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Review of Survey activities 2017

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

Cover photographs from left to right

1. Hyperspectral analysis of inaccessible rock faces using land- or sea-based platforms has potential to become a powerful geological mapping tool, as individual mineral species can be identified with this method. Example from central West Greenland.
2. 3D imaging by hand-held digital photogrammetry is used in both current geological mapping and assessment of landslide risks in Greenland. Photograph: Jonas Petersen.
3. Potential storage sites for unwanted brine around the Lille Torup gas storage facility in Jylland, and seismic lines used in the location of suitable sites.
4. Studying intense glaciotectonic fracturing of Cretaceous chalk at Stevns Klint.

Frontispiece: facing page
The GEUS ice-sheet field camp photographed on 20 July, 2017 above the former Camp Century buried in the Greenland ice sheet near Thule Air Base.

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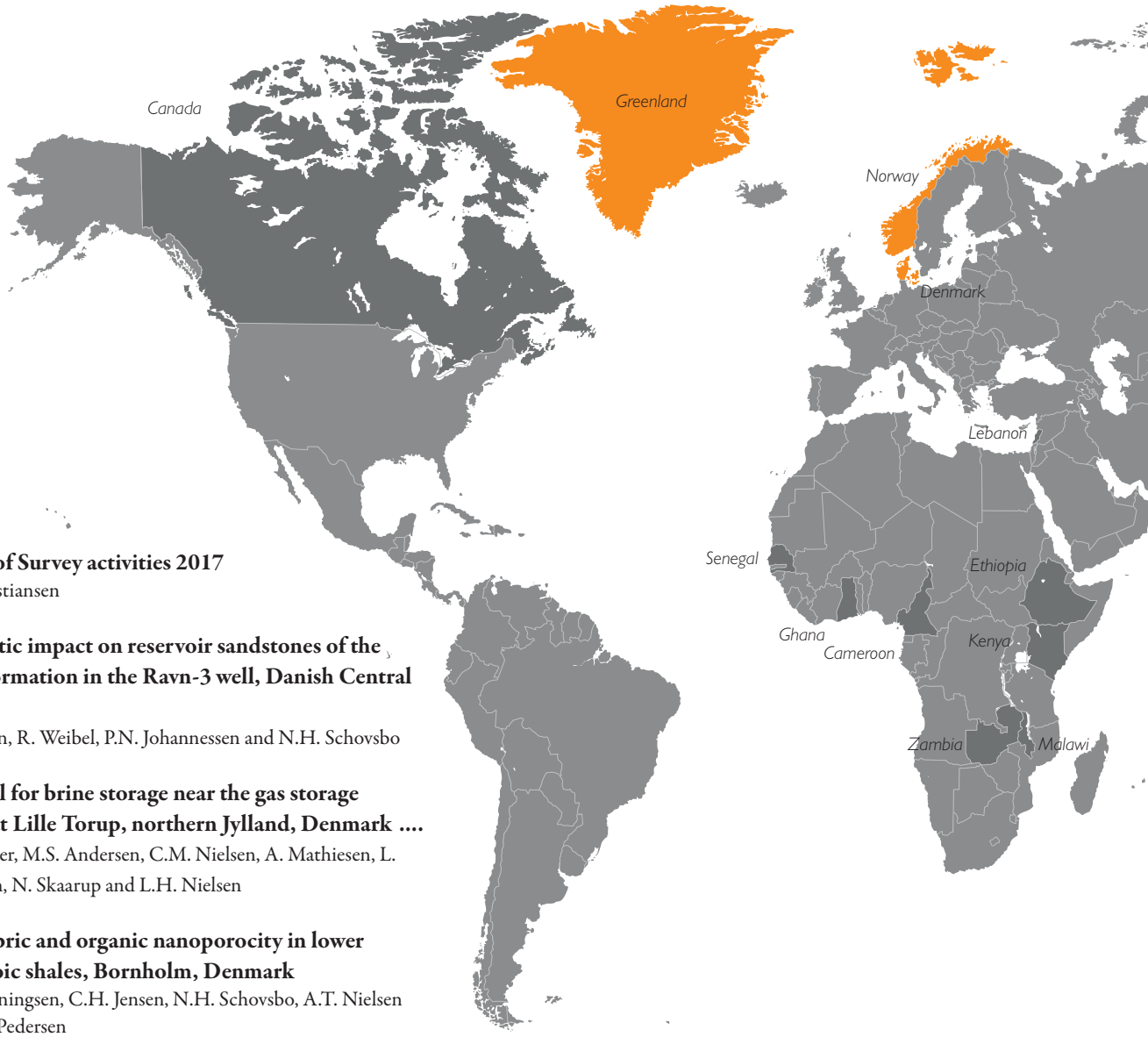

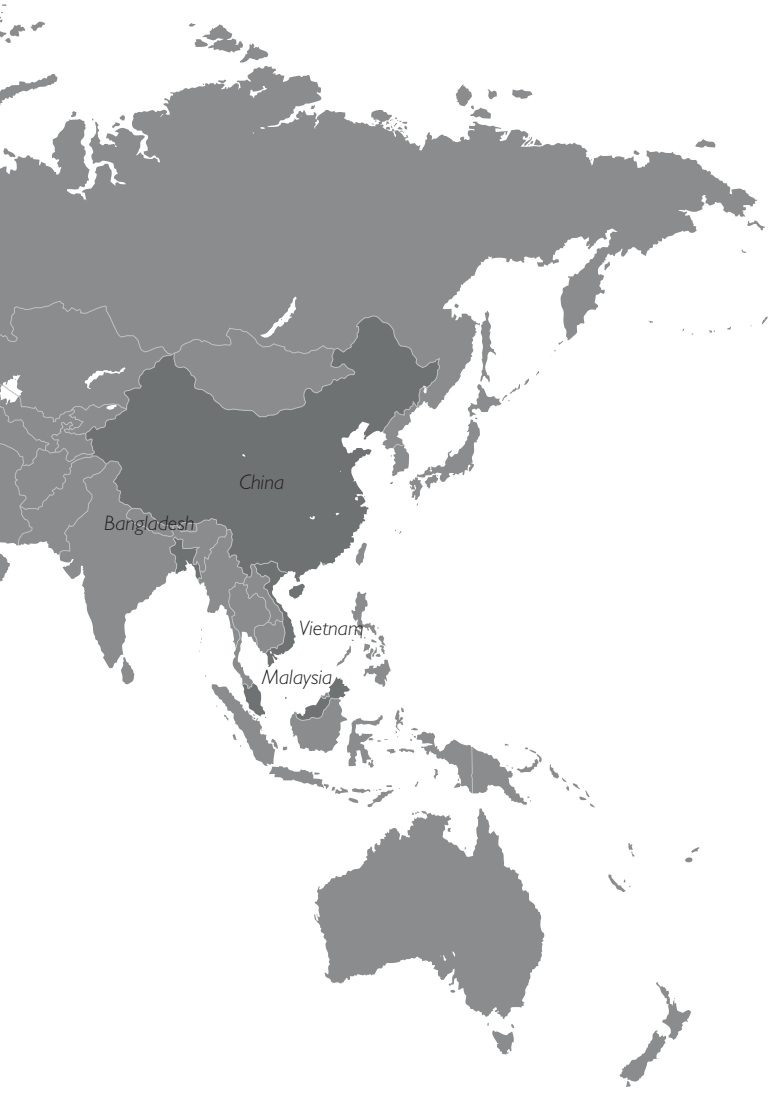

Dark grey indicates non-european countries where GEUS has ongoing or recently completed projects.

Orange indicates countries with GEUS projects described in this volume.

Review of Survey activities 2017

Flemming G. Christiansen
Deputy Director

2017 was a year where we all experienced how fatal geological forces can be for society. On June 17, a tragic natural disaster hit Greenland. Following a huge landslide into Karrat Fjord, major waves flooded the settlements of Nuugaatsiaq and Illorsuit. Four persons were lost and many houses in Nuugaatsiaq were destroyed. Due to the continued high risk for more landslides, the inhabitants of the two settlements have not returned and the Greenlandic authorities advise against visiting the risk area.

Such a natural disaster together with many extremes in weather and climate conditions around the World, also in Denmark and Greenland, directs our focus on the consequences of the changing climate. This requires regularly updated climate models and response with suggestions for adaptation to climate change and will have strong implications for GEUS' continued research and monitoring in many years to come, including further studies and monitoring of geohazards.

GEUS will have an important role in guiding society for better and safer living conditions in both Denmark and Greenland. It is necessary to work with such topics and provide society and authorities with transparent information. GEUS has presented a new website providing key information on many different research areas and with specific information and data from monitoring programmes like *www.promice.dk*, celebrating its 10 years anniversary in 2017 and *www.campcenturyclimate.dk* that was established in 2017.

It is essential that such key information builds on results of a high scientific standard and that data are well documented in international publications, and in papers and maps in our own series. This issue of GEUS' Review of Survey activities includes 22 papers covering many different activities in Denmark, Greenland and internationally. Seven papers are on Denmark, 11 on Greenland and four on other themes.

Activities in Denmark

GEUS works with many different – and often closely related – topics in Denmark such as the use of water, energy and mineral resources, protection of nature when exploiting resources, and the impact of climate change. The economic and political implications are very significant, and making up-to-date geological and geophysical data and information available for society, authorities and industry is of great value in this context.

One paper is on the diagenetic impact of Upper Jurassic sandstones in the Ravn-3 well in the Danish Central Graben. Understanding these processes is important for the production of oil from deeply buried oil fields. Another paper is on the thickness, depth and properties of reservoir rocks within the sedimentary succession close to the Lille Torup gas storage facility in northern Jylland. To increase the volume of caverns, saline brine from the salt structure must be stored elsewhere, and one of the options could be to re-inject the brine into the subsurface. A third paper deals with the controlling factors of porosity development in Palaeozoic shales and the implications for shale-gas plays in Denmark. An example from Bornholm, demonstrates that this is controlled by both shale fabric and organic nanoporosity, in contrast to conventional sandstone reservoirs.

Understanding rocks formed by glacial processes is important in Denmark, e.g. for flow modelling of ground water and for handling geotechnical problems when establishing new infrastructure. One paper describes the formation of chalk-glaciotectonite with examples from former glaciated terrains covering chalk and limestone bedrock from localities on Møn, Sjælland and Jylland. A second paper presents sedimentological and glaciotectonic interpretation of georadar data from NW Sjælland, where the interior structure of ridges has been characterised.

For cost-reduction reasons, there is a growing interest for oil exploration in the youngest and shallowest part of the sedimentary succession in the North Sea. A paper gives a detailed description of nanofossils, microfossils and palynomorphs in a Miocene oil-bearing diatom ooze from the Valhall field area in the Norwegian sector. A final paper is on the shallow geology of Tannis Bugt in Skagerak where habitat mapping has been carried out in a Natura2000 area. The geological history here is very complex with deformed units and possibility of pre-Quaternary bedrock being exposed on the sea bottom.

Activities in Greenland

As in previous years, there was a high level of geological and glaciological activities in Greenland in 2017: both traditional studies with focus on geological mapping, the mineral and petroleum potential and monitoring and research related to climate changes and their effects.

One paper discusses the implications of a new 1:100 000 map from Kilen in North Greenland for the seamless 1:500 000 regional map of Greenland. New procedures and documentation are necessary, as many geological maps from Greenland are likely to be updated in digital versions in the coming years. A second paper on North Greenland describes base-metal and rare-earth elements (REE) anomalies in lower Palaeozoic sedimentary rocks and discusses the implications for the zinc and lead potential.

Hyperspectral remote sensing has a great potential for geological mapping and exploration in Greenland. A paper from West Greenland provides details on mineralogical mapping of basement rocks in the Nagssugtoqidian Orogen using airborne, ship-based and terrestrial platforms. Another paper focuses on how the signal from lichens that often cover rocks in the Arctic can be distinguished from the mineralogical signal, with examples of ultramafic rocks such as kimberlite.

One paper presents results from subsurface mapping offshore southern West Greenland using seismic interpretation also including various geological and geochemical analysis. This paper includes new and critical information from oil exploration wells drilled in 2010 and 2011 that penetrated the deeper part of the sedimentary succession and reached underlying basement and volcanic rocks. Another paper uses 3D photogrammetry for lithological mapping and structural analysis, in this case from Karrat Fjord in West Greenland. Such understanding is also important for further evaluation of risk of landslides.

Climate-related research and monitoring at GEUS provide important data for global climate models and are often based on ground-truth data from the ice and fjords or offshore. One paper compares historical records of European trading and whaling in the Disko Bugt region with climate data from marine sediments and show interesting examples of the physical remains from the whaling period. Another paper introduces an important climate indicator – the snowline elevation that is the maximum elevation during the melt season where snow remains from the previous accumulation season. Based on satellite data and direct comparison with data from PROMICE stations, a series of snowline maps covering all of Greenland from 2011 to 2017 have been constructed.

With new and updated climate models, there are concerns that remains from the former US Camp Century base buried under the ice in the Thule area might get closer to the surface within the next century and that meltwater may interact with its waste long before. GEUS has started a new climate-monitoring programme and has mapped the extent and depth of the debris from the base with an ice-penetrating radar survey; results from the first field season are summarised in one contribution. A second paper describes results from airborne surveys in 2007, 2011 and 2015 where the elevation of the ice surface, top of bedrock, and the variation in thickness of the Greenland ice sheet through time have been measured. Another paper is on the sea-ice distribution along eastern Greenland and Iceland. Original maps by Lauge Koch covering the 19th and 20th century have been digitised and analysed statistically. This can be very useful for future models of sea-ice variation in a changing climate.

Other themes

As the national geological survey, GEUS has a strong obligation to participate in international assessments of resources, use state-of-the-art laboratory equipment, constantly develop new analytical techniques and make the ever-increasing volume of data available with systematic quality control and updated, user-friendly databases and distribution systems.

One paper presents an examination of the supply-demand balance of REE, which is important for future global wind power scenarios; especially lack of neodymium and other elements for permanent magnets may be critical. Another paper describes how analysis of the microchemistry of cod otoliths (ear stones) with the LA-ICP-MS technique can be applied to understand the age, growth history and migration of fish stock. A third paper gives an overview of the development and organisation of a common geological data infrastructure (EGDI) for Europe. EGDI is important for the research collaboration and geological data sharing between the member states of the EuroGeoSurveys. Finally, the last paper presents the procedures for 3D mapping at the photogeological laboratory at GEUS. This is a very strong tool for geological mapping, structural analysis and evaluation of the risk of natural geohazards such as landslides.