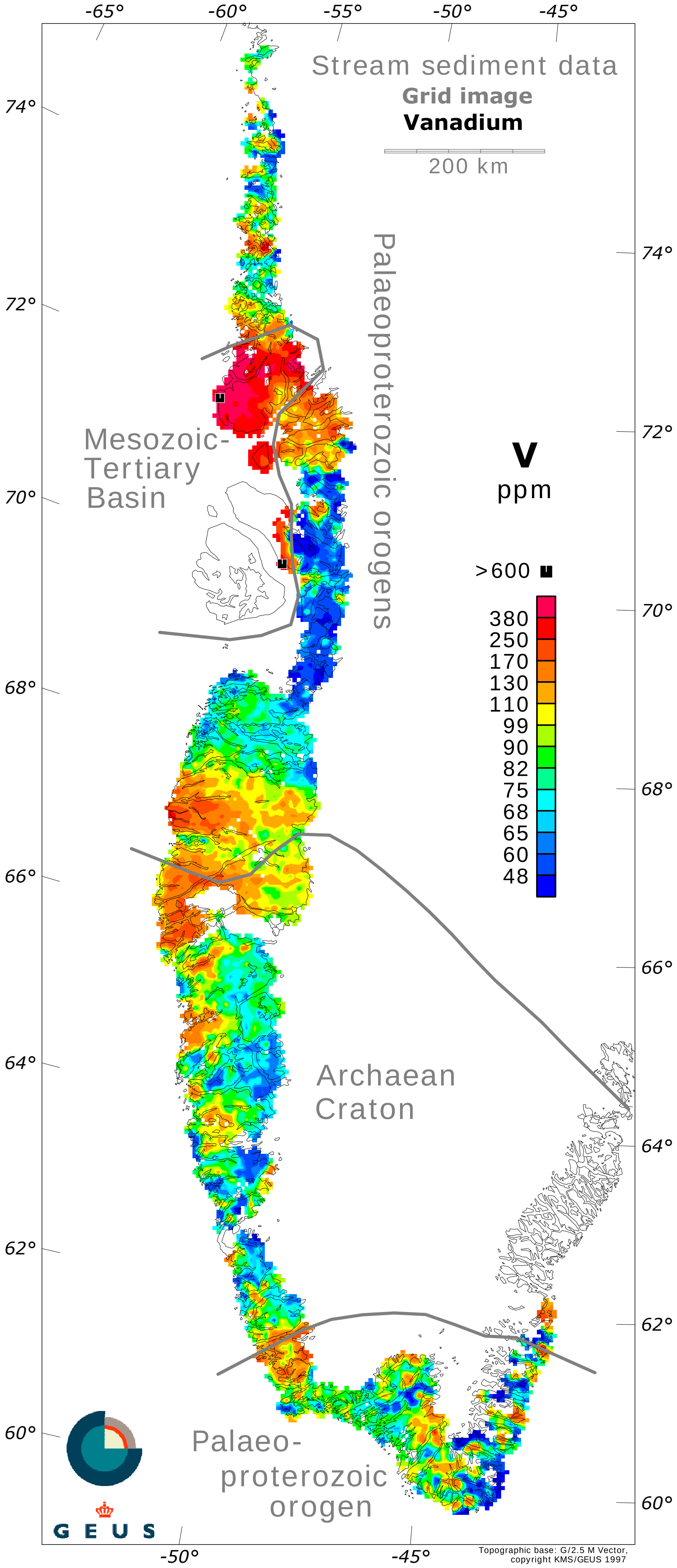
Statistics

U ppm	Samples	Cells
Number	6573	6822
Maximum	1400	669.0
Minimum	0	-13.6
Mean	15.12	10.06
Std. dev.	43.55	23.21
10th perc.	0.0	0.5
20th perc.	1.2	1.1
30th perc.	1.8	1.7
40th perc.	2.7	2.4
50th perc.	4.0	3.5
60th perc.	6.0	4.9
70th perc.	9.7	7.5
80th perc.	16.4	12.1
90th perc.	34.9	23.8
95th perc.	60.7	40.7
98th perc.	112.6	69.5
99th perc.	180.3	99.7

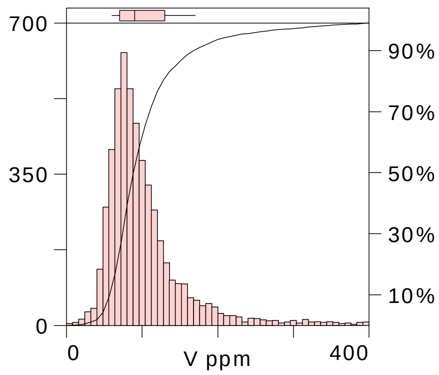
Upper crustal mean: 2.8
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

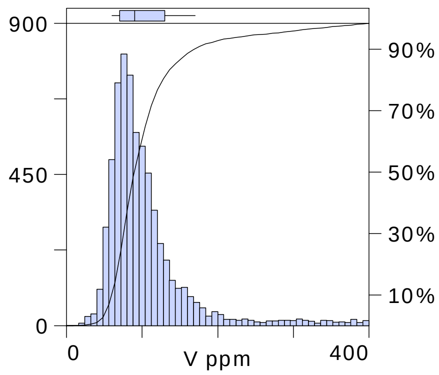
West and South Greenland



Sample values



Grid cell values



Statistics

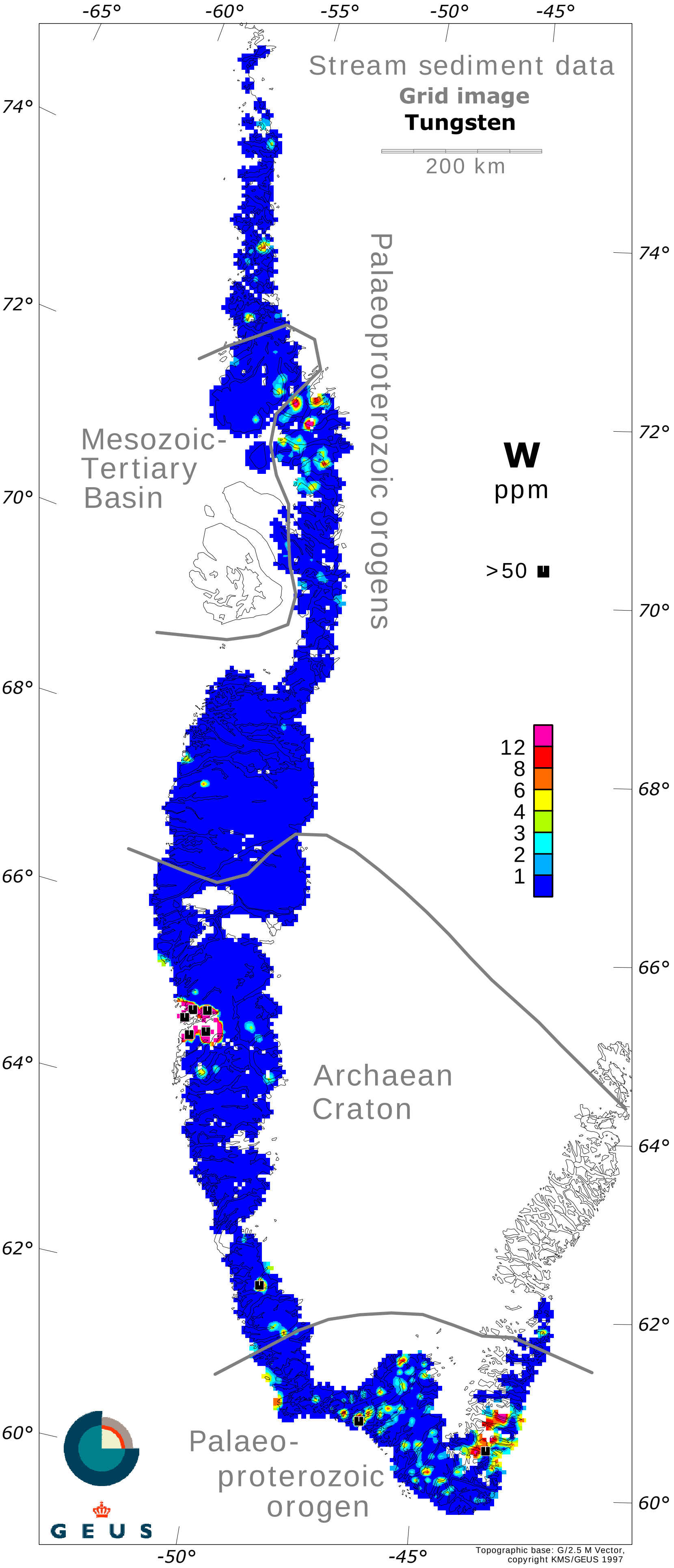
V ppm	Samples	Cells
Number	5319	6708
Maximum	1030	534.8
Minimum	0	3.9
Mean	105.46	109.41
Std. dev.	65.91	70.54
10th perc.	56	59.7
20th perc.	66	68.5
30th perc.	73	75.3
40th perc.	80	81.8
50th perc.	88	89.4
60th perc.	97	99.1
70th perc.	109	109.8
80th perc.	127	127.2
90th perc.	168	168.2
95th perc.	223	264.6
98th perc.	334	381.0
99th perc.	400	428.3

Upper crustal mean: 60

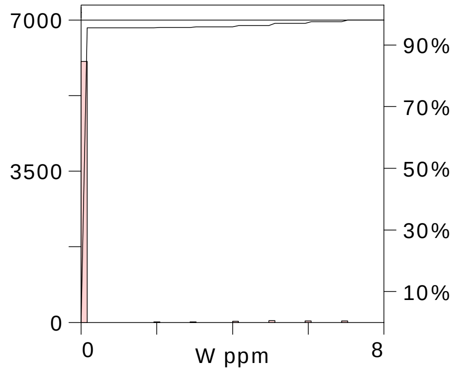
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

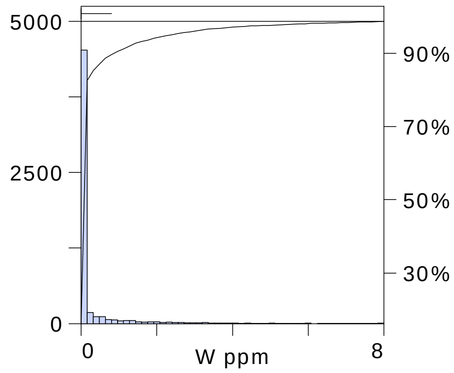
West and South Greenland



Sample values



Grid cell values



Statistics

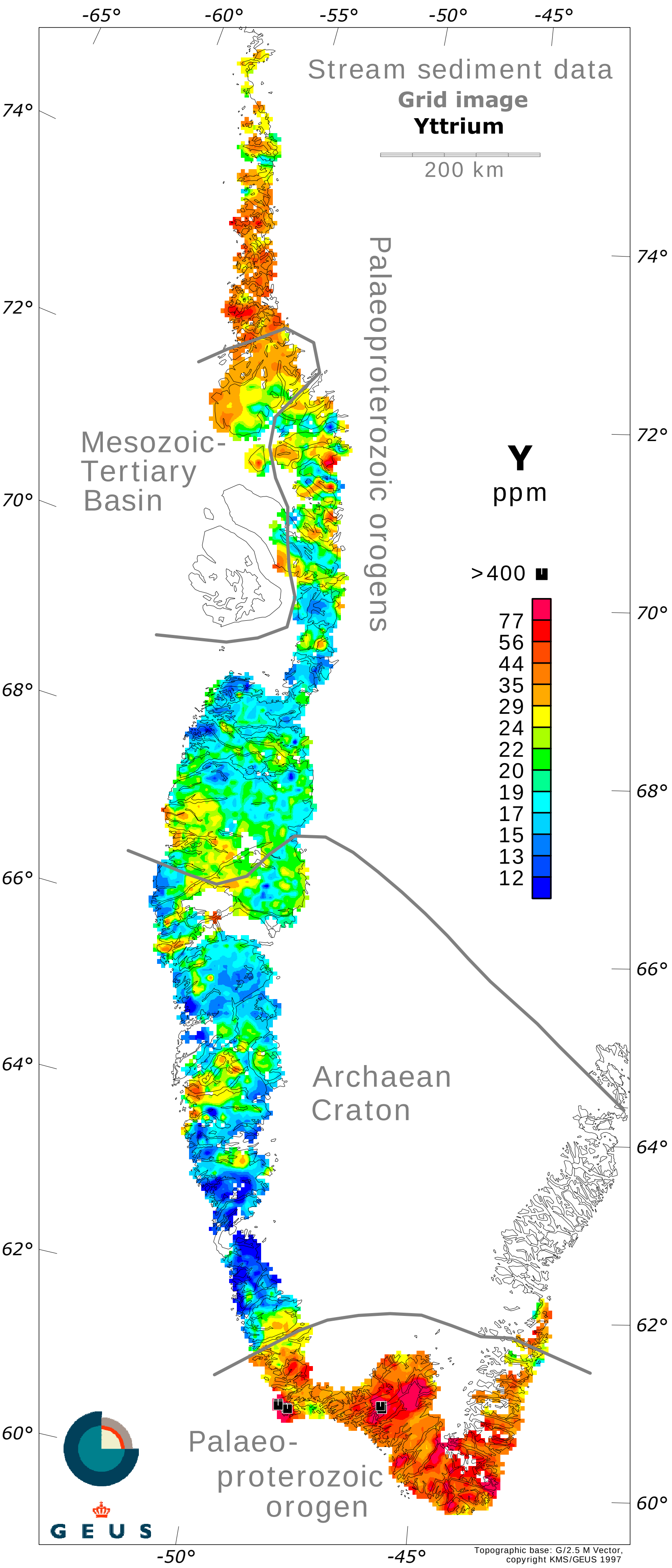
W ppm	Samples	Cells
Number	6326	6815
Maximum	220	145.0
Minimum	0	-4.2
Mean	0.51	0.62
Std. dev.	4.97	4.57
10th perc.	0	0
20th perc.	0	0
30th perc.	0	0
40th perc.	0	0
50th perc.	0	0
60th perc.	0	0
70th perc.	0	0
80th perc.	0	0.1
90th perc.	0	0.9
95th perc.	0	2.4
98th perc.	7	5.8
99th perc.	12	9.7

Upper crustal mean: 2

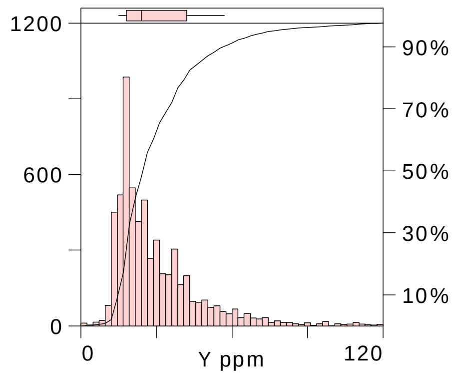
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

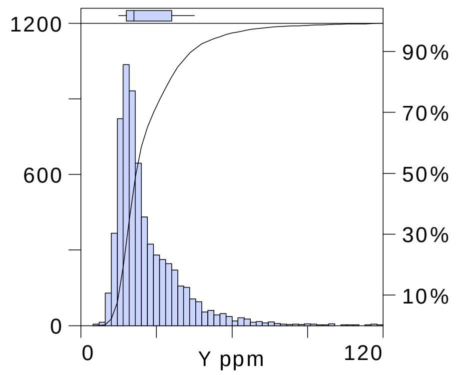
West and South Greenland



Sample values



Grid cell values



Statistics

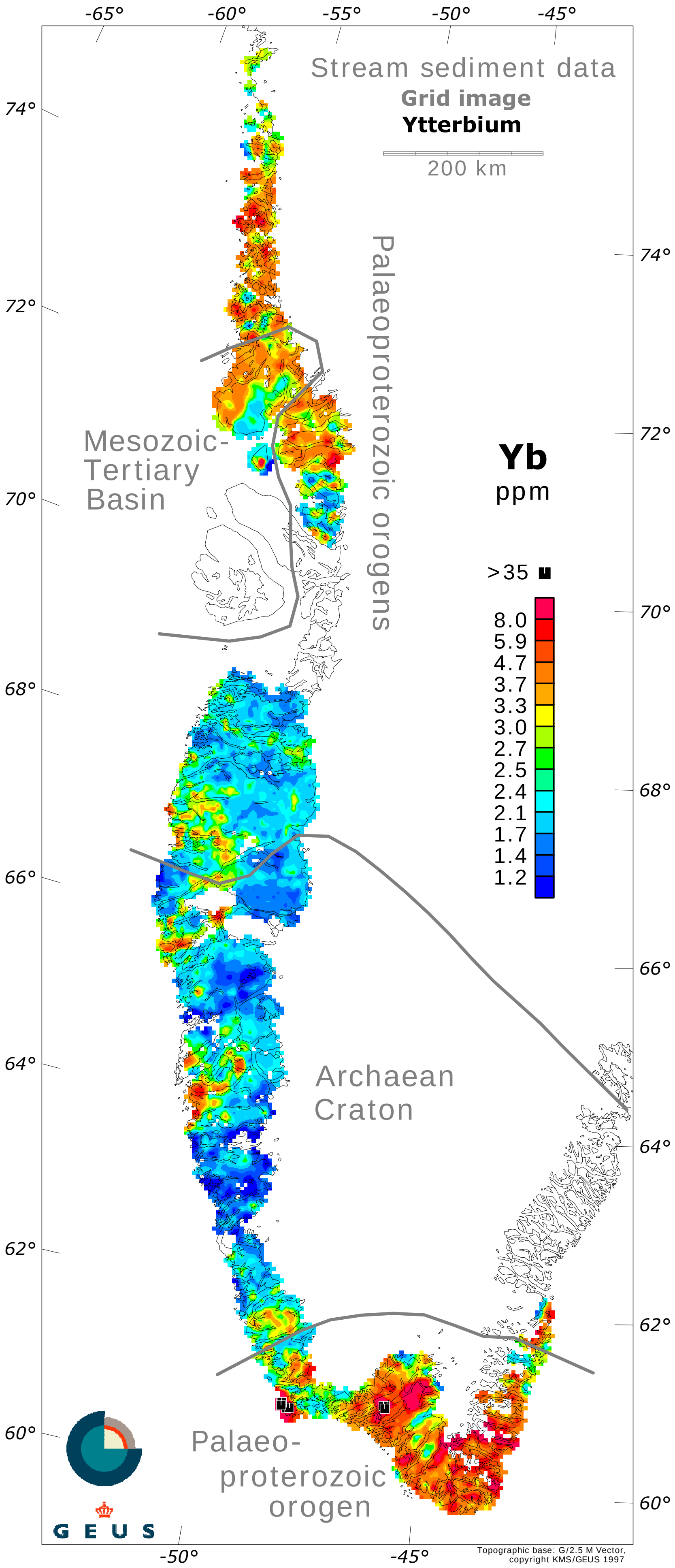
Y ppm	Samples	Cells
Number	6339	6730
Maximum	542	284.0
Minimum	0	5.4
Mean	33.53	27.48
Std. dev.	33.71	19.22
10th perc.	15	14.9
20th perc.	17	16.8
30th perc.	19	18.3
40th perc.	21	20.0
50th perc.	24	21.8
60th perc.	29	24.4
70th perc.	34	28.8
80th perc.	41	34.9
90th perc.	56	43.8
95th perc.	75	55.7
98th perc.	128	76.4
99th perc.	185	107.5

Upper crustal mean: 22

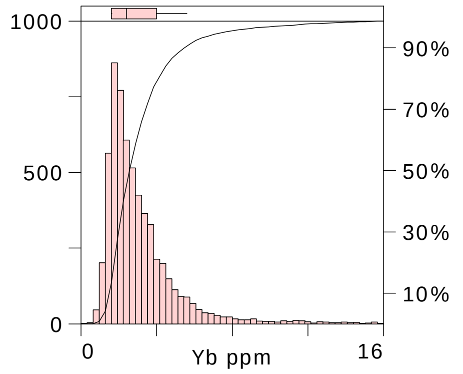
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

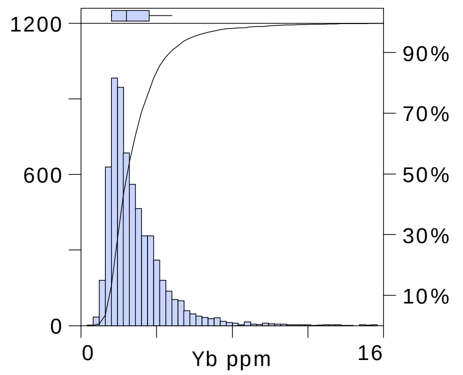
West and South Greenland



Sample values



Grid cell values



Statistics

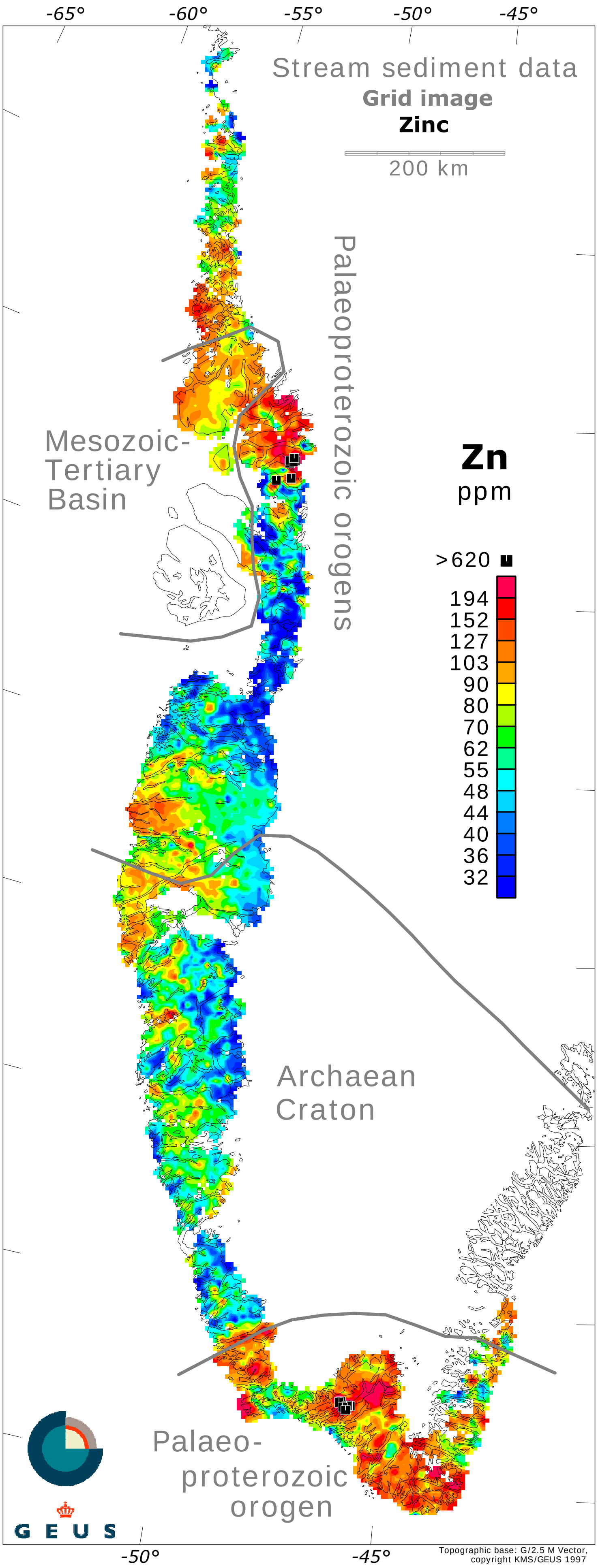
Yb ppm	Samples	Cells
Number	6071	6374
Maximum	60	36.5
Minimum	0	0.4
Mean	3.37	2.95
Std. dev.	3.36	2.07
10th perc.	1.5	1.5
20th perc.	1.7	1.7
30th perc.	2.0	1.9
40th perc.	2.2	2.2
50th perc.	2.5	2.4
60th perc.	2.9	2.8
70th perc.	3.4	3.2
80th perc.	4.1	3.7
90th perc.	5.5	4.7
95th perc.	7.5	5.9
98th perc.	12.7	8.0
99th perc.	18.0	10.8

Upper crustal mean: 2.2

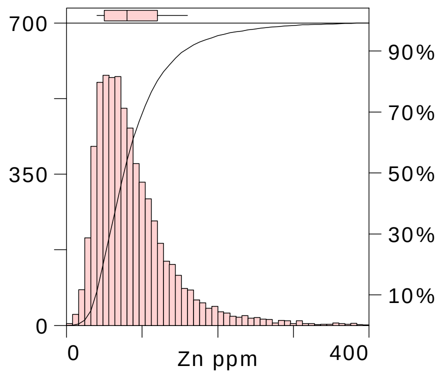
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

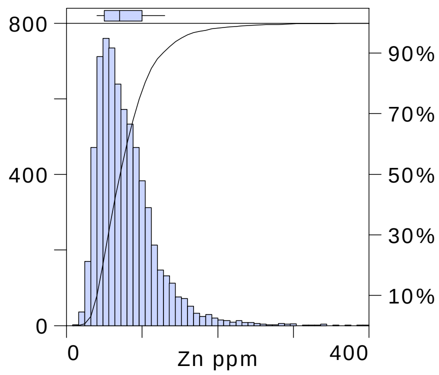
West and South Greenland



Sample values



Grid cell values

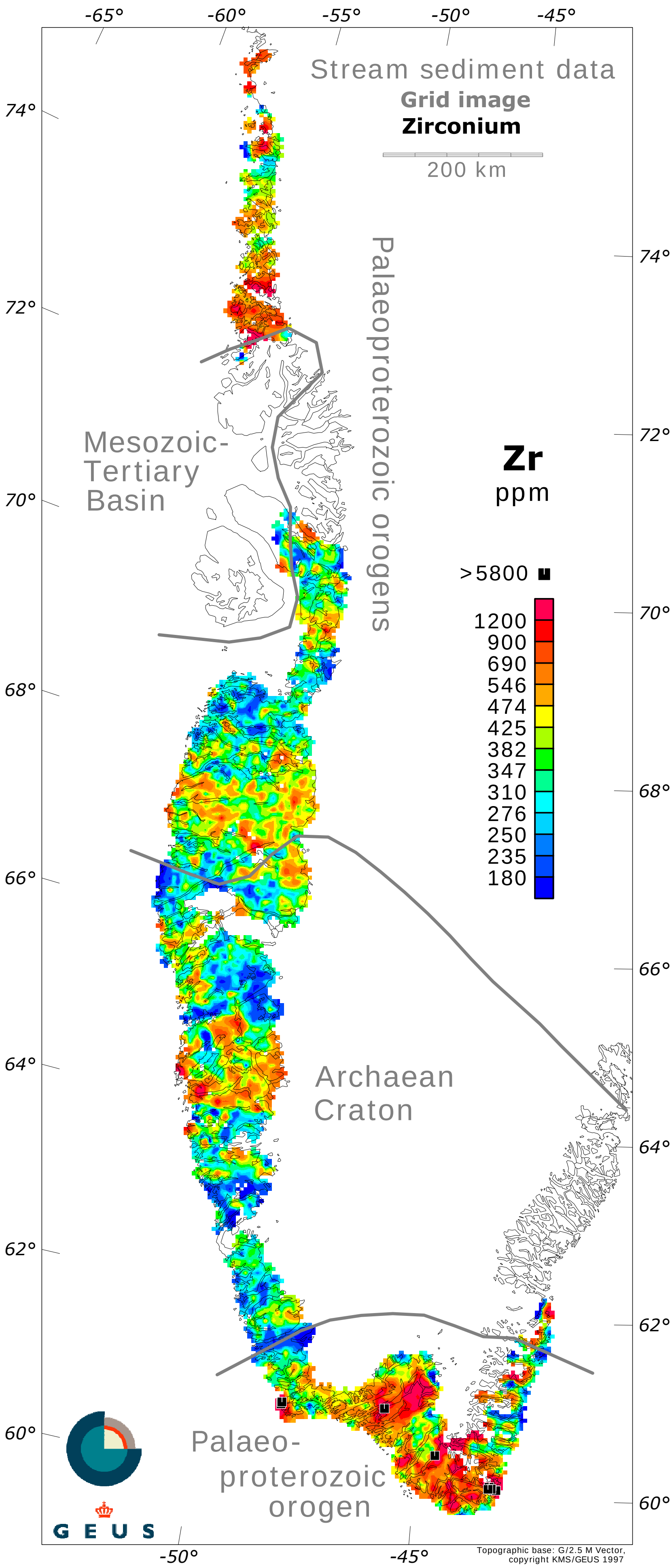


Statistics

Zn ppm	Samples	Cells
Number	6505	6824
Maximum	1786	823.2
Minimum	0	14.6
Mean	92.26	79.76
Std. dev.	80.87	44.87
10th perc.	38	40
20th perc.	48	48
30th perc.	57	55
40th perc.	66	62
50th perc.	75	70
60th perc.	86	80
70th perc.	100	90
80th perc.	119	103
90th perc.	155	127
95th perc.	199	152
98th perc.	276	194
99th perc.	362	233

Upper crustal mean: 71

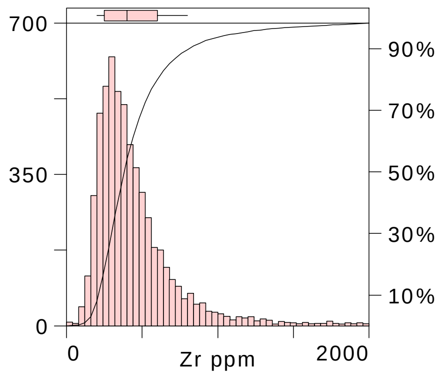
(Taylor & McLennan 1985)



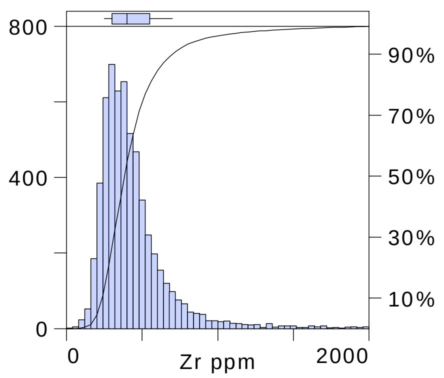
Geochemical atlas of Greenland

West and South Greenland

Sample values



Grid cell values



Statistics

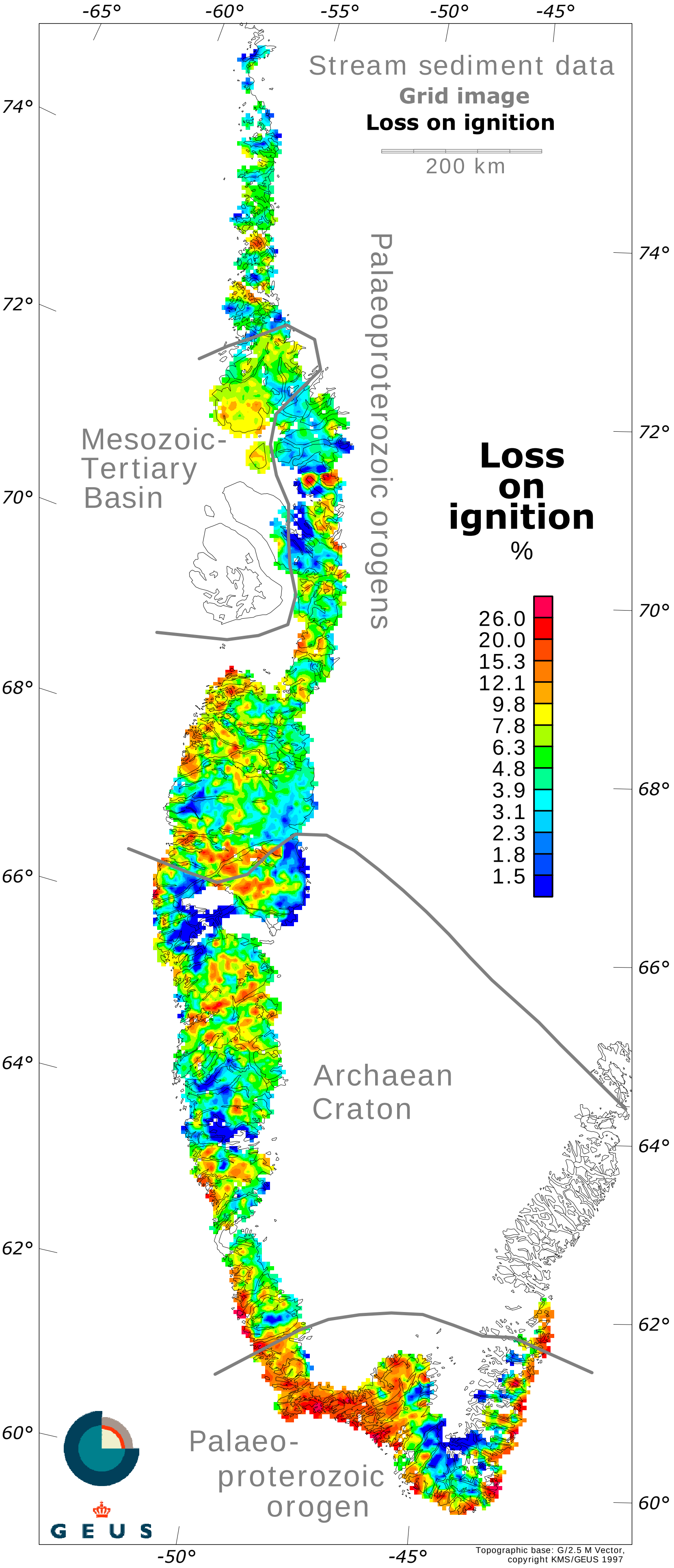
Zr ppm	Samples	Cells
Number	5905	5928
Maximum	9241	6131.0
Minimum	4	1.1
Mean	496.72	456.52
Std. dev.	513.35	339.48
10th perc.	209	235
20th perc.	254	276
30th perc.	296	310
40th perc.	336	346
50th perc.	379	382
60th perc.	432	425
70th perc.	498	474
80th perc.	600	547
90th perc.	811	700
95th perc.	1130	897
98th perc.	1873	1392
99th perc.	2585	1913

Upper crustal mean: 190

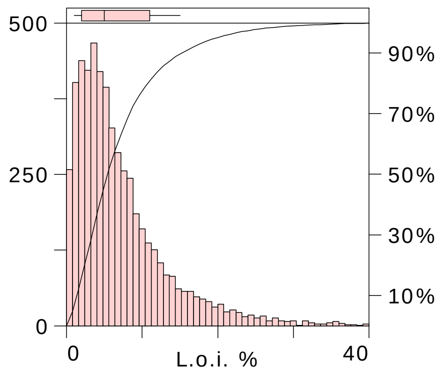
(Taylor & McLennan 1985)

Geochemical atlas of Greenland

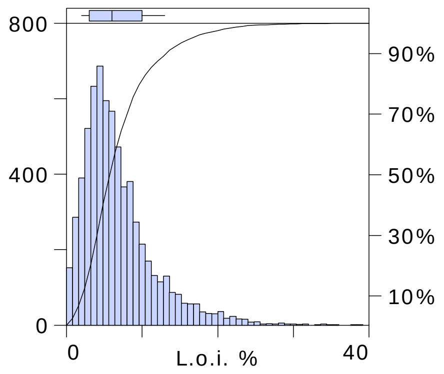
West and South Greenland



Sample values



Grid cell values

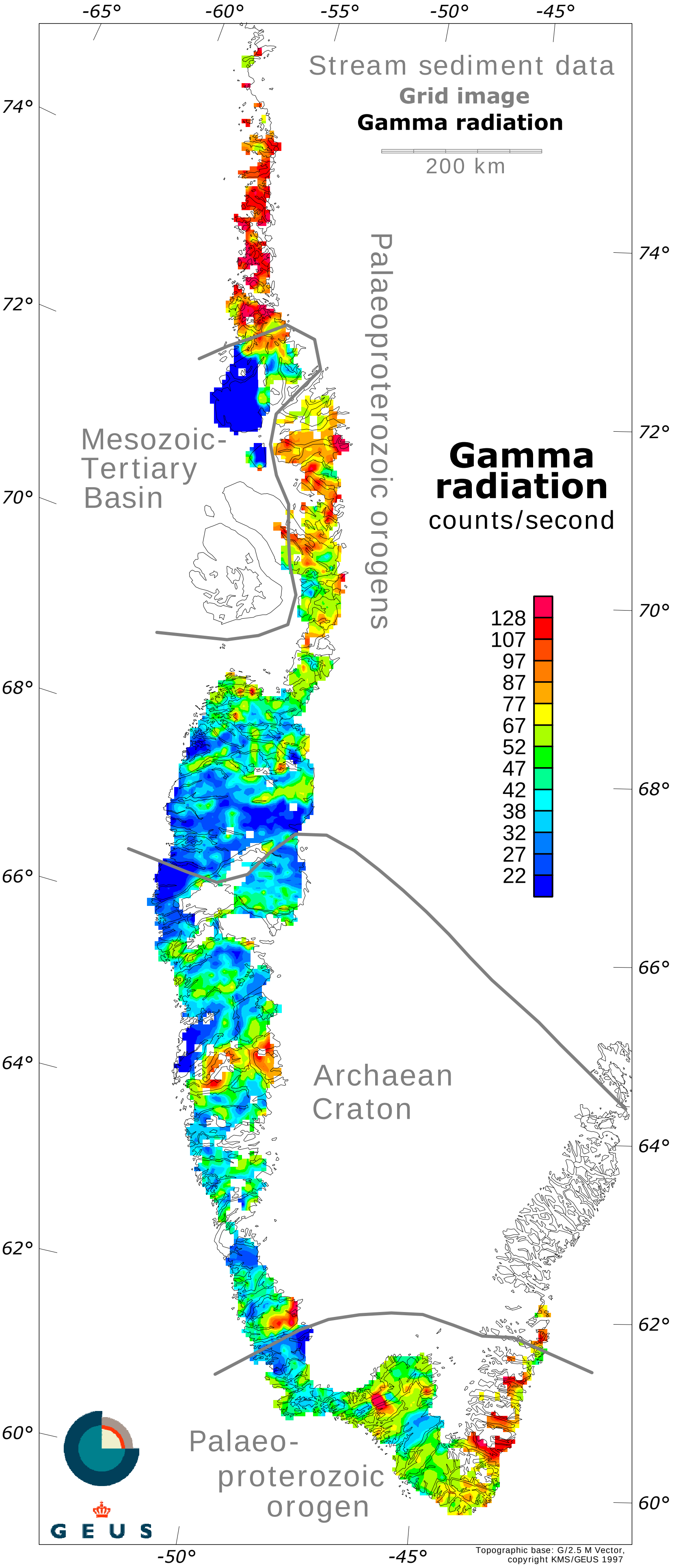


Statistics

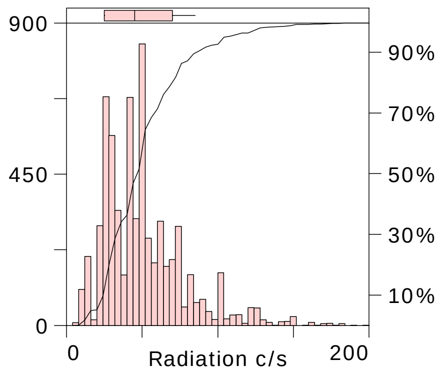
L.o.i. %	Samples	Cells
Number	5398	6706
Maximum	48.96	41.2
Minimum	0	-2.4
Mean	7.16	6.82
Std. dev.	6.32	4.82
10th perc.	1.35	2.1
20th perc.	2.39	3.2
30th perc.	3.39	4.0
40th perc.	4.34	4.8
50th perc.	5.38	5.7
60th perc.	6.70	6.7
70th perc.	8.34	8.0
80th perc.	10.72	9.7
90th perc.	15.29	13.1
95th perc.	19.94	16.6
98th perc.	25.99	20.7
99th perc.	31.08	23.2

Geochemical atlas of Greenland

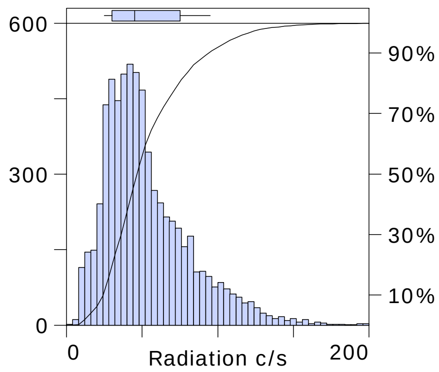
West and South Greenland



Site values



Grid cell values

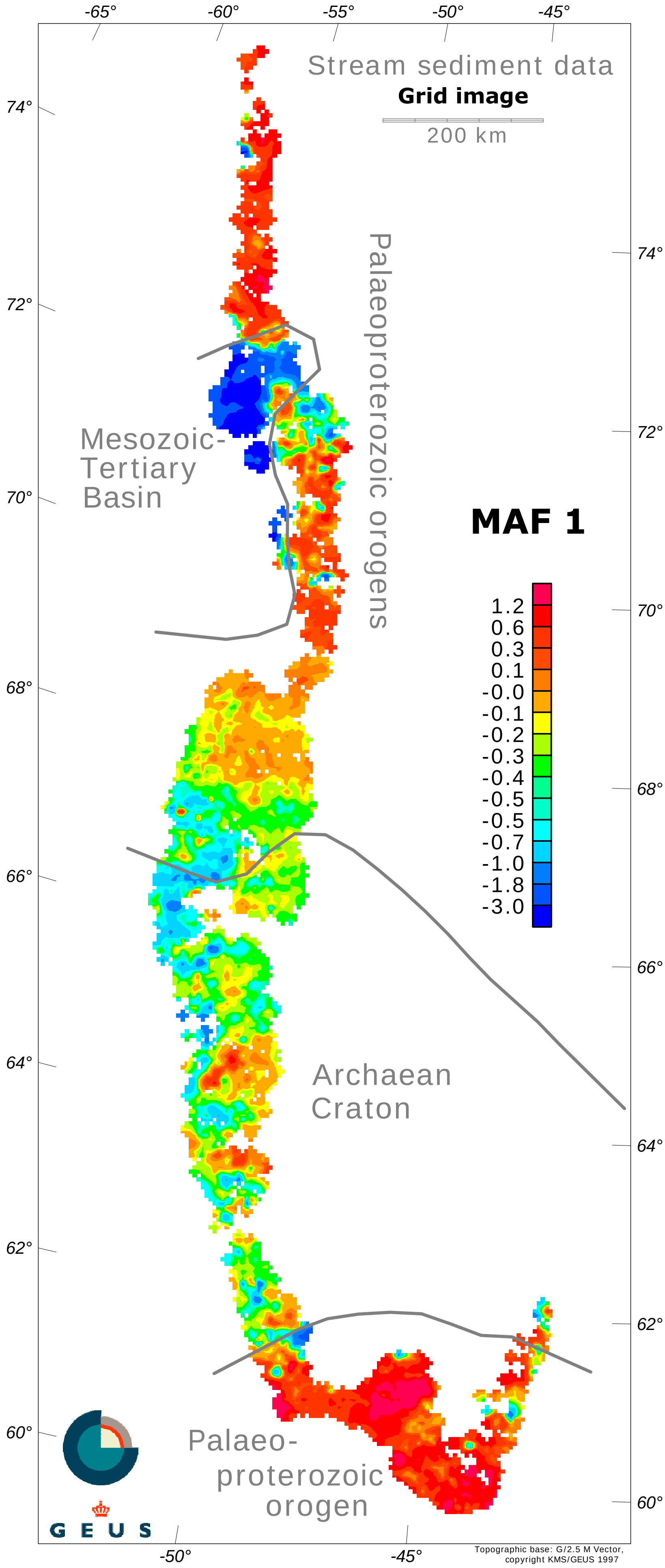


Statistics

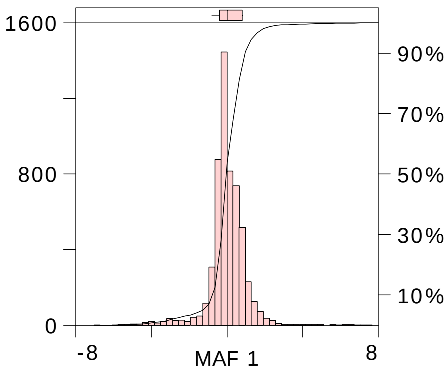
Radiation c/s	Sites	Cells
Number	6528	6764
Maximum	817	351.2
Minimum	5	3.7
Mean	50.95	53.54
Std. dev.	31.93	29.85
10th perc.	25	24
20th perc.	27	30
30th perc.	34	36
40th perc.	40	41
50th perc.	45	46
60th perc.	50	52
70th perc.	57	62
80th perc.	70	75
90th perc.	85	94
95th perc.	104	112
98th perc.	130	131
99th perc.	150	148

Geochemical atlas of Greenland

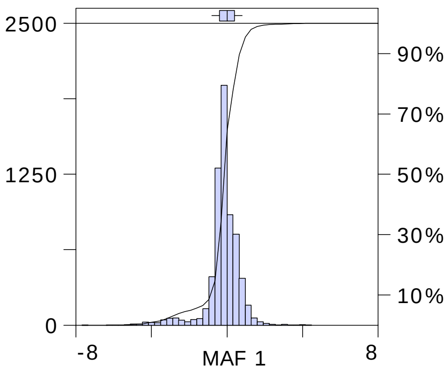
West and South Greenland



Sample values



Grid cell values



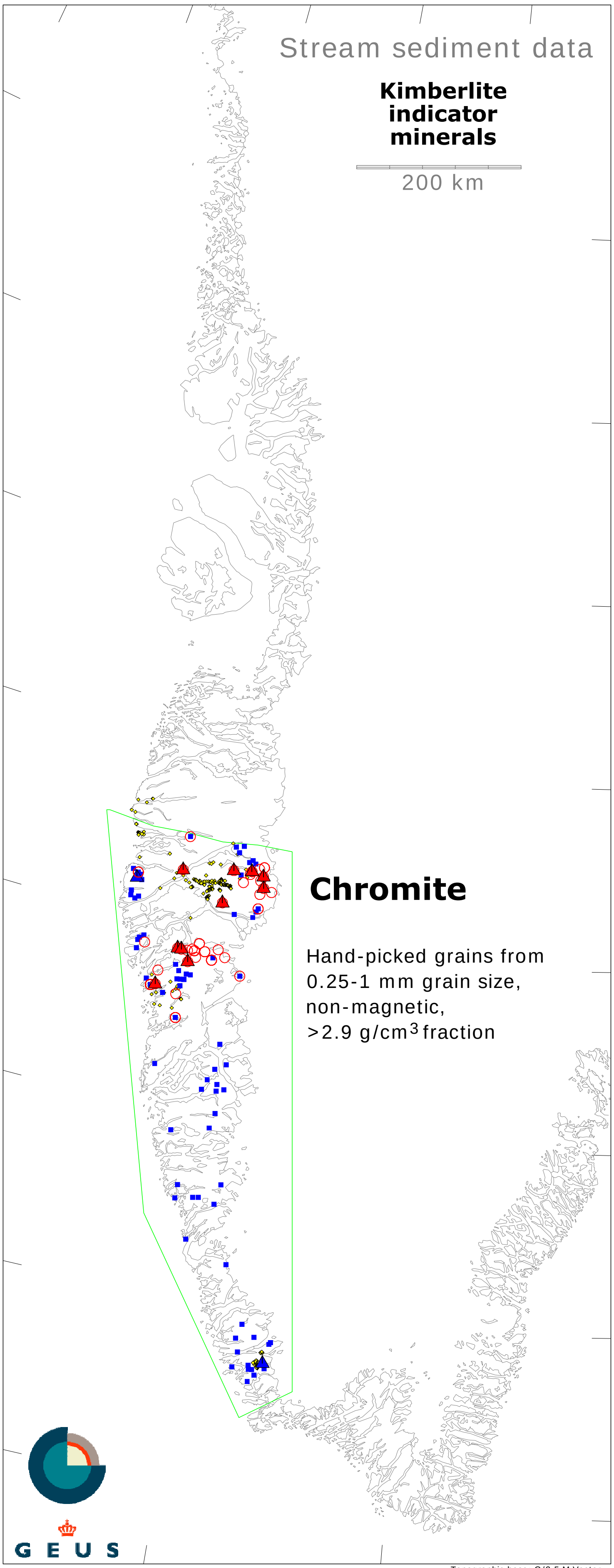
MAF

Maximum autocorrelation factor analysis

using data for As, Ba, Co, Cr, Cu, Cs, Hf, La, Ni, Rb, Sc, Sm, Sr, Th, U, Zn

Red end of colour scale:
high proportion of elements in felsic rocks

Blue end of colour scale:
high proportion of elements in mafic rocks



Chromite

Hand-picked grains from 0.25-1 mm grain size, non-magnetic, >2.9 g/cm^3 fraction

GEUS

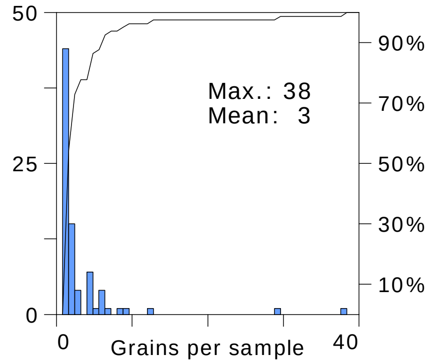
Geochemical atlas of Greenland

West and South Greenland

Result of picking

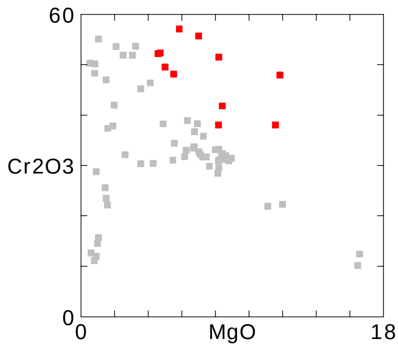
Total number of processed samples: 2960

Samples with chromite: 81



Chemical analyses

70 grains analysed in 35 samples

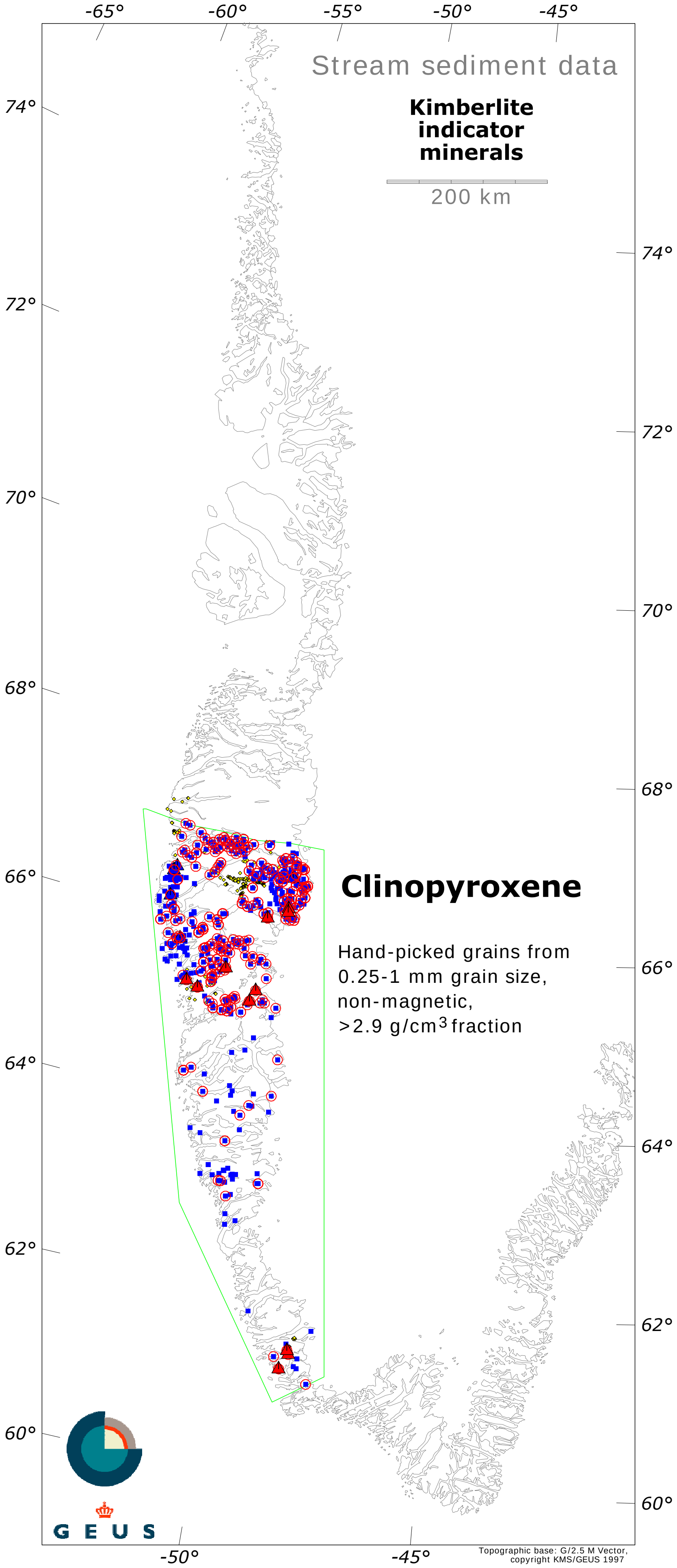


Symbols on map

- High-Cr, high-Mg chromite, red symbols in scatter plot
- Analysed grains
- >10 grains per sample
- 1-10 grains per sample
- Investigated area
- Kimberlite (known localities including floats)

Geochemical atlas of Greenland

West and South Greenland



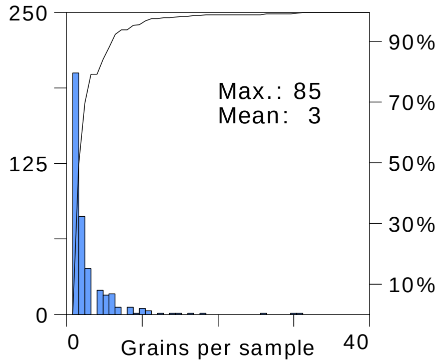
Clinopyroxene

Hand-picked grains from 0.25-1 mm grain size, non-magnetic, >2.9 g/cm³ fraction

Result of picking

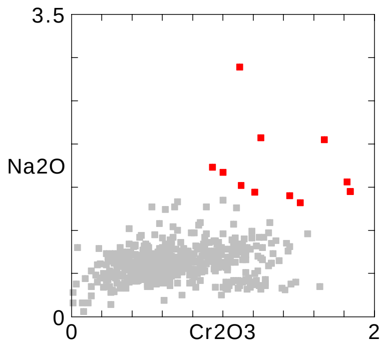
Total number of processed samples: 2960

Samples with clinopyroxene: 403



Chemical analyses

586 grains analysed in 227 samples



Symbols on map

- High-Cr, high-Na cpx, red symbols in scatter plot
- Analysed grains
- >20 grains per sample
- 1-20 grains per sample
- Investigated area
- Kimberlite (known localities including floats)

Geochemical atlas of Greenland

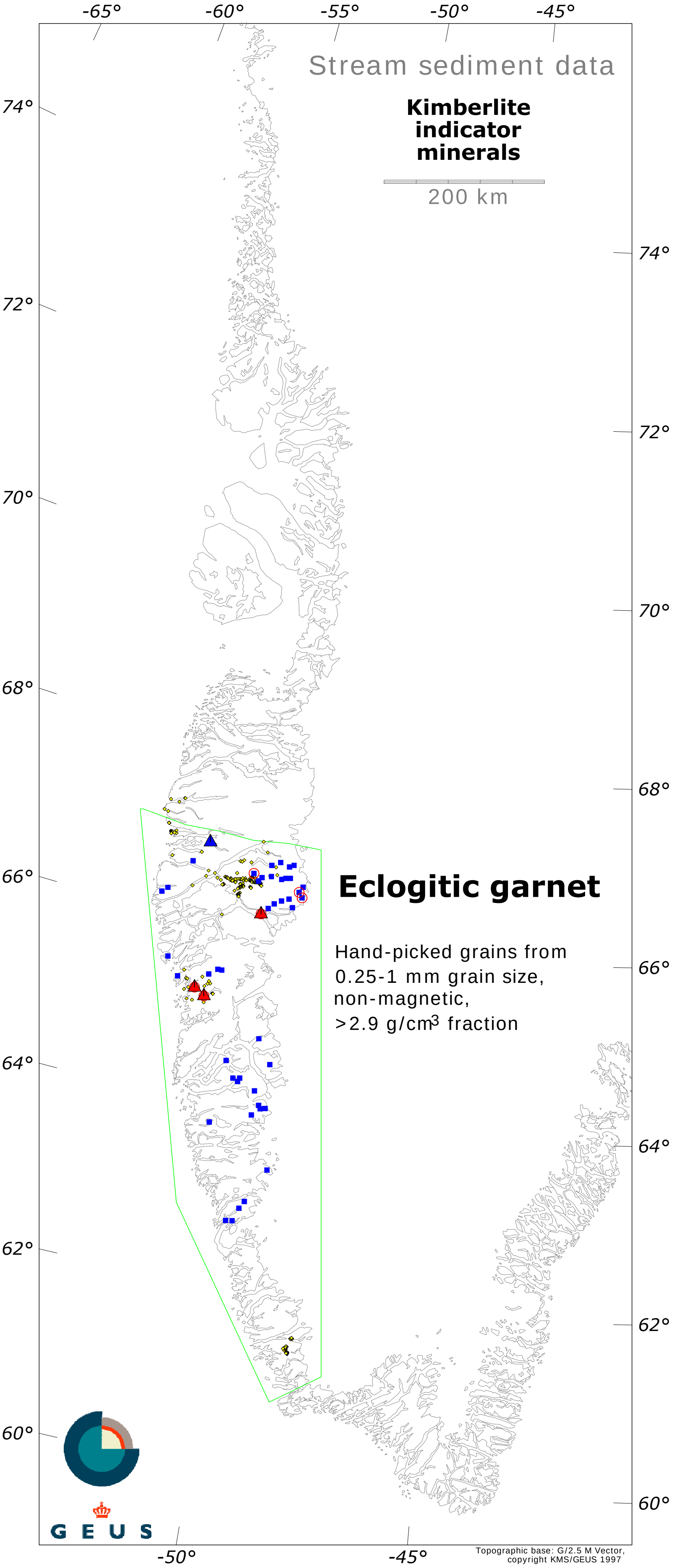
West and South Greenland

Stream sediment data

Kimberlite indicator minerals

Eclogitic garnet

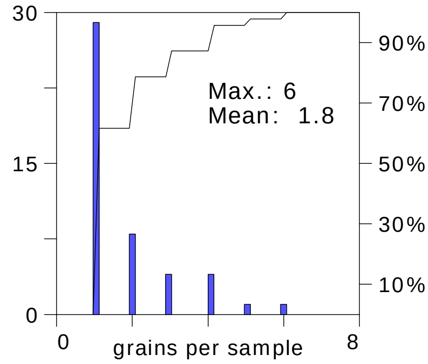
Hand-picked grains from
0.25-1 mm grain size,
non-magnetic,
>2.9 g/cm^3 fraction



GEUS

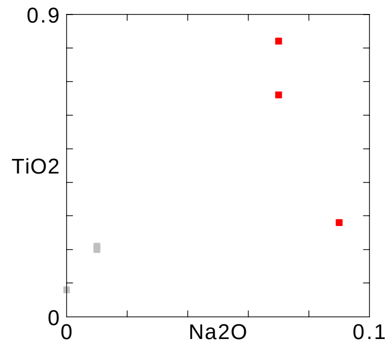
Result of picking

Total number of
processed samples: 2960
Samples with Ecl.garnet: 47



Chemical analyses

6 grains analysed
in 6 samples

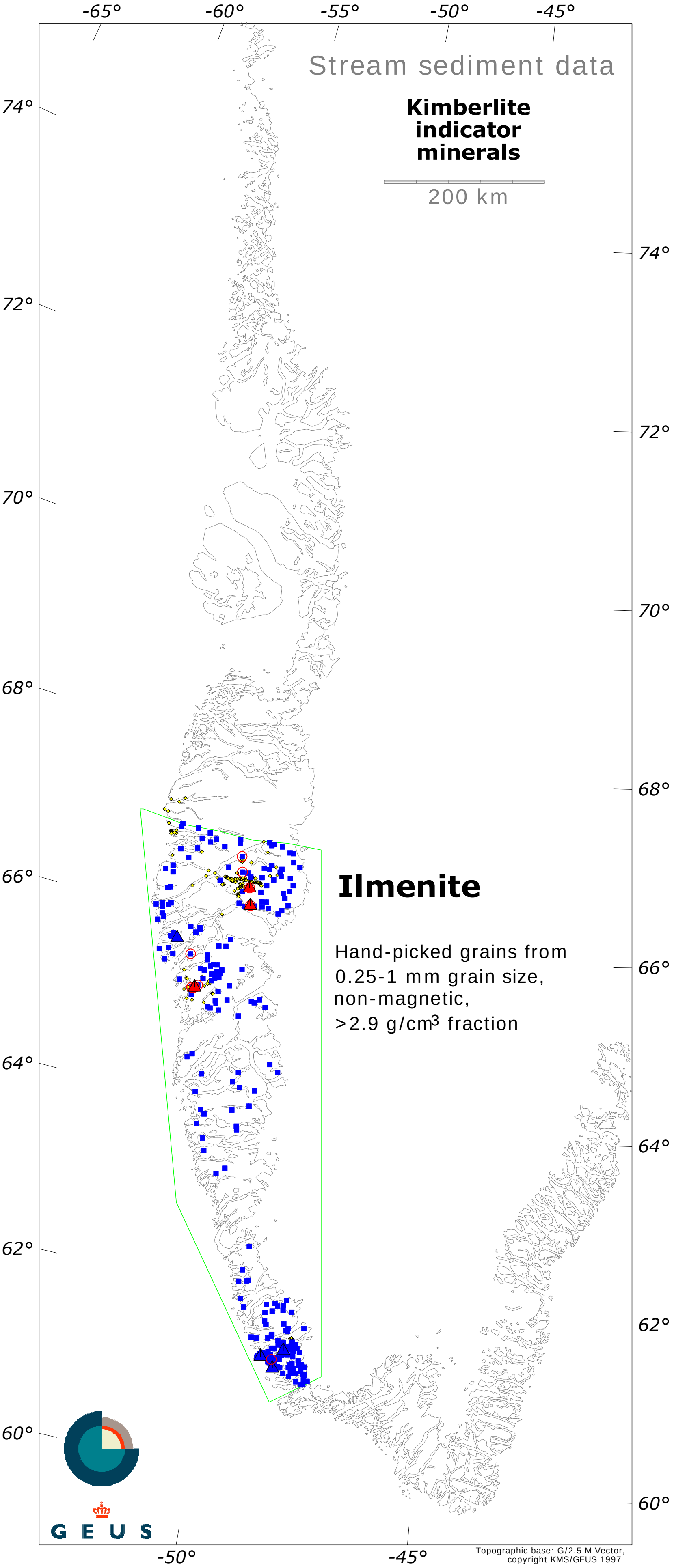


Symbols on map

- High-Ti, high-Na garnets, red symbols in scatter plot
- Analysed grains
- >5 grains per sample
- 1-5 grains per sample
- Investigated area
- Kimberlite (known localities including floats)

Geochemical atlas of Greenland

West and South Greenland

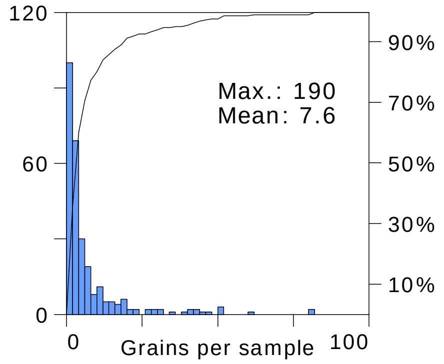


GEUS

Result of picking

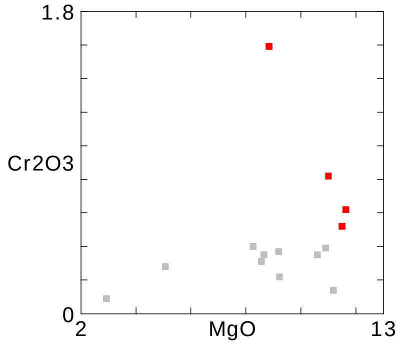
Total number of processed samples: 2960

Samples with ilmenite: 282



Chemical analyses

14 grains analysed in 9 samples

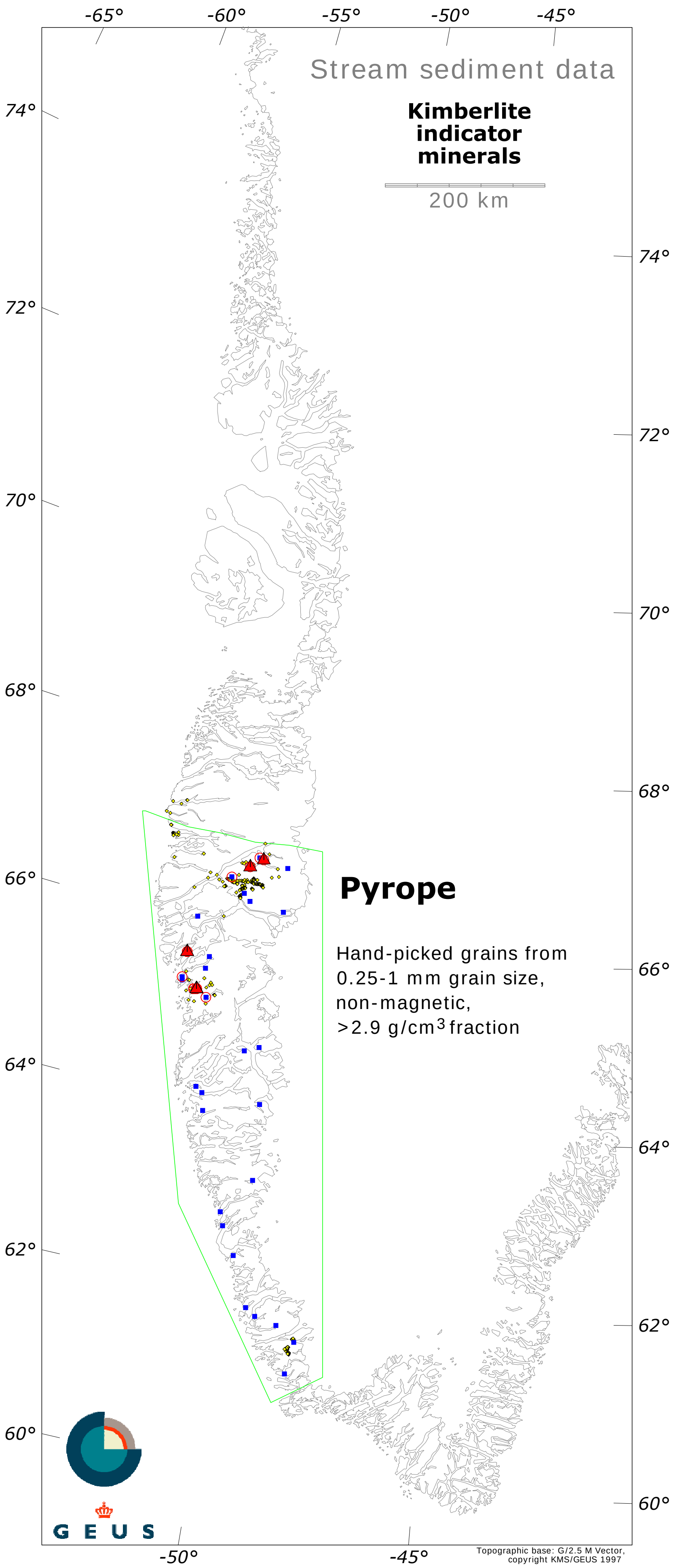


Symbols on map

- High-Cr, high-Mg ilmenite, red symbols in scatter plot
- Analysed grains
- >50 grains per sample
- 1-50 grains per sample
- Investigated area
- Kimberlite (known localities including floats)

Geochemical atlas of Greenland

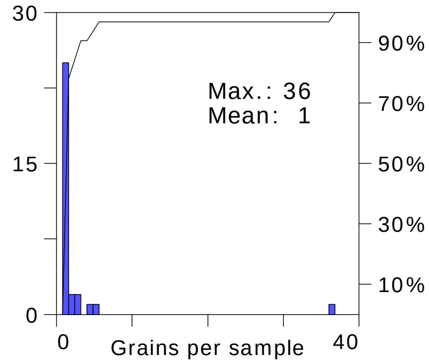
West and South Greenland



Result of picking

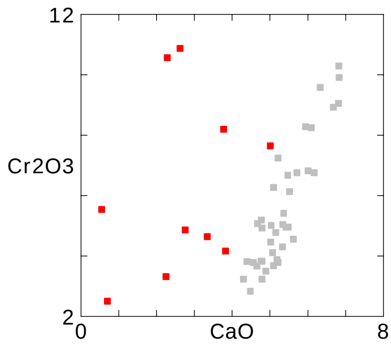
Total number of processed samples: 2960

Samples with pyrope: 32



Chemical analyses

47 grains analysed in 9 samples



Symbols on map

High-Cr, low-Ca pyropes, red symbols in scatter plot

Analysed grains

>30 grains per sample

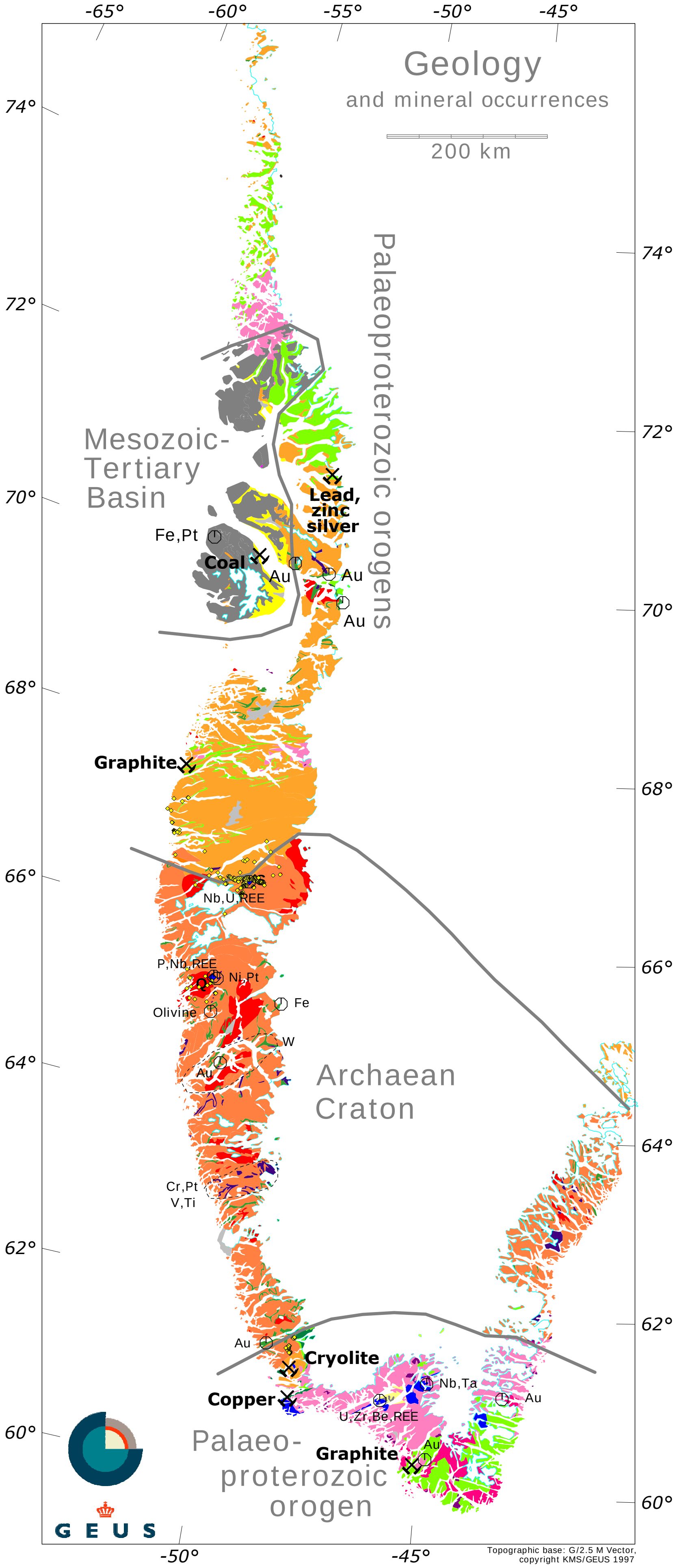
1-10 grains per sample

Investigated area

Kimberlite (known localities including floats)

Geochemical atlas of Greenland

West and South Greenland



Simplified geology based on digitised version of Geological map of Greenland, 1:2 500 000
(Escher & Pulvertaft 1995)

Archaean Craton
- Gneiss
- Supracrustal rock
- Felsic intrusion
- Mafic intrusion

Palaeoproterozoic orogens
- Reworked Archaean gneiss
- Supracrustal rocks
  - Sedimentary origin
  - Volcanic origin
- Felsic intrusion
- Mafic intrusion
- Rapakivi-type intrusion

Mesoproterozoic alkaline province
- Lava
- Sediment
- Intrusive complex

Mesozoic-Tertiary Basin
- Lava
- Sediment

Carbonatite complex
- S Cambrian
- Q Jurassic

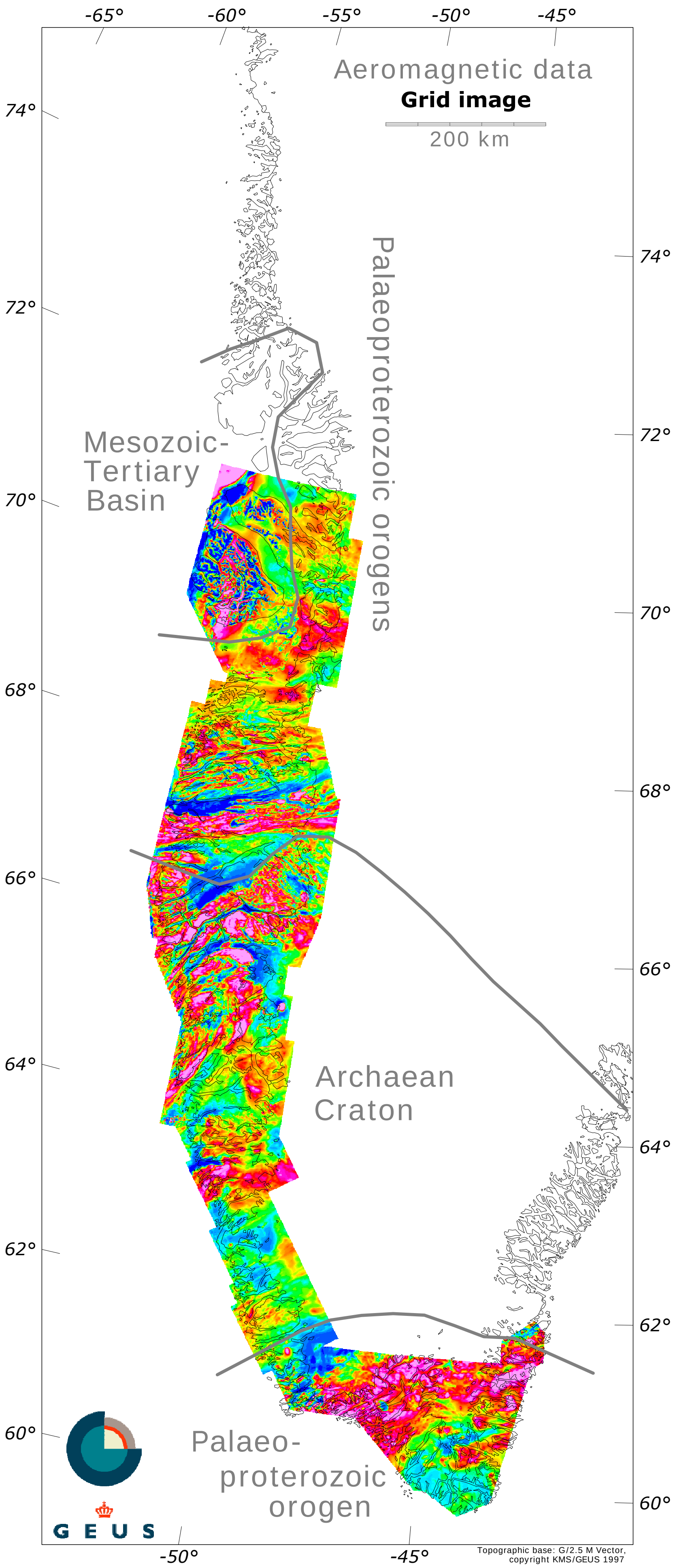
Kimberlite
- Dykes, sheets, floats

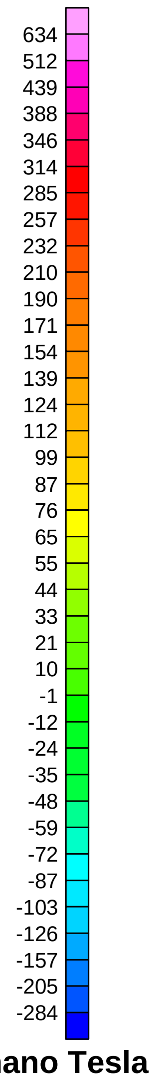
- Surficial deposit
- Inland Ice and ice caps

- Former mine
- Main mineral occurrence
- Area with several mineral occurrences

Geochemical atlas of Greenland

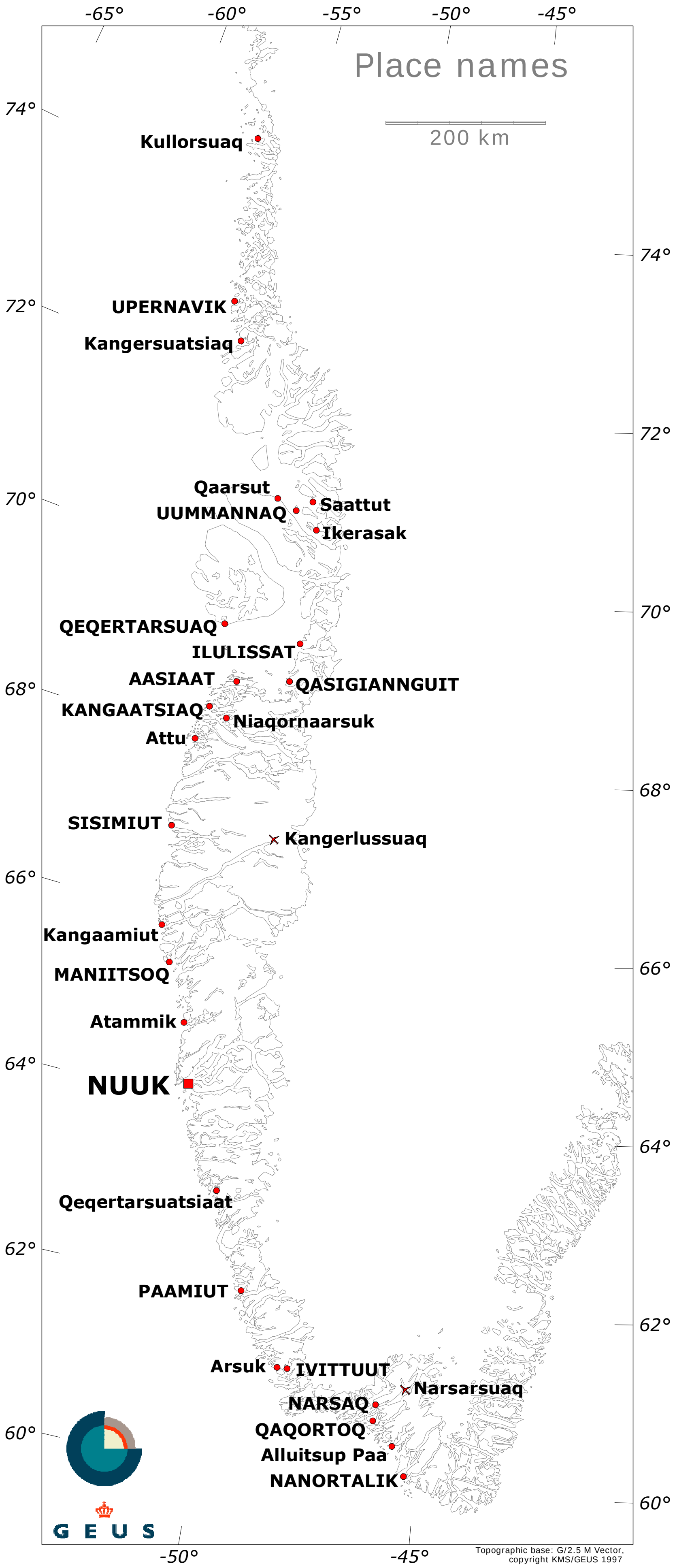
West and South Greenland





Geochemical atlas of Greenland

West and South Greenland



■	**NUUK**	Capital
•	**NARSAQ**	Town
•	**Arsuk**	Settlement with more than 200 inhabitants
✕		International airport