Knowledge for growth and welfare

GEUS

Annual Report 2011

THE GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE, ENERGY AND BUILDING

GEOLOGY for society

Knowledge for growth and welfare – new strategy

Under the heading 'Geology for society – knowledge for growth and welfare', GEUS launched its new strategy in 2012. The strategy was prepared by the board and management of GEUS during the period June 2010 to September 2011, when it was endorsed by the board. GEUS' employees have been involved in the process at employee strategy meetings, and, encouraged by management, have contributed a great number of written proposals.

The strategy has an eight-year span and comprises the strategic foundation for GEUS' performance contract with the Ministry of Climate, Energy and Building for the period 2012-2015.

The strategy reflects development trends in Denmark and abroad as well as the driving forces that will be decisive for GEUS' choices and priority setting in the future. The driving forces include: transition to sustainable energy sources, adaptation to future climate conditions and keeping water resources in check, as well as heightened competition for minerals and mineral resources. All the while, human health will be in focus, and access to nature and recreational areas will have great importance for the well-being of the population.

The strategy consists of a number of targets and strategic topics as well as organisational initiatives to support GEUS in its tasks. The strategic targets are long-term, general and functional targets, which GEUS will follow so as to best complete its mission, while the topics are scientific and technical, dealing with the subjects and overall objectives at which GEUS will direct its activities strategically for the benefit of society.

A printed version of the strategy is available from GEUS or electronically at www.geus.dk (in Danish only).

Preface

This Annual Report 2011 provides a brief overview of some of the work and events that GEUS has been involved in over the year. GEUS has had a good and productive year, with an increasing number of tasks for many stakeholders, as well as many new research projects. The year also saw preparation of GEUS' strategy for the period up to 2020, which will also form the foundation for GEUS' performance contract with the Ministry of Climate, Energy and Building for 2012-2015.

2011 was the final year of GEUS' previous four-year performance contract with the Ministry of Climate, Energy and Building, and by far the majority of the tasks agreed have been completed as expected. Production of scientific and other publications has exceeded targets, and participation in the education of PhD and thesis students has grown considerably, while at the same time GEUS has achieved its financial targets.

There has been a marked increase in interest in minerals and mineral resources in the Arctic. GEUS has compiled and published digital geological maps of Greenland with mineral-relevant data making them easy to use in exploration work in Greenland. The results are being included in activities to market Greenland's mineral potential, in which GEUS is working with the Greenland Bureau of Minerals and Petroleum at conferences, meetings and trade fairs.

Oil and gas resources in the Arctic also continue to attract international attention. In order to prepare upcoming licensing rounds, GEUS has been working on a number of research projects in North-East Greenland. The area has great potential, so it has attracted the attention of the entire oil industry, but there is very little research history.

Mapping the continental shelf around Greenland and the Faroe Islands and preparation of submissions of demands to the UN in collaboration with the Danish, Faroese and Greenlandic authorities and institutions continue to be demanding tasks. In 2011, the Swedish icebreaker, *Oden*, completed yet another cruise off North-East Greenland, and a submission is being prepared for the area south of Greenland.

The resources crisis and the dramatic increases in oil and gas prices have rejuvenated focus on the North Sea, and in 2011, GEUS launched a large research project on the exploration possibilities in the Jurassic strata lying beneath the chalk from which most Danish oil production takes place. Within renewable energy, GEUS' main contribution has been knowledge about the potentials and project risks of geothermal heat supply.

Increased exports of green technologies and green solutions can help growth in Denmark, and water has been targeted as one of the drivers to realise this goal. GEUS has applied its experience in groundwater mapping in Denmark to initiate, in collaboration with Danish companies, capacity building for similar mapping in Thailand, where GEUS' work includes training as well as establishing a database.

The more frequent and more serious flooding in Denmark has meant that there is greater interest in understanding how climate change affects the water cycle; both nationally and locally. GEUS has taken part in a number of research projects aiming at improving emergency preparedness, flood management and at studying how flooding affects the infrastructure and water resources. Results from these projects will be used to prepare water plans.

The measurement programme on the Greenland ice sheet is supplying ever better data, and with the Technical University of Denmark, GEUS has carried out new aerial measurements of the margin and reconstructed glacier variations and climate change over the past 120 years.

The portfolio of tasks for 2011 has demonstrated that GEUS has commenced realisation of its new 'Knowledge for Growth and Welfare' strategy, and with the vital social tasks of which GEUS is a part, we look forward to coming years with great optimism.

Per Buch Andreasen
Chairman of the Board

Johnny Fredericia
Managing Director

Databanks and information

Storage, quality-assurance and presentation of geological knowledge and data

User-friendly access to more data on wells and water

The Jupiter database run by GEUS is a public-sector database with nationwide information on wells, groundwater and drinking water. The database is part of the Danish Nature & Environment Portal, together with other nationwide databases with nature and environmental information. The database is used every day by employees from municipalities, regions and agencies who work in groundwater, environment and mineral resources management. In 2011, several new WMS and WFS services for the Danish Nature Agency were developed so that employees working with water and the environment can get access to various topics compiled from the Jupiter database directly in their own IT systems. Data include information on wells and soundings as well as the presence of various chemical substances in the groundwater. The topics are also available via the GEUS website, and at the end of the year they included four general topics with information on extraction wells and types of water as well as information on ten groups of substances, such as pesticides, and 41 individual substances. For some time the public have been able to check the quality of drinking water from their local water works. They can still do so, but this facility is now available through other search options in the Jupiter database.

Digital geological map of the whole world

Geological maps are an important key to understanding nature and its resources, and today they are used extensively to address and solve environmental and resources problems. In 2011, GEUS completed compilation of a new digital geological map of Greenland on the scale 1: 500 000. Together with a digital map of Denmark, the new map is contributing to the largest and most ambitious geological mapping project ever, in which geologists from 117 countries are working together to establish a global geological foundation for management of the Earth's nature and resources. This is taking place under the OneGeology project, which aims at preparing a digital geological map of the entire world on a scale of 1:1 000 000 or better. Geological surveys and other research institutions supply data to a webportal, from which the data are accessible as a dynamic geological map, which is constantly being updated as new data tick in from around the world. The map presents the rocks beneath our feet in the same way as Google Earth presents maps of the Earth's surface. In this context, GEUS has also prepared a Danish version of a geological teaching programme for children called 'OneGeology for kids', and this is also available via the www.onegeology.org portal.

New book on geological wonders

In 2011 the Danish book: Geologiske Naturperler – danske brikker til Jordens puslespil (Geosites – Danish pieces of the Earth's jigsaw) was published by Gyldendals Forlag. The book has been published in collaboration with GEUS and it is intended as a sort of geological-geographic canon with descriptions of selected sites in Denmark which have in a unique way helped international science to put together the jigsaw which makes up the history of the Earth.

The book describes 12 extremely important types of locations, known as GeoSites. This is a formal term, which means that the locations illustrate an element in the development of the Earth or life, which is especially well documented in Denmark and which is one of the best examples internationally and scientifically. Two of the Danish GeoSites in the book are Stevns Klint on Sjælland and Molerklinterne near Limfjorden, both of which have been included in the tentative list of World Heritage sites. Each site description in the book is a complete individual history, and together they make up the experiences, which demonstrate the diversity and uniqueness of Danish nature. The aim of the book is to spur interest and curiosity, as well as to help the reader understand the geological and geographic information in the landscape. Parts of the book could be included in basic natural science courses at upper secondary schools.

Treats for upper secondary schools

Never before has geoscience meant so much for society. Without a good geoscientific foundation, we cannot exploit, manage or understand the resources; water, energy, building materials and minerals. In 2011, a new subject, Geoscience A, was introduced in upper secondary schools. In this connection, in a special edition of its geoscience magazine, Geoviden, GEUS and its partners at Geocenter Denmark presented a taste of what the new subject could include. The object of the magazine is to inspire and initiate establishment of the subject at Danish upper secondary schools. In connection with the general academic courses (AT) at upper secondary schools, GEUS presented a series of materials on its website to support the AT topic for the year: monitoring by using modern technology. The materials include articles, leaflets and thematic pages on GEUS' monitoring of the groundwater, the Greenland ice sheet and earthquakes.

Provision of knowledge to optimise the management of Danish water resources

Water resources

The impact of climate change on the water cycle

Calculations show that climate change will affect the water cycle in Denmark considerably. It is likely that there will be both flooding and, periodically, more water shortages. The HYACINTS project, headed by GEUS, is developing better tools to assess the size of the impacts both nationally and locally. The project is working to couple meteorologists' climate models directly with the hydrological model, which calculates water flows in the ground and on the surface.

Another part of the project is assessing the uncertainties in the calculations, so that prognoses can be as realistic as possible. This work has included an analysis and assessment of the uncertainties throughout the entire chain of calculations, which span from calculations in the global climate model, to calculations of groundwater flow in which local soil parameters, for example, are a controlling factor. It appears that the uncertainty in the climate models has greater significance than the uncertainty in the groundwater models. Another result is that the uncertainty regarding temperature, potential evaporation and precipitation in the climate models has been assessed. This is important information, which has already been used in several other research projects, including a project in which GEUS is working with the Danish Road Directorate on securing a new motorway near Silkeborg against future flooding. Several Danish research institutions, consultancy firms, water companies and authorities are taking part in the HYACINTS project, and it is being funded by the Danish Council for Strategic Research.

Securing the infrastructure against climate impacts

The cloudbursts in recent years have caused problems for the Danish infrastructure, including large amounts of water on roads. Climate models predict heavy rainfalls in the future which will exacerbate the problems. The new motorway through Silkeborg is one place where things may go wrong because a stretch of the motorway is to be sunken to avoid noise problems. The groundwater aquifers are high on this stretch and the installations around the motorway will block more than half of the water-carrying layers, and this could mean risks of flooding and pressure on the road construction when the groundwater rises during heavy downpours.

Therefore, a research collaboration has been set up between GEUS and the Danish Road Directorate to assess the significance of future groundwater conditions for dimensioning this section of the motorway. Since the start of the project in 2010, researchers from GEUS have been mapping the groundwater flows and they have set up a groundwater model of the area. Calculations have been made of how the future climate is likely to affect the groundwater levels around the motorway in extreme conditions. The calculations are based on data from climate models which are still very uncertain. "It's impossible to eliminate all uncertainty," says Jens Christian Refsgaard from GEUS, who is leading the project, and he continues, "there isn't just one figure for future precipitation, and the various climate models give very different results. So we provide an interval for the likely extreme groundwater levels and leave it to the decision-makers to decide which level to use."

New technology to remediate soil and water contaminated with pesticides

More than 99% of Danish drinking water comes from the groundwater, and usually this water is of very high quality. However there are still pesticide residues in the groundwater and therefore it is very important to develop new techniques to protect the drinking-water resource. GEUS is heading the MIRESOWA project, which is developing new microbiological techniques to remediate soil and drinking water contaminated with pesticides.

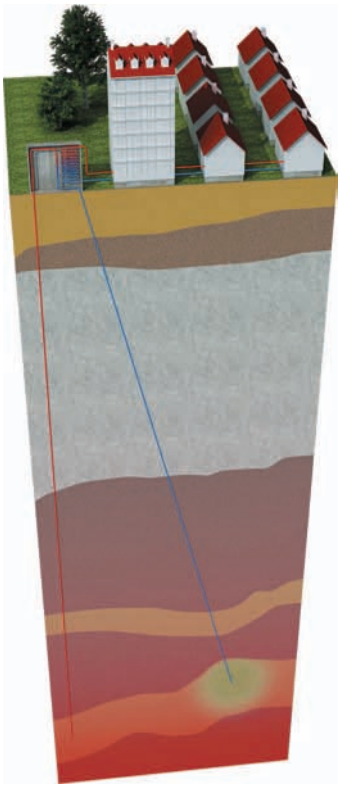
Both microfungi and bacteria can break down pesticides, and the research is focussing on establishing microbial consortia comprising bacteria and fungi in order to achieve effective and complete degradation. GEUS is working on adding pesticide-degrading micro-organisms to the soil and to zones around drinking-water wells, as well as to sand filters at waterworks in order to purify the water. One specific bacterium has been effective in the sand filters at waterworks. In preliminary tests it removed up to 50% of the pesticides in the drinking water, and an optimised installation would improve this effect. With regard to soil remediation, fungi have proved to be effective when they are used with bacteria.

There is also an educational element in the project in which two postdocs, six PhDs and several thesis students are learning about microbiological techniques. The project is being funded by the Danish Council for Strategic Research and it is a collaborative project between research institutions in Denmark and Belgium as well as authorities, water utilities, and enterprises.

Mapping Danish groundwater

The national groundwater mapping continues apace at the Danish Nature Agency. Work includes mapping areas of special drinking water interest (OSD) and catchment areas for waterworks outside these areas. As a specialist datacentre, GEUS is assisting the Danish Nature Agency with technical coordination and advisory services, so that national groundwater mapping is as uniform as possible in situations where there are comparable issues.

A wealth of data have come out of the mapping, and in 2011 GEUS systematically worked to ensure that all the data and interpretations from the mapping are reported to the Survey's nationwide databases of wells, groundwater, geophysics, reports and geological models. Work is firstly on documenting the mapping, and secondly on ensuring that data and interpretations are accessible for public authorities, consultants and waterworks. Similar work has commenced to collate the hydrogeological GIS themes described in the administrative basis of the groundwater mapping. GEUS has also worked on developing a new GIS theme which includes the most important groundwater aquifers; a theme which will also form the foundation for the subsequent more specific mapping of aquifers such as maps of clay thickness and potentials. An application has been developed to calculate the location of well intakes in groundwater aquifers and deposits. GEUS has also worked on ensuring that geological data from new inspection boreholes are rapidly quality-assured and entered into the Jupiter database. This work has included development of an application to input data which have not been collected by GEUS. Finally, GEUS has taken part in working groups at the Danish Nature Agency and published reports and guidelines which are available (in Danish) on the website: Grundvandskortlægning.dk.



Green energy from shallow geothermal wells

A new project started in 2011 to obtain more knowledge and tools to exploit the energy in geothermal wells, where heat is obtained from holes drilled into the subsurface down to a depth of 100–300 metres. The method can potentially contribute to significantly reducing CO^2 emission to the atmosphere, but its use in Denmark is limited compared with Germany and Sweden. There is a lack of knowledge and experience, and the aim of the project is to pave the way for more extensive use of the technology. The project is focusing on heating and cooling buildings as well as storing energy in the ground, and currently data on the thermal properties of Danish soil types are being collected as well as information on the heat flows in the upper 300 metres. In this connection, researchers are developing a publicly accessible database. Furthermore, researchers are investigating drilling methods and sealing techniques as well as assessing systems with a view to optimising the technology. Finally, the project is assessing the groundwater and heat flows as well as the energy balance in the soil in order to protect the environment as much as possible, and to establish cost-effective and well-functioning installations. The project is being led by GEUS and supported by the energy technology development and demonstration programme (EUDP) under the Danish Energy Agency. Other Danish institutions and companies are also taking part.

Great interest in geothermal energy

Climate change calls for new energy solutions which can reduce emission of CO^2 to the atmosphere. Heat from inside the Earth in the form of geothermal energy is one of the renewable energy sources available. In Denmark, geothermal energy is exploited by plants on the island of Amager and in Thisted, where hot water is extracted from water-carrying layers lying 1–3 kilometres down in the subsurface. In 2009, GEUS published an extensive assessment of the Danish geothermal potential, and since then the Survey has seen a strong increase in interest in geothermal energy. Therefore, during 2011, GEUS advised about the geological opportunities for exploiting heat in the subsurface close to a number of urban areas in southern, mid- and northern Jylland as well as several sites in the Copenhagen area. Furthermore, in cooperation with the geothermal energy company under the Danish District Heating Association, GEUS drew up a report describing insurance conditions, subsidy schemes, and a model for assessing and maturing geothermal energy projects. Finally, GEUS continued its research in geothermal energy, with special focus on reducing the uncertainty in geological prognoses. This project is being funded by the Danish Council for Strategic Research.

Focus on the oil potential in North-East Greenland

There is great interest in Arctic oil resources and no less than 13 oil companies are now active in exploration in West Greenland and Baffin Bay. In 2011 the Bureau of Minerals and Petroleum (BMP) in Nuuk announced two new licensing rounds to take place in 2012 and 2013, for an offshore area in North-East Greenland. Since 2007, GEUS has been surveying the onshore area in order to update and expand understanding of the oil-geological potential of the area; work which will help prepare the offshore area for the licensing rounds. The research project is being conducted in collaboration with the oil industry and in 2011 field work involved the strata from the Cretaceous Period in the area from Traill Ø to Hold with Hope. Several teams of geologists worked during the summer to understand the area's geological and structural development, and they collected samples for dating and chemical analysis. At Hold with Hope, geologists completed a 170 m deep drilling of the Cretaceous strata to assess the possibility of finding reservoir, seal and source rocks. The results of the surveys in North-East Greenland were introduced to the oil industry at workshops during the year, and GEUS has provided consultancy to BMP for the new licensing rounds as well as Cairn's five drilling operations in connection with the company's exploration activities in West Greenland.

Delimitation of the continental shelf around Greenland

In 2004, Denmark ratified the United Nations Convention on the Law of the Sea, which opens for opportunities to claim subsurface and seabed resources outside the 200-nautical-mile limit. Any claims have to be documented, primarily with data on sea depths and sediment thickness. As project manager for the Continental Shelf Project, since 2003, GEUS has been busy collecting and interpreting data from the five areas in question. These include one area in the Arctic Ocean, two off North-East Greenland and South Greenland as well as two areas north-east and south-west of the Faroe Islands. In August/September 2011, the EAGER 2011 cruise was completed by the Swedish icebreaker Oden offshore North-East Greenland, in which bathymetric, seismic and gravimetric data were acquired. These data will be included with other, previously acquired, data in the documentation for the claim in the area offshore North-East Greenland. Finally, work on data documentation for the area south of Greenland was completed in 2011. It is planned to submit the claim to the UN around 1 July 2012. The Continental Shelf Project is being funded by the Ministry of Science, Innovation and Higher Education, with contributions from the Faroese Government, and work is being carried out in collaboration with other institutions from Denmark, the Faroe Islands and Greenland.

Marketing the minerals of Greenland

During 2011, GEUS participated in a series of activities to market the mineral resources of Greenland to the international mining industry, in cooperation with the Bureau of Minerals and Petroleum (BMP) in Greenland. These included participation at minerals conventions and events in Canada, Australia and China. In January and March, at minerals conventions in Vancouver and Toronto, GEUS and BMP had stands at which they presented the geological environments of Greenland and the potential for copper, nickel and rare-earth elements (REE). Activities in Toronto included a Greenland feature day – Greenland Day – arranged by BMP, at which geologists from GEUS presented data from their surveys in South-East Greenland.

A similar feature day took place later in Perth, Australia, where REE and base metals, for example, were featured. Finally, GEUS and BMP were present with a stand at the China Mining Congress and Expo in Tianjin, offering materials and information about various mineral resources in Greenland and about legislation with relevance for exploration and exploitation. This represented the first marketing of Greenland's mineral resources in China, and activities included a series of presentations by BMP and GEUS as well as the companies Avannaa Resources and London Mining, which are both active in exploration work in Greenland, as well as Sinomine Resource Exploration Co.

South-East Greenland close up

Following several years of geological surveys in South-West Greenland in order to appraise the mineral potential in the Archaean block, GEUS is now undertaking similar work in South-East Greenland between 62°N and 67°N. This is one of the least explored areas of Greenland, and to make up for the missing data, in 2009 and 2010 GEUS performed geological reconnaissance and geochemical surveys. Furthermore, in 2011, full survey and appraisal work of the region's geology and mineral resources was commenced, and several teams of geologists carried out detailed geological surveys and mapping.

Initially, the appraisal work is focusing on the Skjoldungen area between 62°N and 64°N, where, during the summer, samples were collected in order to determine the age of the rocks and for use in geochemical, mineralogical and petrological analyses. Field work in 2011 also included follow-up of results from the two previous years, in which samples collected showed various chemical anomalies, which could be related to mineralisations. On the basis of this work, new, small nickel mineralisations were discovered, which in the follow-up proved to be greater in extent than previously inferred. The work is being carried out in cooperation with the universities of Aarhus and Copenhagen, as well as with universities in South Africa, Germany and Australia. The work is being funded by GEUS and BMP in Greenland.

Mineral resources at sea and a new database

In Denmark, we primarily excavate mineral resources on land for use in the building and construction sector. Increased extraction on land in some areas conflicts with desires to preserve landscapes and nature, and GEUS is therefore working to find suitable mineral resources at sea, which can be exploited sustainably. In 2011, GEUS completed its report to the Danish Nature Agency on a major survey of the North Sea, which took place in 2010. During the year, a major survey of 26 areas in the Kattegat and the western part of the Baltic Sea was completed, also on behalf of the Danish Nature Agency.

Activities in the North Sea and the coastal waters included a survey of mineral resources and habitats on the seabed. In 2011, GEUS also launched its new national database for marine geological metadata, MARTA. This database contains all shallow seismic data acquired in Danish waters, i.e. data which are to be reported to GEUS pursuant to the Mineral Resources Act. MARTA is an important tool in the management of mineral resources at sea and in the protection of marine habitats. In December, GEUS hosted a workshop on the database providing users with an overview of what the database contains, how the online map services work, as well as the range of possible uses of the database. Finally, GEUS hosted a workshop for employees at the Danish Nature Agency. The purpose of the workshop was to provide the employees with up-to-date knowledge about routines, tools and professional challenges associated with surveying mineral resource and habitats at sea.

Expert appraisals of zinc and copper

World demand for zinc and copper is considerable, and Greenland has potential for both metals. In 2011, GEUS hosted a workshop to evaluate the potential for sedimentary zinc deposits in Greenland. In addition to experts from GEUS, international experts on zinc deposits and several exploration and mining companies participated in the workshop. The workshop followed a standardised procedure in which a panel of experts debated and appraised possible undiscovered zinc deposits within delineated areas following a review of data, literature, earlier work, maps, etc. A report on the conclusions of the experts is expected to be published in mid-2012. Similar workshops were held in 2009 on the potential for sedimentary copper deposits in Greenland and in 2010 on rare-earth elements (REE). In 2011, GEUS published reports with results from these workshops. Some of the main conclusions from the two workshops were presented in two editions of the Geology and Ore magazine. It appears from the results that Greenland has several sedimentary areas deemed as favourable and which show signs of the mineralisation processes necessary for the formation of copper deposits. All three workshops were arranged in cooperation with BMP in Greenland.

Glacier responds quickly to climate change

The Greenland ice sheet is contributing considerably to the rise in global sea level. In the early 2000s, several of Greenland's glaciers began suddenly to calve, melt and shrink at a far quicker pace than previously, and the ice sheet lost considerable mass. One of these glaciers is Helheimgletscher, the third-largest in Greenland. Over several summers, GEUS geologists have been collecting sediment cores with climate information from the Sermilik fjord in South-East Greenland into which the Helheimgletscher empties, to understand the relationship between climate variations, sea currents and changes in the ice sheet. Results from the research project were published in 2011 in Nature Geoscience, documenting large fluctuations in calving patterns over the past 120 years.

The results also show that the rate of calving in the 1930s was equal to the rate we are seeing today. Thus the studies suggest that these periods of increased calving are linked to periods in which the area off the coast of South-East Greenland is relatively strongly influenced by hot Atlantic water and less so by cold water from the north, and by warm summers and the phase of the North Atlantic Oscillation (NAO). The studies document that the Helheimgletscher reacts to short-term, three-to-ten-year changes in sea currents and atmospheric conditions. The studies were carried out in cooperation with researchers from Woods Hole Oceanographic Institution, USA, the Danish Meteorological Institute and the University of Copenhagen, and they are a part of the SEDIMICE project, which is being funded by the Free Research Council, and Geocenter Denmark.

An extreme year for the Greenland ice sheet

To date, 2010 was the most dramatic year since measurements of the ice sheet began. The summer melt season lasted longer and the ice melt was greater than ever. Such was the message in the first newsletter issued in 2011 by glaciologists from GEUS, which is heading the PROMICE project. The project is monitoring the loss of mass from the Greenland ice sheet. In 2010, the ice melt measured by glaciologists in West Greenland was as much as 70% above the more normal year, 2009. Monitoring is being performed by 24 fully automatic monitoring stations, which measure the ice melt, the climate and ice movement, and then submit the data to GEUS in Copenhagen via satellite.

The glaciologists supplement surface measurements with measurements by aircraft and satellite. In 2011, the height and thickness of the edge of the ice sheet were measured by aircraft in cooperation with the Technical University of Denmark. Danish monitoring activities are being supplemented with measurements from several foreign measuring stations on the ice. In upcoming years, overall international efforts will provide a more accurate picture of the degree to which the ice sheet is melting, and thus how much this is contributing to global sea-level rises. PROMICE is being financed by the DANCEA programme (Danish Cooperation for Environment in the Arctic) under the Ministry of Climate, Energy and Building.

Satellite monitoring of European coastal areas

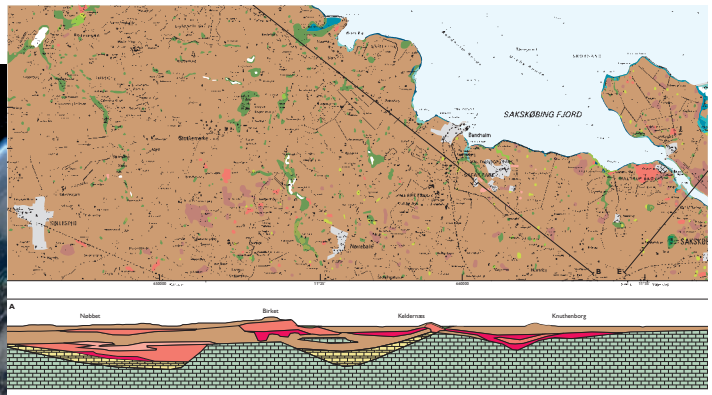
A great proportion of the Earth's population live in low-lying coastal areas, which are vulnerable to storm surges, tsunamis and effects of climate change, such as increases in sea level and flooding of estuaries due to increased runoff from rivers. The European project SubCoast is spotlighting coastal areas in danger of coastal subsidence. Using satellite radars, it is possible to measure land movement to millimetre accuracy. This is taking place in three test areas in northern Italy, at the coast of the Netherlands and in the Baltic area, where subsidence of e.g. dikes can be of great significance.

Together with Polish and Lithuanian actors, GEUS is participating in work in the Baltic area to map land subsidence and thereby identify the vulnerability of coastal areas to sea-level rises and storm surges. Surveys in the area around Rødby in Denmark have shown that the salt diapirs in the subsurface are still very active, causing land uplift. Satellite data show that the dikes along the south coast of Lolland are stable, although with minor depressions in the soft-ground area east of Rødbyhavn. In June 2011, GEUS hosted an experience-exchange workshop for the European partners in the project. The project, which is being financed under the EU 7th Framework Programme, is associated with the extensive satellite monitoring programme, GlobalMonitoring for Environment and Security (GMES), which is being managed by the European Commission in cooperation with the European Space Agency and the European Environment Agency.

Geological maps for planning and management

Geological maps are an important tool in spatial planning and management, and surface geological maps are being used increasingly by local authorities in connection with work related to groundwater protection and zoning, soil contamination, preservation, set-aside, operations planning, afforestation, wetlands, as well as development and infrastructure planning.

In 2011, field work included mapping the Mariager Fjord area. Furthermore, the Nykøbing Falster map sheet on a scale of 1:50 000 was published. The map data collected in the field are digitalised on an ongoing basis and included in a map database, to which users can subscribe for data and updates to existing map sheets. Furthermore, the soil maps on a 1:25 000 scale have been published as an overall Quaternary geological base map on CD-ROM, and in 2011, the most recent update was published, so that now the base map contains all areas mapped in Denmark up to spring 2011.



Groundwater mapping in Thailand

In many parts of the world, groundwater is an important drinking water resource and efforts have been launched in many places to assess the size and vulnerability to contamination of ground water. In 2011, GEUS took part in a pilot project for the Department of Groundwater Resources in Thailand. The project is testing the applicability of the SkyTEM method to map groundwater reservoirs in a 1,000 km^2 test area in the Upper Central Plane, around 350 km north of Bangkok.

The activities were carried out in cooperation with the Danish company, Danwater. GEUS' contribution concentrated on delivering and implementing a geophysical database, as well as providing know-how and assistance with the SkyTEM mapping efforts. GEUS submitted Terms of Reference (TOR) for the airborne TEM measurements, geologists/geophysicists contributed to a training course in Bangkok and subsequently planned and hosted a 30-day training course for eight Thailanders in Denmark. Finally, considerable on-line assistance and consultancy were offered throughout the year.

Capacity building in Vietnam – phase three

The oil and gas sector is important for Vietnamese society. GEUS has been active in Vietnam for several years, and is currently active in the third and final consolidation phase of a cooperation project between GEUS and the Vietnam Petroleum Institute (VPI). The project's ambition is to enhance Vietnamese skills to appraising the country's oil and gas resources. The project is being financed by the Danida's ENRECA programme, and the third phase continues the work of two previous phases, where Vietnamese researchers were trained in oil geological disciplines through teaching and completion of specific research projects.

The project aims not only at capacity building at VPI, but also at enhancing cooperation with universities in Vietnam and Denmark. With teaching capacity from the University of Copenhagen, the project is conducting joint MSc/PhD programmes for young researchers and students from VPI, Hanoi University of Mining and Geology (HUMG) and Hanoi University of Science (HUS). The project's third phase is concentrating on oil geological research in the Song Hong Basin, and the guiding principle of the project is to help Vietnamese researchers and students to help themselves. In 2011, work included planning an ENRECA-3 well on the island of Bach Long Vi in the Gulf of Tonkin, which is a site of great interest for researchers and local oil companies alike. During the year, eight students followed the joint MSc/PhD programme, which involves PhD students trained during earlier phases of the project as a training resource. Towards the end of 2011, GEUS arranged an oil and gas seminar in Hanoi, which coincided with the visit by a Danish trade delegation to Hanoi, headed by the Danish Crown Prince Frederik.

GEUS around the world

Knowledge-building in developing countries through research and consultancy

Environment-friendly and more viable small-scale mining in the Philippines and Indonesia

In recent years, on behalf of the World Bank, GEUS has been working in several developing countries to map the extent of small-scale mining and has advised on a more environmentally friendly practice in this type of mining. Small-scale mining (SSM) is an important source of income for up to 100 million people throughout the world. Mineral mining often takes place under very poor safety conditions in cramped and deep shafts. Mercury is used in gold mining and this causes enormous environmental and health problems if it is not managed properly. In 2011, GEUS was active in the Philippines and Indonesia, where local gold miners and physicians were taught the symptoms of mercury poisoning.

Activities included an introduction of a promising alternative gold extraction method using borax. This method has a series of benefits: it is not harmful to the environment or human health, and the process yields more gold. Furthermore, an instruction video in the use of borax was produced during the year. The video can be viewed on GEUS' website and YouTube. Finally, activities in the Philippines included developing and testing a method for the removal of mercury and gold residues from tailings already in the environment. This work received funding from The Sumitomo Foundation in Japan.

Improving knowledge about the climate and water resources in Tanzania

The fourth report from the Intergovernmental Panel on Climate Change (IPCC) highlights Tanzania as one of the countries most vulnerable to climate change. Climate predictions show that we can expect large variations in many climate conditions, especially precipitation, which has major significance for agriculture and life in general. GEUS heads the climate project CLIVET, which, through research and development, builds knowledge and capacity in Tanzanian institutions, so that Tanzania will be better able to adapt to future climate change.

The project includes climate studies and calculations of hydrological conditions in the large Ruaha River Basin, where conflicting interests, e.g. agriculture, hydropower and national parks, compete for the scarce water resource. The purpose of the water resource studies is to create a better foundation for new strategies for how Tanzanian agriculture can best adapt to the new climate conditions. In 2011, GEUS prepared a hydrological model for the upper part of the river basin. Furthermore, training of three African MA students and three PhD students commenced at the relevant institutions in Tanzania. The project has also attracted great attention in Denmark, where four MA students and two BA students from the University of Copenhagen were involved in different aspects of the project. GEUS is cooperating with the following institutions in the project: the Department of Geography and Geology at the University of Copenhagen, Danish Climate Centre at the Danish Meteorological Institute, the Institute of Resources Assessment and the Faculty of Engineering both at the University of Dar es Salaam and the Tanzania Meteorological Agency. The project is funded by Danida.

Better knowledge about earthquake risk assessment

The risk of an earthquake in the Nordic region ranges from very high in Iceland, to very low in the Baltic States. However, as society becomes ever more high-tech, the risk of earthquakes has to be considered when developing infrastructure, even where the risk of an earthquake is low. The recent earthquakes in New Zealand and Japan are examples, which clearly show that even remote earthquakes can affect our economy and the choices made by companies and private individuals. With support from NordForsk, under the Nordic Council of Ministers, GEUS has been commissioned over the next three years to head a Nordic research network on earthquake risk. “We want to exploit the specialist competences within earthquake risk assessment available in the Nordic and Baltic seismologic research groups, so that our technical knowledge throughout the region is enhanced,” says Peter Voss from GEUS, who has received a grant of DKK 800,000. The work of the research network will include training of students in earthquake risk assessment tools.

On-the-job training and student jobs

In cooperation with its partners in Geocenter Denmark, GEUS offers on-the-job training for pupils at municipal primary and lower-secondary schools. In 2011, twelve pupils were in on-the-job training at the Geocenter, where they had the opportunity to discover what geologists actually do. The pupils spent two days at GEUS and one day at the Geological Museum and the Department of Geography and Geology at the University of Copenhagen, respectively. Furthermore, GEUS organised a field trip to Stevns Klint, where the pupils experienced geology first hand at the world-famous site. The on-the-job training programme also includes a reporting phase, and upon completion of the programme most of the pupils handed in a report on their experience. Both pupils and parents expressed great satisfaction with the programme, which will continue in 2012. Finally, has been GEUS striving to increase recruitment of geology students from Greenland, and in this context, a scheme was introduced, which guarantees student jobs for all students from Greenland enrolled on a geology study programme at Aarhus University and the University of Copenhagen.

GEUS geologists in demand

Geologists from GEUS were in demand during the Day of Research and the Danish Science Festival in 2011. At both events, researchers from GEUS visited several schools to lecture on subjects ranging from groundwater and earthquakes to ice and the climate. Both primary schools, and lower and upper secondary schools were afforded visits, and several students and teachers expressed their great satisfaction with the breath of fresh air provided by the lecturers. In the autumn, Copenhageners were given the opportunity to learn more about energy at a popular event at the Danish Energy Agency during the Night of Culture. At this event, GEUS and other agencies and institutions under the Ministry of Climate, Energy and Building showed visitors how energy is made, how to save energy, and how our energy consumption will affect the future climate.

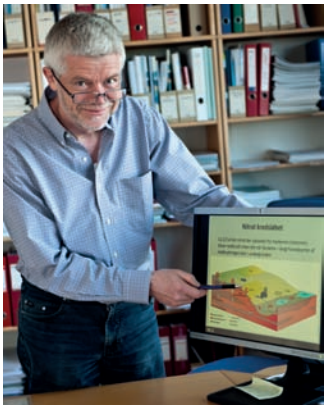
New research professor

In 2011, a new research professor joined GEUS. Jochen Kolb took up the position of research professor of ore geology at the Department of Petrology and Economic Geology at GEUS, where he is to help strengthen research within ore-forming processes. Jochen Kolb has worked as senior researcher at GEUS since 2007, and has worked in particular with Archaean geology in Greenland as well as gold and iron-oxide-copper-gold ore deposits (IOCG). Professor Kolb has a PhD on gold mineralisation in the Renco mine in Zimbabwe from RWTH Aachen University in Germany. From 2000 to 2007, Jochen Kolb was employed as lecturer and senior researcher at this university, where he also attained his professor qualification. He has worked in India, Namibia, Mauritania and the Philippines. In the Philippines, he participated in a six-month research project in his capacity as senior researcher at the University of Western Australia in Perth.

A plethora of prizes and medals for GEUS employees

Several employees at GEUS were awarded prizes and medals in 2011 for their work. In mid-March, senior researcher Troels Frederik Daugaard Nielsen was awarded the Danish Geology Prize for his comprehensive and innovative contribution to the understanding of Greenland's magma rocks and their mineral content. At the end of March, senior researcher Jonathan Ralph Ineson was awarded the British Polar Medal for his surveys of sediment basins in North Greenland and Antarctica. The medal was presented by Prince Charles, at an official ceremony at Buckingham Palace in London. Later in the year, senior consultant Niels Springer, received the Regional Service Award 2011 from the Society of Petroleum Engineers for his long and professionally strong involvement in the oil and gas industry in the North Sea. In December research professor Jens Christian Refsgaard from GEUS and professor Karsten Høgh Jensen from the University of Copenhagen received the *G.O. Andrup's Grundvandspris* for their more than 30 years' work on developing groundwater modelling as a discipline. During a seminar in Hanoi, Vietnam, project manager Ioannis Abatzis was presented with a prize by the vice-president of PetroVietnam for his more than 15 years' cooperation with the oil and gas sector in Vietnam. Finally, Jakob Lautrup received the royal Danish Medal of Merit for 40 years of service as a photographer, especially in Greenland.

GLIMPSES of the year



Key figures 2011

More detailed key figures for the activities of GEUS are available in Årsrapport – Regnskabsåret 2011 (Report and Accounts 2011), and in Faglige resultater 2011 (the latter in Danish only). Both of these are available at www.geus.dk – publikationer – institutionsrapporter.

Number of employees: **324.5**
Number of scientific projects: approx. **600**

ACCOUNTS 2011

Amounts in million DKK	
Revenue:	**338.3**
Net figure (appropriation):	141.7
Operating income:	196.6
Expenditure:	**328.3**
Salaries:	171.3
Other operating expenditure:	157.0

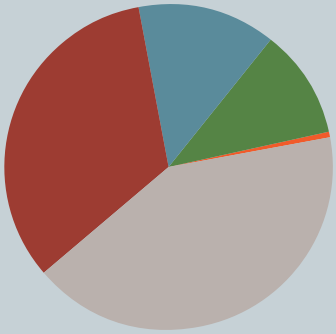
PRESENTATION ACTIVITIES

Long-term knowledge building	
Articles in international scientific journals/publications	120
Articles in GEUS' own scientific series	25
Other scientific publications	10
Conference contributions with abstracts or posters	194
Ongoing scientific tasks, consultancy and presentation	
Publicly available reports	85
Confidential reports	94
Memoranda, opinions, expositions etc.	99
General presentation	
Institution reports (annual report etc.)	7
General and popular-science presentations	102
Memoranda, opinions, expositions etc.	54

RESEARCHER TRAINING WITH GEUS TUTORS

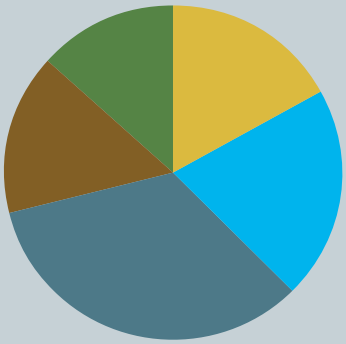
Current PhD students	67
Completed PhD degrees	17

Revenue broken down by sources of revenue in million DKK



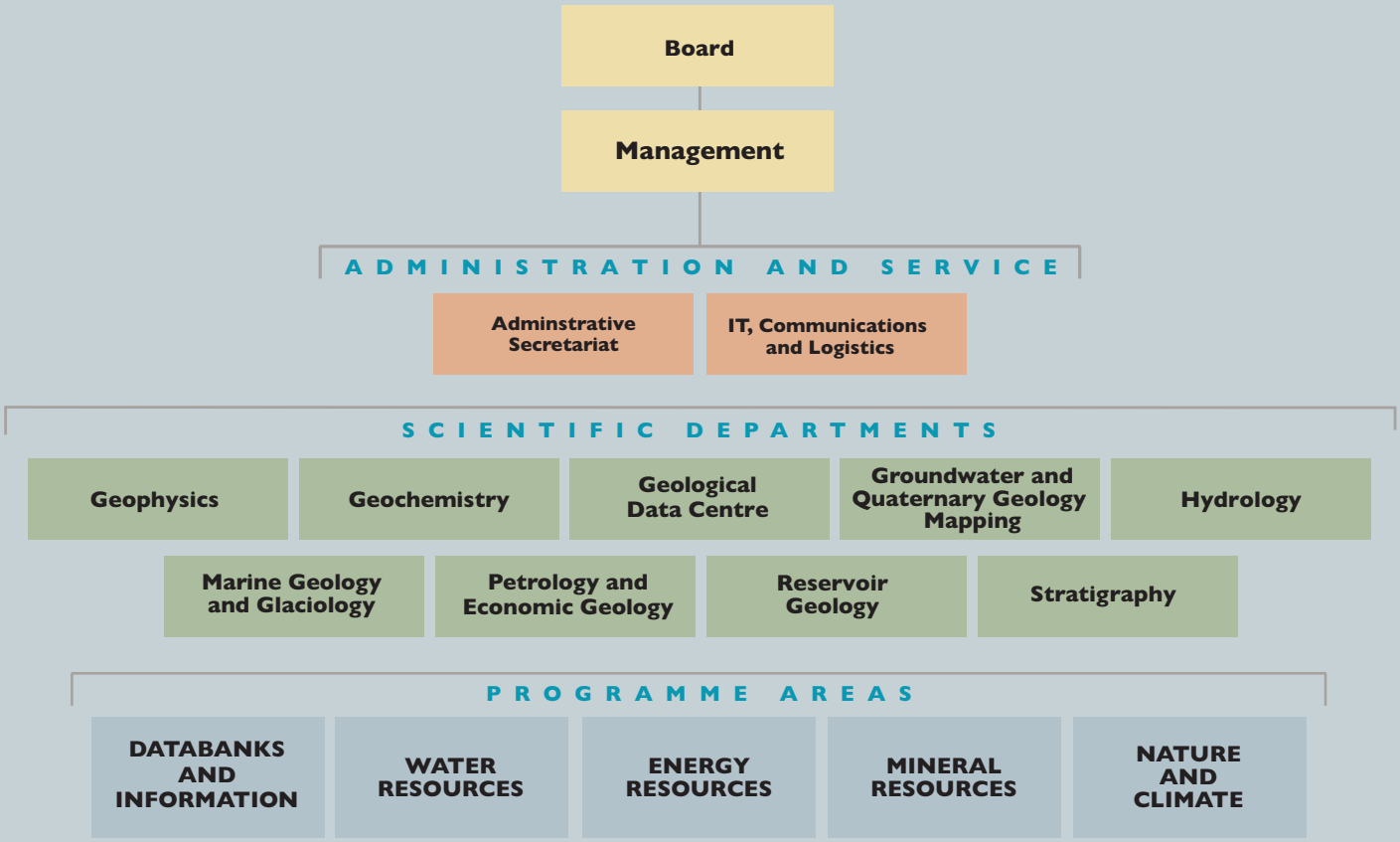
National budget and supplementary government appropriations:	141.7
Programme and external resources:	112.5
Other co-financed contract research:	46.5
Commercial contracts and sales of data:	36.5
Other revenue:	1.1

Expenditure broken down by programme area in million DKK



Databanks and general information:	55.7
Water resources:	67.5
Energy resources:	110.4
Mineral resources:	51.0
Nature and climate:	43.7

Organisation



In 2011 there were nine research departments at GEUS and two administrative/service departments.
Scientific work is being done in five programme areas, where tasks are carried out in project groups in a matrix structure.

PROGRAMME AREA:
DATABANKS AND INFORMATION
Archiving and data processing in connection with statutory reporting of geodata to GEUS. The aim is to establish a level of quality of data and sample collections which helps work on monitoring, emergency management, advisory services and research. In addition, the programme area comprises IT projects, which ensure efficient and modern IT-tools at GEUS, as well as presentation of data to the scientific community and the public.

PROGRAMME AREA:
WATER RESOURCES
Providing the necessary basis for management of water resources. Activities are directed at the water cycle, the extent and quality of water resources, and transport and decomposition of xenobiotic substances in the aquatic environment, focusing mainly on the groundwater. The activities also form the basis for advisory services to authorities, regions and municipalities.

PROGRAMME AREA:
ENERGY RESOURCES
Providing and contributing the basis for continued exploration and sustainable exploitation of the energy resources of the Realm. This work comprises own research projects and international co-operation within oil/gas and renewable energy. The collected knowledge forms the basis for GEUS' advisory services to authorities in Denmark and Greenland, and also for projects carried out for the industry.

PROGRAMME AREA:
MINERAL RESOURCES
Providing the scientific basis for targeted and environment-friendly exploitation of raw materials and mineral deposits in Greenland and Denmark. This work includes geological mapping and mineral exploration in Greenland, as well as official processing and advisory services for the Greenland Self Government. In addition, surveys are carried out in connection with raw materials and construction work in Denmark and internationally.

PROGRAMME AREA:
NATURE AND CLIMATE
Examining processes in Denmark and the North Atlantic area which have led to the current climate and environmental situation. The objective is to improve the prospects of distinguishing between natural and human-induced environmental changes. The programme area also includes a mapping of onshore and offshore geological conditions, as well as earthquake research and monitoring.

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2011

New strategy for GEUS
Databanks and information
Water resources
Energy resources
Mineral resources
Nature and climate
GEUS around the world
Glimpses of the year

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