

Review of Survey activities 2012

Edited by

Ole Bennike, Adam A. Garde and W. Stuart Watt

Keywords

Geological Survey of Denmark and Greenland, survey organisations, current research, Denmark, Greenland.

Cover photographs from left to right

1. The 1097 m high Finnefjeld is located in the central part of the Maniitsoq impact structure, West Greenland. Photograph: Adam A. Garde.
2. Investigation of a coastal cliff section at a potential disposal site for radioactive waste. Photograph: Merete Binderup.
3. Setting up an automatic camera to monitor frontal variations of a glacier in West Greenland. Photograph: Robert Fausto.
4. Collecting samples in Cameroon, using a hand auger. Photograph: Christian Knudsen.

Frontispiece: facing page

In 2012 GEUS published a geological map of the island of Mors in north-west Jylland. The map sheet comprises the coastal cliff section Hanklit on northern Mors, with exposures of light layers of moler and dark layers of volcanic ash, overlain by glaciofluvial deposits from the last ice age. The moler has been folded and up-thrusted by ice advancing from the north. Photograph: Stig A. Schack Pedersen.

Chief editor of this series: Adam A. Garde

Editorial board of this series: John A. Korstgård, Department of Geoscience, Aarhus University; Minik Rosing, Geological Museum, University of Copenhagen; Finn Surlyk, Department of Geosciences and Natural Resource Management, University of Copenhagen

Scientific editors: Ole Bennike, Adam A. Garde and W. Stuart Watt

Editorial secretaries: Jane Holst and Esben W. Glendal

Referees (numbers refer to first page of reviewed article): Holger Lykke Andersen (21); Anonymous (37); Luke B. Bateson, UK (25); Stefan Bernstein, DK (45); Albertas Bitinas, LT (21); Kristian Bitsch, DK (33); Dave Burgess, CA (69); Jakob Qvortrup Christensen, DK (13); Gregers Dam, DK (61); Ole Gravesen, DK (65); Christoph A. Hauzenberger, G (53); Jens Havskov, NO (41); Jens Asger Jensen, DK (33); Maths Halstensen, NO (37); Larry Hulbert, CA (45); Joakim Stiel Korshøj, DK (25); John Korstgård, DK (65, 73); Peter Langen, DK (69); Nicolaj Krog Larsen, DK (29); Poul-Henrik Larsen, DK (61); Björn Lund, SE (41); Mogens Marker, NO (57); Claudio Milisenda, G (53); Matthias Moros, G (17); Ole Bjørslev Nielsen, DK (9); Asger Ken Pedersen, DK (49); Anette Petersen, DK (29); Alar Rosentau, EE (17); Martin Sønderholm, DK (9); Inga Sørensen, DK (13); Henrik Stendal, GL (49, 73); Jeroen van Gool, DK (57); Thomas Zack, SE (73).

Illustrations: Benny M. Scharck, Jette Halskov, Stefan Sølberg, Kristian A. Rasmussen, Willy L. Weng, Frants v. Platen-Hallermund

Layout and graphic production: Kristian A. Rasmussen

Printers: Rosendahls-Schultz Grafisk A/S, Albertslund, Denmark

Manuscripts received: 22 January 2013 – 14 March 2013

Final versions approved: 15 February 2013 – 21 May 2013

Printed: 10 July 2013

ISSN 1604-8156

ISBN 978-87-7871-357-5

Citation of the name of this series

It is recommended that the name of this series is cited in full, viz. *Geological Survey of Denmark and Greenland Bulletin*.

If abbreviation of this volume is necessary, the following form is suggested: *Geol. Surv. Den. Green. Bull.* 28, 76 pp.

Available from

Geological Survey of Denmark and Greenland (GEUS)

Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

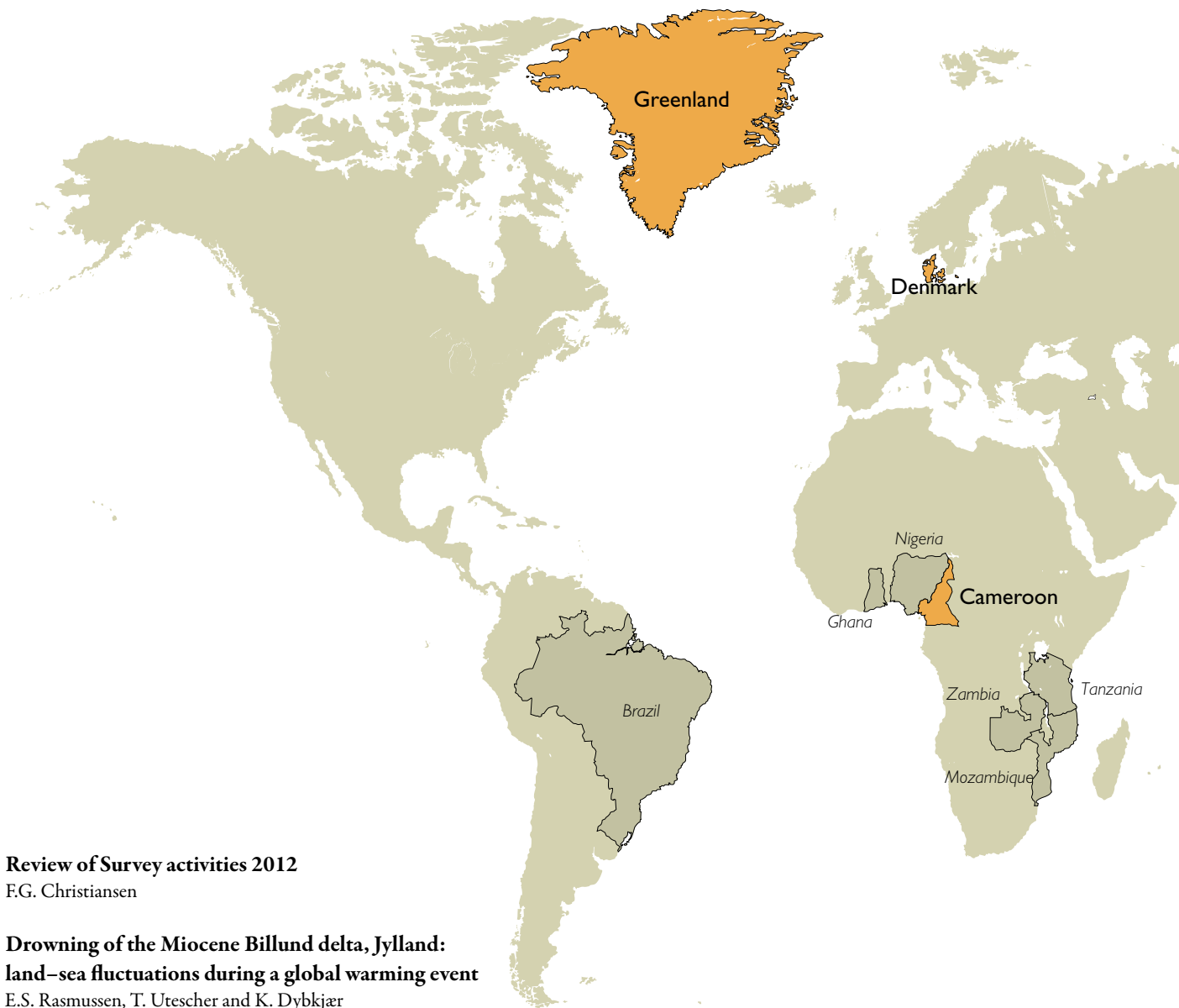
Phone: +45 38 14 20 00, fax: +45 38 14 20 50, e-mail: geus@geus.dk

and at www.geus.dk/publications/bull

© De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS), 2013

For the full text of the GEUS copyright clause, please refer to www.geus.dk/publications/bull





7 Review of Survey activities 2012
F.G. Christiansen

9 Drowning of the Miocene Billund delta, Jylland: land–sea fluctuations during a global warming event
E.S. Rasmussen, T. Utescher and K. Dybkjær

13 Geology, seismic activity and groundwater conditions at six potential disposal sites for radioactive waste from Risø, Denmark
P. Gravesen, B. Nilsson, M. Binderup, T.B. Larsen and S.A.S. Pedersen

17 A Baltic Ice Lake lowstand of latest Allerød age in the Arkona Basin, southern Baltic Sea
O. Bennike and J.B. Jensen

21 Late glacial to early Holocene development of southern Kattegat
C. Bendixen, J.B. Jensen, O. Bennike and L.O. Boldreel

25 Terrain subsidence detected by satellite radar scanning of the Copenhagen area, Denmark, and its relation to the tectonic framework
P. R. Jakobsen, U. Wegmuller, R. Capes and S.A.S. Pedersen

29 Geological map of Denmark 1:50 000 – map sheet Mors, NW Denmark
S.A.S. Pedersen, P.R. Jakobsen, L.Tougaard and P. Gravesen

33 Assessing urban groundwater table response to climate change and increased stormwater infiltration
M.T. Randall, L. Trolldborg, J.C. Refsgaard and J.B. Kidmose

37 Evaluation of total groundwater abstraction from public waterworks in Denmark using principal component analysis
B.L. Sørensen and R.R. Møller

41 Seismic activity in Denmark: detection level and recent felt earthquakes
T. Dahl-Jensen, P.H. Voss, T.B. Larsen and S. Gregersen



GEUS working areas 2012.

Orange areas are covered in this volume.

- 45 The norite belt in the Mesoarchaeic Maniitsoq structure, southern West Greenland: conduit-type Ni-Cu mineralisation in impact-triggered, mantle-derived intrusions?**

A.A. Garde, J. Pattison, T.F. Kokfelt, I. McDonald and K. Secher

- 49 Geochemistry and petrology of gold-bearing hydrothermal alteration zones on Qilanngaarsuit, southern West Greenland**

M. Koppelberg, A. Dziggel, D.M. Schlatter, J. Kolb and F.M. Meyer

- 53 Fingerprinting of corundum (ruby) from Fiskenæsset, West Greenland**

N. Keulen and P. Kalvig

- 57 Lineament mapping and geological history of the Kangerlussuaq region, southern West Greenland**

K.E.S. Klint, J. Engström, A. Parmenter, T. Ruskeeniemi, L.C. Liljedahl and A. Lehtinen

- 61 Calibration of spectral gamma-ray logs to deltaic sedimentary facies from the Cretaceous Atane Formation, Nuussuaq Basin, West Greenland**

G.K. Pedersen, N.H. Schovsbo and H. Nøhr-Hansen

- 65 A new seamless digital 1:500 000 scale geological map of Greenland**

M. Pedersen, W.L. Weng, N. Keulen and T.F. Kokfelt

- 69 Darkening of the Greenland ice sheet due to the melt-albedo feedback observed at PROMICE weather stations**

D. van As, R.S. Fausto, W.T. Colgan, J.E. Box and the PROMICE project team

- 73 Titanium minerals in Cameroon**

C. Knudsen, J. Penaye, M. Mehlsen, R.K. McLimans and F. Kalsbeek

Review of Survey activities 2012

Flemming G. Christiansen

Deputy Director

2012 was a good and stable year for the Geological Survey of Denmark and Greenland (GEUS). In recent years GEUS has been through a long – and very constructive – process of establishing a new strategy that reflects the changes in society and new demands from many different stakeholders. With a new strategy in place there has been greater focus on GEUS' activities and research projects.

2012 was a very active year with many projects, field work and offshore data acquisition, which promises well for maintaining a high level of research in the coming years.

With the establishment of the new series *Geological Survey of Denmark and Greenland Bulletin* in 2003 it was decided to make a yearly *Review of Survey activities*. This issue is the tenth and, together with previous issues, provides a good overview of the Survey's wide range of research and advisory activities. This issue contains a total of 17 four-page papers, nine on Denmark, seven on Greenland and one on a project in Cameroon.

Activities in Denmark

The activities and research in Denmark by GEUS cover many different topics within our main programme areas: data, water, energy, mineral resources as well as nature and climate.

As a follow-up on many previous studies of the Miocene succession and its groundwater resources, one paper gives a detailed discussion of the drowning of the Billund Delta in Jylland during a period of previous global warming.

GEUS has been involved in the technical work that is required before a permanent disposal site can be selected for low- and intermediate-level radioactive waste. One paper describes the geological data and knowledge and key parameters such as lithology, groundwater, seismic activity, effect of climate change and local infrastructure that have been applied to narrow down the initial number of 22 areas to six potential sites.

GEUS is involved in many studies of Quaternary and recent geological processes. One paper describes deposits from the Baltic Ice Lake in the Arkona Basin in the southern Baltic Sea. Another paper presents results on the late glacial to early Holocene development of southern Kattegat. A third paper describes terrain subsidence interpreted from satellite

radar scanning with special focus on Copenhagen and its tectonic framework.

Systematic geological mapping on a scale of 1:25 000 and publication of 1:50 000 scale systematic sheets continues. In some places it is appropriate to make regional maps of, for example islands, on a single sheet. An example of this is described in a paper on the map sheet Mors. Geologically, Mors is an interesting island with beautifully exposed glaciotectonic structures in cliff sections, and the characteristic Eocene clayey diatomite with volcanic ash layers, a unit known as 'moler'.

The use of groundwater is very important for Danish society and GEUS carries out many studies on water resources and possible future changes due to climate and use. One paper discusses models for urban groundwater table response to climate change and increased stormwater infiltration using the town of Silkeborg and a proposed course of a new motorway around Silkeborg as a case study. Another paper evaluates groundwater abstraction from public waterworks in Denmark by using advanced statistical methods to correct data.

GEUS records seismological events at six locations in Denmark. One paper describes the developments in detection level and completeness from 2000 to 2012 with examples of recent felt earthquakes (North Sea on 19 February 2010 and Kattegat on 6 August 2012) and explosions.

Activities in Greenland

There was a high level of field activities in Greenland in 2012 with a major mapping and geochemical programme in South-East Greenland, a large field and shallow-core drilling programme in North Greenland, and the LOMROG III cruise in the Arctic Ocean. The latter was the last data acquisition of the Danish Continental Shelf Project. Many other field studies were also carried out. Results from these large and small projects will be presented in the coming years. In this issue results are presented from other completed and ongoing projects.

One paper discusses the possibility that nickel and copper occurrences in the norite belt in the Maniitsoq area could be impact-induced as they are found in a recently described giant and deeply eroded, very old (3 Ga) impact structure

in this area. Gold occurrences have been reported during GEUS expeditions to West Greenland some years ago, and another paper provides more constraints on ore formation and fluid-rock interaction.

Corundum in gem quality (ruby) has been known since the 1960s near Fiskenæsset in southern West Greenland and it is possible that mining will start within a few years. One paper gives a detailed description of the geochemistry that can be used to fingerprint the Greenlandic rubies.

Since 2008, the Greenland Analogue Project (GAP) has carried out a wide range of studies in an area near Kangerlussuaq in West Greenland to understand the many different processes that might take place if a deep geological repository for spent nuclear fuel is affected by glaciation. One paper focuses on structural investigations in this area, especially the mapping of lineaments and other late features. As a follow-up on several decades of studies in the Nuussuaq Basin in West Greenland, a spectral gamma-ray characterisation has been made on the Cretaceous Atane Formation to set up a better model for interpretation of lithology and grain-size variation in wells without cores.

Systematic geological overview mapping of Greenland has been the backbone of the Survey's work in Greenland over

the past 65 years ago. In the period 1971–2004, 14 maps were published on a scale of 1:500 000. With the development of the Internet, geological maps worldwide are rapidly changing from traditional paper sheets to digital publications. GEUS has produced a new seamless digital 1:500 000 scale map covering the whole of Greenland. One paper describes the background, the digitisation and the geological harmonization involved. It is expected that such maps will be widely used in the future. The new map is an important GEUS contribution to the global OneGeology portal.

The important monitoring programme of the Greenland Ice Sheet (PROMICE) continuously supplies new crucial data and one paper discusses the darkening of the Greenland ice sheet and the increase in surface melting.

International activities

Internationally GEUS works in many different countries with a variety of projects. The last paper in this issue is about titanium minerals in Cameroon and it focuses on understanding the primary formation, weathering and re-deposition of rutile in the area.