Geoscience for society

ANNUAL REPORT 2014
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE, ENERGY AND BUILDING

GEUS

New cooperation agreement with Greenland

A new cooperation agreement to strengthen development of the oil and mineral resources sector in Greenland was signed on 19 August 2014 in Nuuk by the Greenlandic Minister of Industry and Minerals, Jens-Erik Kirkegaard and the Danish Minister for Climate, Energy and Building, Rasmus Helveg Petersen.

The agreement runs from 1 January 2015 to 31 December 2019, and it replaces the previous five-year cooperation agreement. The agreement means that the Geological Survey of Denmark and Greenland (GEUS) will assist in developing and securing geological competences in Greenland through consulting services and specific research and marketing projects. Similarly, GEUS will support development of geological competences and knowledge in Greenland.

The new agreement has three parts: A framework agreement, a project agreement and a consultancy agreement. The framework agreement is the foundation for the establishing of a project agreement and a consultancy agreement.

"I'm proud of the agreement we've drawn up together with the Danish Ministry of Climate, Energy and Building. The agreement means that GEUS will continue to play a major role in the geological exploration and that they will help us actively to enhance our geological competences here in Greenland. I'm very pleased about this," said Jens-Erik Kirkegaard.

"I'm happy that, with the new agreement, we'll be able to continue our long cooperation on developing the minerals industry in Greenland. The agreement also encompasses the direction for development Greenland wants," said Rasmus Helveg Petersen, Danish Minister for Climate, Energy and Building.

Foreword

A continued joint effort in the Arctic was the most important event in 2014, when the Danish Minister for Climate, Energy and Building and the Greenlandic Minister for Mineral Resources, as well as GEUS and the Ministry of Mineral Resources entered into new five-year cooperation agreements. The agreements ensure that the extensive knowledge held at GEUS can directly and without interruption be exploited in developing the mineral resources sector in Greenland. This is crucial, both when the mineral fever is raging and when current or new stakeholders need to be attracted.

A second landmark event was when the Danish Realm delivered its fifth, and for the moment final, submission to the UN Commission on the Limits of the Continental Shelf (CLCS) for the area around the North Pole. The mapping and the specialist work, headed by GEUS, has now been completed, but in the many years over which the negotiations are likely to continue, the foundation will have to be maintained and the submission was a milestone in the history of GEUS.

The Arctic has also attracted a great deal of attention in other fields covered by GEUS. These include monitoring and research on ice melt from the Greenland ice sheet, where a net loss of ice is still being observed; publishing reports about rare-earth elements and uranium of major interest to politicians and the industry; and finally knowledge-building about the geology of Greenland where GEUS' office in Nuuk among other events organised a conference and knowledge-sharing with the Canada-Nunavut Geoscience Office and the Greenland Ministry of Mineral Resources.

Collaboration with geological surveys in Europe reached new heights in 2014, with large joint projects within most fields, including completion of the North Atlantic Tectonic Atlas and establishment of an extensive network on urban geology. GEUS has also been active and carried out tasks on several continents and has helped establish a firm foothold for Danish water-supply solutions in the populous Asian countries.

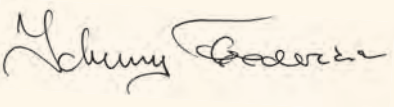
At home, research, monitoring and mapping groundwater resources have kept GEUS busy. Mapping will be completed in 2015, and during the year GEUS took part in important model development work with DHI and the Danish Centre for Environment and Energy. This work will form the foundation for a more differentiated land regulation of nitrate emissions from agriculture as a follow-up on recommendations from the Nature and Agriculture Commission. There has also been focus on the results of GEUS' pesticide monitoring programme.

Within geothermal exploitation of the subsurface for heating – and for cooling – GEUS has worked on identifying suitable reservoirs, including at sites below 28 towns, and also provided advice and guidelines on developing and exploiting geothermal energy.

Finally, the sea and the seafloor have increasingly been attracting attention, and GEUS has published a new nation-wide map of the seafloor around Denmark based on compilation of data from work on the seafloor over several decades. The map is available on GEUS' website.

This annual report describes just a small extract from the broad spectrum of tasks carried out by GEUS over the year. Key figures for the year are included at the end of the report and they show a slight reduction in revenues and thus activity, primarily because of the slow-down in the oil/gas and minerals sectors. This development is likely to impact fully in 2015 and it will challenge GEUS' ability to build up a sufficiently large portfolio of projects. However, GEUS has a strong and robust specialist foundation, ready to tackle new tasks and new types of task.

Minik Rosing
Chairman of the board



Johnny Fredericia
Managing director

Databanks and information

Storage, quality assurance and presentation of geological knowledge and data

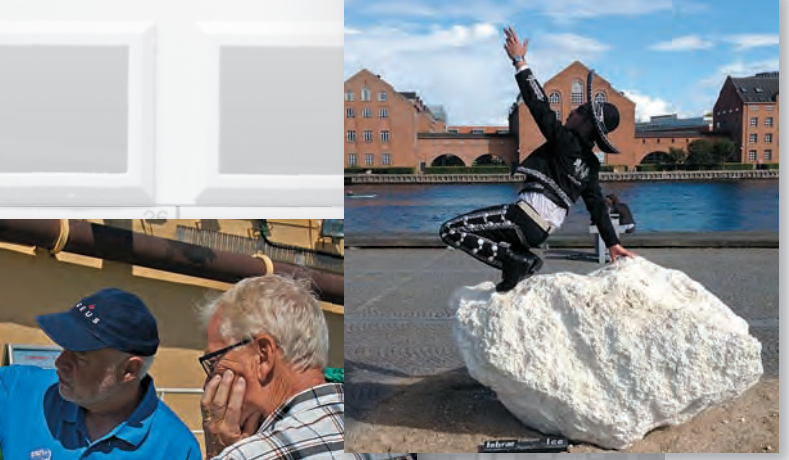
Popular GEUS map and data services

The Jupiter database run by GEUS is a national, common database with nationwide information on wells, groundwater and drinking water. The database contains information from more than 280 000 boreholes and it has been incorporated in the Danish Natural Environment Portal with other nationwide Danish databases containing nature and environment information. The database is used every day by employees in municipalities, regions, agencies and companies working on the groundwater, the environment and mineral resources. GEUS has developed so-called WMS and WFS services for the Jupiter database and other national databases run by the institution, so users can view directly in their own IT systems different themes compiled from the databases. For example, there is information on wells, availability of geophysical data, or the presence of various chemical substances in the groundwater. The services are very popular, and from 2012 to 2014, there were around 200 000 requests per month to the WMS maps service on the GEUS website. Most of this data extraction is for information on wells, water utilities and water extraction sites from Jupiter, but many users have also searched in GERDA, the geophysical database, and in MARTA, the marine mineral resources database, to find information about where geophysical measurements have been made in Denmark and what type of data has been collected. In order to cope with these large demands on the databases, in 2014 GEUS set up new servers for the Jupiter map services in order to provide better response times for users.

Opportunities for a common European infrastructure for geodata

Like the rest of the world, Europe has a growing need for access to data about nature, the environment and mineral resources to manage resources in the best possible way. Therefore exchanging geodata and environmental data is high on the EU agenda. Geological data is an important tool in exploration for water, oil and minerals, or when attempting to minimise the consequences of natural disasters such as earthquakes and volcanic eruptions. In 2014, GEUS completed two EU-funded research projects together with several European sister organisations. Both these projects were to promote exchange of geodata across European countries. The projects were to help implement the EU INSPIRE Directive on the establishment of a common European infrastructure for spatial information to enable easier exchange of data across national borders.

The projects were the Scoping Study for a pan-European Geological Data Infrastructure (EGDI-Scope) and InGeoCloudS. The EGDI project has uncovered opportunities and needs for a common European digital infrastructure for geological data. This includes data from common European projects such as OneGeology Europe about geological maps and EuroGeosource, about mineral resources. GEUS' role in the EGDI-Scope project was to investigate which data sets the users want to be included in the infrastructure and to specify functionality requirements. The InGeoCloudS project has identified opportunities to use cloud computing to share and disseminate geological data at both national and European levels. This included analyses of whether the cloud can be used to store common basic data and to share intelligent services, which can combine data and, for example, deliver themes to aid management of the European resources and environment.



New online shop for the oil industry

In 2014, GEUS introduced a new online shop named FRISBEE where it is possible to search for and buy data regarding oil and gas exploration in Denmark. The database contains reports, logs, merged logs and digital core photographs from released deep boreholes in Denmark. On its introduction in March, FRISBEE invited customers to retrieve data from the Danish sector of the North Sea and pay by credit card or via invoice, and the system was used extensively by the industry in connection with the 7th licensing round in the North Sea. New types of data and data from other parts of Denmark will be added regularly, and later in 2014, data from 71 Danish onshore wells and five wells in the inner Danish waters were added to the database. In this connection, GEUS has been working to expand FRISBEE so that it can also manage seismic data. This version of the system is expected to be put into operation during the first six months of 2015.

Geological communication to schools and the public

In 2014, Danes had rich opportunity to hear about GEUS' research. At the nationwide events, Day of Research and the Danish Science Festival, researchers from GEUS went out to institutions and schools to talk about groundwater, climate change, the geological development of Denmark and delimitation of the continental shelf north of Greenland, among other things. During the major Science in the City festival in Copenhagen, the public could meet marine geologists on board the research vessel Dana where they could get an insight into some of the areas for marine research currently being worked on at GEUS. Aboard the largest icebreaker in Scandinavia, Oden, GEUS researchers talked about mapping the Arctic seabed during four cruises for the Continental Shelf Project. Geology has also been communicated to schools and the public via the Internet. In 2014, GEUS opened its e-learning program 'Når jorden skælver' (When the Earth quakes) in which the most important concepts within earthquakes and plate tectonics are explained and brought alive through illustrations and examples. The website 'Ture til geologiske naturperler' (Trips to geological gems) was also launched, where the public can find easy-to-read descriptions of more than 90 locations in Denmark with interesting geology, and directions to these sites.

Mapping Danish groundwater

National groundwater mapping continues apace, headed by 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 data centre, over the years GEUS has assisted the Nature Agency with professional coordination and consulting services so that the national groundwater mapping can be completed uniformly as far as possible, where there are comparable issues. A wealth of data has been harvested through the mapping, and in 2014 GEUS focussed in particular on ensuring that all data and mapping results were processed and stored in the institution's nationwide databases for wells and water chemistry, geophysics, reports and geological models. The work entails documenting the mapping as well as ensuring that, in future, data and interpretations are available for public authorities, consultants and waterworks, etc. During the year, GEUS also assisted the Danish Nature Agency in assessing and quality-assuring geological and hydrological modelling tasks carried out by consultants in connection with the groundwater mapping. GEUS has reviewed the results of the mapping to identify the location of buried valleys that could contain important groundwater aquifers and could be highly significant for groundwater protection. They have also worked on updating a 3D geological model for the Miocene strata.

New methods to determine nitrate reduction

Nitrate leaching from agriculture must be reduced to comply with the European Water Framework Directive, primarily to improve the condition of Danish inlets and marine areas. Previous regulation has been the same for all areas, without taking into account that the geological conditions for nitrate reduction in the subsoil vary significantly. These general regulations also apply for the parts of Danish agricultural land where the nitrate is degraded in the geological layers between the root zone and the streams.

In 2014, GEUS completed the NICA research project that has developed new methods to map nitrate reduction in the subsoil on a hectare scale, and the results were presented at a seminar for stakeholders in October. Researchers from the NICA project have further developed the SkyTEM method to collect geophysical data from a helicopter so that now it is possible to identify local geological structures and heterogeneities on a smaller scale in the upper 30 metres of the subsurface. Furthermore, models have been developed to estimate nitrate reduction in the subsoil from the bottom of the root zone to the streams. The methods have been tested in the catchment area for Norsminde Fjord around Odder where researchers have assessed prediction uncertainties due to incomplete geological knowledge. The project received support from the Danish Council for Strategic Research and the work was completed in collaboration with Aarhus University and the University of Copenhagen; Laval University in Canada; DHI; Aarhus and Odder municipalities; the Knowledge Centre for Agriculture, and the private companies SkyTEM, ALECTIA A/S and Aarhus Geophysics.

Water resources

Knowledge to optimise the management of Danish water resources

More measurements in pesticide leaching programme

The Danish Pesticide Leaching Assessment Programme (VAP) is a comprehensive monitoring programme to investigate whether approved pesticides leach into young groundwater in concentrations above the limit value. The findings from VAP enable rapid assessment and, if relevant, removal of approved pesticides from the market, if they leach into the groundwater in excessive concentrations. The programme was established in 1999 and today it comprises five test fields in ordinary farming which are treated with pesticides in approved dosages. The fields represent soil and climate conditions in Denmark and they have been instrumented so that pesticides and their degradation products can be monitored from the surface, through the soil column and down to drains and the groundwater. As a result of the Government's Pesticides Strategy 2013–2015, in 2014–2015 VAP received an additional DKK 1 mill. to extract more water samples from the groundwater and to analyse for more substances, while in 2015–2018 a further DKK 2 mill. per year has been granted for a new field and additional analyses. In VAP, researchers have investigated whether 101 pesticides or their degradation products leach into the groundwater. Many of the pesticides tested have not given rise to changes in the approval, but on the basis of the results of VAP and other projects, the Danish Environmental Protection Agency has banned the following substances: metribuzin, terbuthylazin, rimsulfuron, metalaxyl-M and bifenox. VAP is a collaboration between Aarhus University, GEUS and the Danish Environmental Protection Agency.

New methods to remediate pesticide-contaminated soil and water

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. In 2014, GEUS concluded the MIRESOWA project, which has developed new microbiological methods to remediate pesticide-contaminated soil and water.

Microfungi and bacteria can degrade pesticides, and the project has found microbial communities composed of both types of microorganisms which work together on the degradation and are good at remediating pesticide-contaminated soil. Among other things, this is through a more efficient dispersion of the bacteria through the hyphae in the fungi which act as highways for the bacteria to move along in the soil. The researchers have also been able to identify and isolate the first bacteria that can degrade BAM, which is a degradation product from the herbicide dichlorobenil used frequently in the past to combat weeds on courtyards and other uncultivated areas. The degradation capability of the bacteria has been tested at full scale by adding it to a sand filter in mobile waterworks, and the tests have shown that the bacteria can remove 70% of the BAM content in drinking water. Finally, post-docs, several PhDs, and students specialising in remediation technologies received their degrees during the project. The project was funded by the Danish Council for Strategic Research and the activities took place in a collaboration between research institutions in Denmark and Belgium as well as authorities, water utilities and enterprises.

Energy resources

Knowledge for exploration and exploitation of energy resources in Denmark and Greenland

Successful 7th licensing round in the North Sea

The application deadline for the 7th licensing round in the North Sea was in October 2014. At this point, the Danish Energy Agency had received 25 applications for licences for new oil and gas concessions in the North Sea. The Danish sector of the North Sea is a mature area with a well-developed infrastructure, but assessments indicate that large quantities of oil and gas have yet to be discovered, among other things in the less well-known Jurassic layers. The GEUS PETSYS project ended in 2014, which was funded by oil companies active in oil and gas exploration in Denmark. The project has resulted in a detailed Jurassic stratigraphy of the Danish Central Graben as well as a series of paleaogeographic and reservoir-geological maps and seismic structure and thickness maps. Together with analyses of the Jurassic oils and source rock types, these maps have been used to develop a number of 1D and 2D basin models.

At the start of the 7th licensing round, GEUS opened a dedicated web-site with relevant information for the exploration on which companies could find seismic data and maps and they could search for and order well and log data and reports from more than 200 exploration wells in the new GEUS online shop FRISBEE. In connection with the licensing round, and in collaboration with the Danish Energy Agency and Nord-søfonden, GEUS marketed exploration opportunities from a stand at the international oil and gas conference, the 76th EAGE Conference & Exhibition in Amsterdam and held a series of lectures around Denmark. Finally, GEUS assisted the Danish Energy Agency with assessment of geological models and work programmes in connection with the appli-cations for licences.

Delimitation of the continental shelf

In 2004, Denmark ratified the United Nations Convention on the Law of the Sea, which opens for opportunities to claim subsurface and seabed resour-ces outside the 200-nautical-mile limit. Claims have to be documented with data on sea depths and sediment thickness. Five areas are at stake: one area in the Arctic Ocean, two off North-East Greenland and South Greenland and two areas north-east and south-west of the Faroe Islands.

During the year, GEUS worked on data documentation on the area in the Arctic Ocean, and on 15 December, the Danish Government and the Gov-ernment of Greenland submitted the scientific documentation for the Kingdom of Denmark's claim to the continental shelf in this area to the UN Commission on the Limits of the Continental Shelf (CLCS). It is an area of approx. 895 000 km^2 outside the 200-nautical-mile limit off the coast of Greenland. Similar documentation for claims to the continental shelf was submitted in 2012 and 2013 for areas off South Greenland and North-East Greenland, and documentation for claims to areas north-east and south-west of the Faroe Islands was submitted in 2009 and 2010, respectively. The Continental Shelf Project is funded by the Ministry of Higher Education and Science, with contributions from the Government of the Faroe Islands and work is being performed in a cooperation between GEUS and several institutions from Denmark, the Faroe Islands and Greenland.

Tectonic atlas of the North Atlantic

GEUS works with geological surveys from neighbouring countries around the North Atlantic to resolve geological issues shared by all the countries. This work is under the framework for cooperation: Northeast Atlantic Geoscience (NAG), with participation by the United Kingdom, Northern Ireland, Ireland, the Netherlands, Norway, Germany, Iceland and the Faroe Islands. One of the first NAG initiatives was a project to compile a new tectonostratigraphic atlas for the entire Northeast Atlantic region (NAG-TEC). The project aimed at collating and making available all publicly available geological and geophysical data, research results and information on the tectonic development of the North Atlantic. Prior to a NAG management meeting hosted by GEUS, where progress in cooperation regarding urban and coastal geological issues were discussed, the concluding workshop of the NAG-TEC project was held, where also the atlas was presented. The final atlas is an A3-sized volume of 340 pages and was edited and graphically produced by GEUS. The results also included an underlying database and GIS model.

Deep and shallow geothermal energy

Climate change calls for new energy solutions, which can reduce emissions of CO_2 into the atmosphere. The goal is for Denmark to be independent of fossil fuels by 2050. The Danish subsurface contains a large green energy resource of deep geothermal energy in reservoirs at 1–3 km depth, as well as a resource of shallow geothermal energy, which involves exploiting the temperatures in the top 100–200 m in geothermal boreholes. Furthermore, there are possibilities to exploit the heat or to store it seasonally in geological strata at depths of 0.2–1 km.

In 2014, GEUS continued its work on analysing the extent and quality of the deep-lying sandstone reservoirs in order to map their geothermal potential. The work includes compiling relevant geological data in GIS to reveal areas with especially favourable conditions for establishing a geothermal facility. The work also entails extensive screening of the subsurface at 28 sites close to towns where it may be relevant to exploit the geothermal energy. Finally, a booklet on geothermal energy has been published: Establishment and operation of geothermal plants to supply district heating. It provides the basic knowledge required for anyone considering implementing a geothermal project. The booklet was completed for the Danish Energy Agency by Grøn Energi, GEUS, Ross Engineering and Danish Geothermal District Heating.

A three-year project within shallow geothermal energy was also completed by GEUS. The project focussed on developing tools to design geothermal boreholes and best practice for establishing plants. The results were presented at a workshop for stakeholders in November, and they include new information on the thermal properties of soil types and temperature in the upper 100–300 m of the subsurface. The project also produced model calculations of groundwater and heat flows in the subsurface to obtain knowledge to establish profitable and well-functioning plants. Finally, the project developed a web-based tool, from which drillers, administrative officers and consultants can download information about geology and thermal properties when they are planning a new shallow geothermal plant. The project was headed by GEUS and was funded by the Energy Technology Development and Demonstration Programme (EUDP) under the Danish Energy Agency, and other Danish institutions and companies also took part.

Mineral resources

Scientific basis for targeted and environmentally sound exploitation of mineral deposits in Greenland and Denmark

Evaluation of Greenland's mineral resources

In recent years, GEUS has carried out field work in South-East Greenland to assess the potential of the area for mineral resources. In 2014, activity was in the region around Tasiilaq from about 64°N to 67°N. Work has included detailed geological investigations and mapping in order to elucidate the geological development of the area. Samples have been collected for geochemical, mineralogical and petrological analyses and for determining the age of the rocks. A number of sites with geochemical anomalies that may originate from mineralisations have been studied more closely. The project is being funded by the Government of Greenland and GEUS. In November, GEUS and the Ministry of Mineral Resources under the Government of Greenland held an international workshop at which the potential for orogen gold in Greenland was evaluated by a panel of experts from the research community and from the industry. The main results were then published in the Geology and Ore magazine and they were presented during Greenland Day at the annual PDAC mining congress in Canada in spring 2015. This is the sixth time GEUS has held a resource-assessment workshop. In 2013, the topic was the wolfram potential in Greenland and during 2014 GEUS issued a report and an edition of Geology and Ore with the results.

Critical minerals and cooperation with the industry

Economic growth in some regions has led to increased consumption of minerals, and there is also increased demand for special minerals for high-technology products. Some of these minerals are critical to the industry. In 2014, GEUS focussed on critical minerals through field studies in Greenland and through collaboration projects with the industry, which could motivate further investments in exploration and mining. GEUS has completed field studies in collaboration with the Korea Institute of Geoscience and Mineral Resources (KIGAM), at the Motzfeldt intrusion in South Greenland. Here it was investigated how mineralisations of niobium, tantalum and rare-earth element metals (REE) have been formed. In an area west of Narsaq, also in South Greenland, GEUS has studied a series of different rocks associated with the magmatic intrusions at Tugtutoq to better understand their formation and mineral content. Finally, GEUS has completed structure-geological surveys and mapping in the Klitdal area and on the Wegener Peninsula in East Greenland with good potential for copper deposits. This project was completed in collaboration with Avannaa Resources and funded by the NordMin programme under the Nordic Council of Ministers.

Information and consulting services on mineral resources

In May 2013, GEUS opened its Center for Minerals and Materials (MiMa), which will analyse and assess conditions regarding the accessibility, vulnerability and scarcity of mineral resources globally and in Denmark. The first two reports from MiMa were issued in 2014. The first report was aimed at exploration companies and it provides an overall geological assessment of the uranium potential in Greenland. The second report (in Danish) was called 'Uranium - from exploration to demand' and it provides a statement of the global uranium resources and expected global consumption of uranium over a 20-year time perspective. The report also discusses whether uranium could become a critical mineral resource. In June, in co-operation with the Danish Centre for Environment and Energy (DCE) at Aarhus University, GEUS published the third edition of a booklet with information and facts about extraction of uranium in Greenland. At the invitation of the Government of Greenland, over the summer, employees from the two institutions took part in a number of information meetings about uranium for citizens in West Greenland.

Finally, MiMa has published the first three fact sheets (in Danish) on aluminium, graphite and gold, which describe the occurrence, use, production conditions and supply risks for a number of the world's most important mineral resources. In 2014, a comprehensive vulnerability analysis was initiated, funded by the green pool. This general analysis work will identify and discuss the consumption of mineral resources in all sectors of Danish industry and it will be followed up with more detailed analyses of selected sectors. The first of these is an overall statement and assessment of the mineral resources occurring in Denmark, and this was also initiated in 2014.

Data and consulting services on marine mineral resources

Basic mineral resources such as sand and gravel are increasingly being extracted from the seabed around Denmark. Extraction is from delimited areas administered by the Danish Nature Agency so that nature, coastal protection and other interests of society are considered. The materials are used in construction, concrete manufacture, coastal protection and landfill.

GEUS is a geological specialist data centre for mineral resources, which includes management and storage of data on mineral resources onshore and on the seabed as well as consultancy and advice on raw materials issues. In 2014, GEUS took part in mapping mineral resources in the inner Danish waters for the Danish Nature Agency, and GEUS advised the Agency on mineral resources and habitats in connection with a mapping project on the quality of the seabed in Øresund.

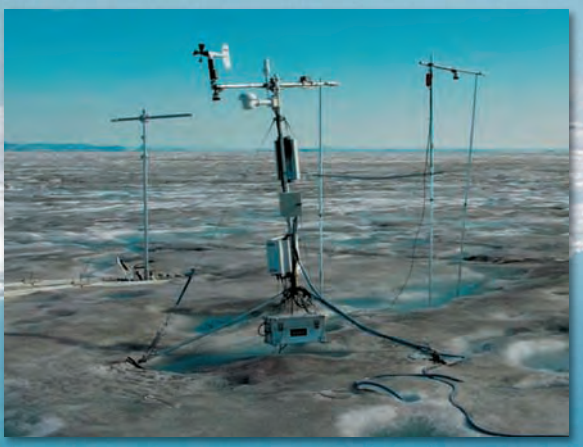
GEUS also runs the national marine metadatabase – MARTA. The database contains all the shallow seismic data (the upper 100 m of the seabed) collected from the Danish area. According to the 2009 Raw Materials Act, these data have to be reported to GEUS. This database is an important tool in the management of mineral resources at sea and in the protection of marine habitats. In 2014, GEUS further developed the web-based marine mineral resources database for the Danish Nature Agency, which contains updated information about the marine mineral resources areas in Danish waters. The database (part of MARTA) contains several types of data, e.g. reports on surveys for mineral resources, marine-geological metadata and information on samples obtained from the seabed.

Adapting society to climate change

Like many other countries, Denmark is adapting to a warmer and more extreme climate. In 2009, with a grant from the Danish Council for Strategic Research, a centre for regional climate change was set up. In the period up to 2014, the centre conducted research into how society can best adapt to a changed climate. Behind the Centre for Regional Change in the Earth System (CRES) are leading researchers from the Danish Meteorological Institute, the Copenhagen and Aarhus universities, the Technical University of Denmark, DHI and GEUS, who have delivered results which contribute to climate adaptation in Denmark and to the international climate negotiations in the UN Intergovernmental Panel on Climate Change (IPCC).

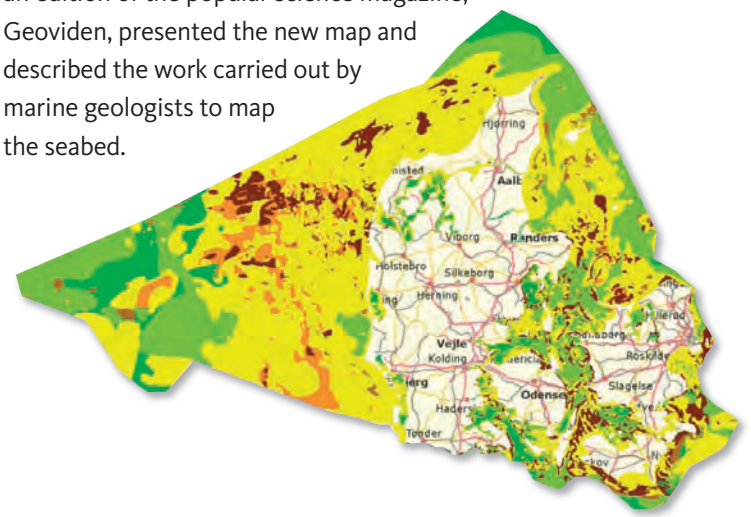
GEUS has taken part in work on water resources in which, on the basis of the catchment area for Odense Å, model analyses have been performed of what will happen to the water and nutrient cycle following changes in climate conditions and changes in farming techniques. The concentration of greenhouse gasses is now so high that it is no longer unrealistic to imagine a climate of the future with significant temperature rises. Researchers have therefore also made model calculations of how stream runoff, groundwater level and the water content in the root zone will be influenced if the global temperature rises by more than six degrees. The study shows that, among other things, it is likely that there will be an undesired effect on the ecological conditions in streams due to longer periods with low runoff. Moreover, pressure on groundwater resources will rise because of greater demands for irrigation on fields with significant drying out in the root zone. Research by CRES has been done in close collaboration with key stakeholders within water, agriculture, insurance and municipalities.

Foto: Kent Pørksen, IGN.



New map of the seafloor sediments

In 2014, GEUS launched a new digital map of the seabed sediments for seabed resources management. The new sediment map shows the distribution of seabed sediments in Danish waters. The map is an update of the sediment map published by GEUS in 2000. The seabed sediment map is the result of extensive collation of all new information available on the characteristics of the seabed. As a national specialist data centre, GEUS registers, stores and communicates seabed data which are collected by both GEUS and other operators in connection with biological, mineral resources and construction survey tasks. The data behind the new map stem from data from the mineral resources mapping completed by the Danish Nature Agency and the minerals industry over the past 5–10 years and from habitat mapping and other mapping completed in Danish waters. In addition, there are large quantities of new data from mapping in the North Sea conducted by the Danish Coastal Authority, as well as data collected in connection with establishing offshore wind farms. All the data used have been gathered in databases at GEUS. The new sediment map is available to the public and can be downloaded without charge from the GEUS website in 1:250 000 scale. Furthermore, during the year an edition of the popular science magazine, Geoviden, presented the new map and described the work carried out by marine geologists to map the seabed.

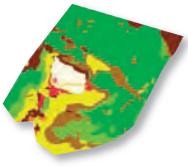


Monitoring the Greenland ice sheet

Ice melt from the Greenland ice sheet has increased considerably since the turn of the millennium, and although 2014 was no record year, large ice melts from the ice surface were recorded. The measurements come from the PROMICE project, which is monitoring the mass loss from the ice sheet using 24 fully automatic monitoring stations, which measure the ice melt and movement and the climate and then transmit the data to GEUS in Copenhagen via satellite.

The increased melt might be reinforced by a diminishing reflection of solar radiation due to a darker surface. Over the summer, glaciologists have found that the darkening was likely due to more dust and microbes as well as more soot from forest fires globally. The first calculations, based on satellite and PROMICE measurements from aircraft, of the ice loss from large ice-calving glaciers throughout Greenland, came in 2014.

Data from PROMICE are distributed free of charge to the international research community via www.promice.org, and the public is informed through www.polarportal.dk, operated in cooperation with the Danish Meteorological Institute. 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 rises in sea levels. PROMICE is being headed by GEUS and funded by the Danish Cooperation for Environment in the Arctic programme under the Danish Ministry of Climate, Energy and Building.



Effective methods for 3D geological modelling

In recent years, large quantities of geophysical data have been collected in Denmark in connection with the ongoing national groundwater mapping. In particular, these data stem from the SkyTEM measurements taken from helicopter, which are used to map the geological strata. It is difficult and time-consuming to translate the large amounts of geophysical data into useful geological models for mapping groundwater aquifers. GEUS is taking part in the ERGO (Effective high-resolution Geological Modelling) project to develop effective methods for use in 3D geological modelling of large sets of data. The aim is to develop a user-friendly software system which, using automated methods, can help researchers interpret data and design useful geological models. Work includes developing software that can 'learn' how researchers can interpret data in one area and enable the program to automatically roll-out this knowledge in another area.

Groundwater surveying is high on the agenda in several developing countries in which there is only limited knowledge available to interpret and translate the large amounts of data into geological models. In the long term, the ERGO project will provide opportunities to export Danish knowhow which will enable local geologists with less experience to build high-quality geological groundwater models. The project is being funded by the Advanced Technology Foundation and it is being conducted as a collaboration with the Niels Bohr Institute, the University of Copenhagen and I-GIS A/S, a software company.

GEUS around the world

Knowledge-building in developing countries through research and consultancy

Building oil expertise in Vietnam

Oil and gas are important sectors for the Vietnamese society. In 1995, GEUS initiated a joint project with the Vietnam Petroleum Institute (VPI) to enhance the Vietnameses' possibilities to assess their oil and gas resources. Training, research and technology transfer have been key words in the project, which has now been completed and which has been funded by the Danida ENRECA programme since 2001. The project has paved the way for future research collaboration.

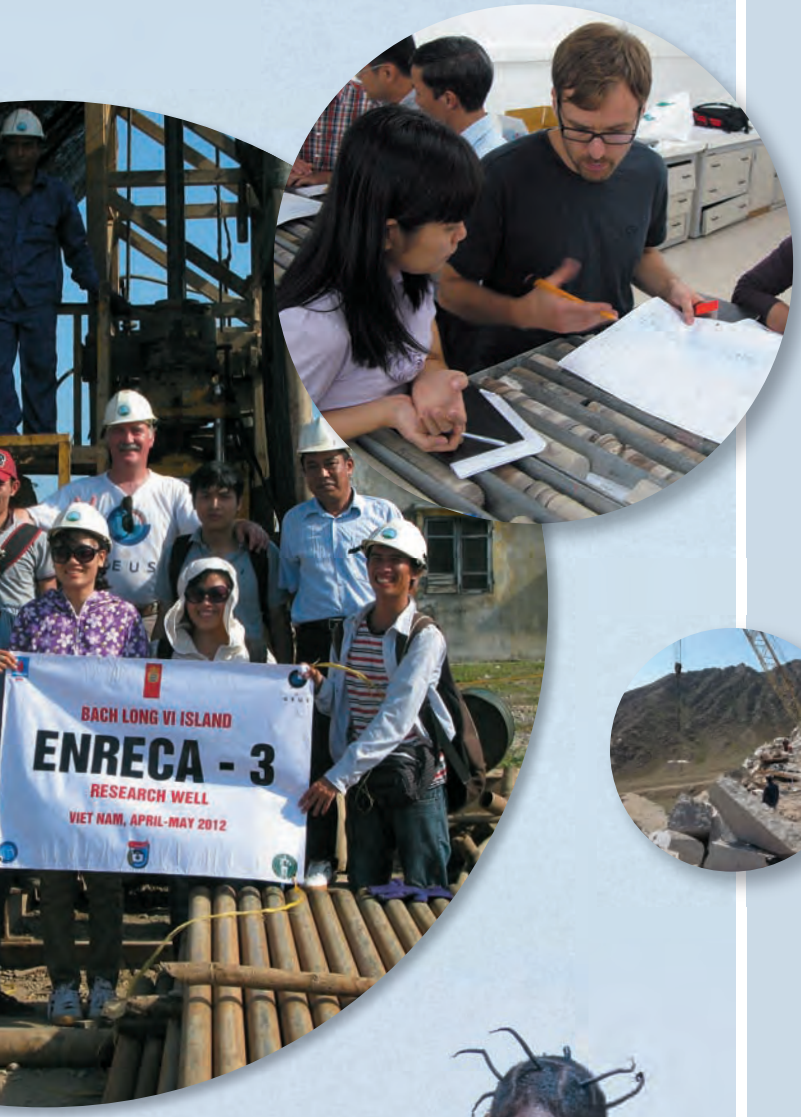
Vietnamese researchers were trained in oil-geological disciplines through classroom teaching and through participation in specific research projects aiming at understanding the geology and possibilities of finding oil and gas in three selected geological basins of interest for both the local energy authorities and for industry. Work has included three 500-metre-deep core drillings in the selected basins, and these have contributed valuable information about the geology as well as the oil and gas potential both onshore and offshore.

In the first phase of the project, GEUS held courses for researchers in Vietnam, and the Vietnamese researchers took part in training programmes in Denmark. A total of eight Vietnamese students from the VPI and Hanoi University of Mining and Geology (HUMG) completed their MSc studies in this phase. Project work not only aimed at capacity building at the VPI, but it also strengthened cooperation between universities in Vietnam and Denmark. Using teaching resources from the University of Copenhagen, in the final two phases of the project, joint MSc and PhD programmes were completed for 17 students from the VPI, HUMG and Hanoi University of Science (HUS). Communication was an important goal for the ENRECA project, and over the years, results of the research were presented to researchers and public players as well as representatives from the oil industry active in Vietnam. The project also presented results at international conferences and published in scientific journals.

The project has strengthened Vietnamese oil and gas competences and activities changed gradually over the project period from training to collaboration. At the conclusion of the project, in Hanoi in November the VPI and GEUS signed a framework agreement for research collaboration to address future oil and gas challenges in Vietnam.

Development of climate and water expertise in Tanzania

The CLIVET climate project was concluded in 2014. Through research and development, the project has built up knowledge and capacity at Tanzanian institutions so that Tanzania can better adapt its agriculture to the climate of the future. Work has included climate studies and hydrological calculations of climate scenarios in the large Ruaha River Basin, and these will provide better knowledge about the consequences of the climate of the future. The calculations show that the climate in the area will become warmer, there will be more precipitation and that there will only be small changes in the size of the water resource because the effects of these climate changes will more or less cancel each other out. Student training and knowledge building at the University of Dar es Salaam were important activities in which knowledge about project operation and management were in focus. A number of Tanzanian students completed their MSc and PhD programmes. Master and Bachelor students were also taught in Denmark. Results of the project were communicated regularly to stakeholders at several workshops, and articles in international scientific journals were published jointly by researchers from Tanzania and Denmark. The project was headed by GEUS and funded by Danida, and activities were in cooperation with the Department of Geosciences and Natural Resource Management, the University of Copenhagen, Danish Climate Center, and the Danish Meteorological Institute, as well as the Institute of Resource Assessment and the College of Engineering and Technology, both at the University of Dar es Salaam and the Tanzania Meteorological Agency.



Sustainable management of mineral resources in Tajikistan

Tajikistan has a large mineral potential and, with help from the World Bank, the country is working on a project to make Tajikistan more attractive for private investors, including by developing the mining industry. Exploitation of mineral resources can be a driver of growth and welfare, however, if not managed well, mineral resources could lead to poverty and environmental disaster. The State Committee on Investments and State Property Management in Dushanbe are conducting a project to develop sustainable management of mineral resources in Tajikistan. In this context, Swedish Geological AB, GEUS and the local NGO – Youth of the 21st Century of Tajikistan – are working on a project to complete a thorough analysis of the mineral resources sector; a so-called Strategic Environmental and Social Assessment (SESA). The primary objective of this analysis is to help raise the environmental, social and economic standards in the mineral resources sector and, as something new in Tajikistan, to involve the local population through a series of workshops in three locations in Tajikistan. The project has completed an assessment of the geology, the minerals potential, the structure of the public administration in the minerals sector, and finally the national plans for the minerals sector. Furthermore, GEUS is taking part in the environmental and socio-economic assessment. The project is coordinated with geological surveys from Finland (GTK) and Germany (BGR), which have nationally financed projects in the mining sector.

Hydrological expertise in Ghana

In 2014, GEUS started a Danida South-Driven Development Research Project. The project is to strengthen research capacity in Ghana within hydrogeology so that Ghana can manage its water resources better. The project will focus on assessing the groundwater resources in the White Volta Basin in northern Ghana, where there is a need to draw up large-scale, sustainable irrigation plans for agriculture. Work will include developing a hydrogeological model and a numerical groundwater model to assess groundwater recharge and variation in size of the resource as a consequence of climate change and large-scale irrigation. The project will primarily use knowledge and historical data that are available from local stakeholders as well as geophysical data collected from aircraft under the comprehensive EU Mining Sector Support Programme. Finally, activities will include training of Ghanaian PhD students in hydrogeological disciplines through classroom teaching and participation in specific research activities. The project is being led by the University of Ghana and it is a collaboration between three Ghanaian institutions; the Water Research Institute, Hydronomics Ltd, and the Center for Savanna Ecosystem Research, as well as GEUS, Aarhus University and the University of Copenhagen.

Glimpses of the year

A busy year at the Nuuk office

In September 2013, GEUS opened an office in Nuuk to enhance cooperation with Greenland and secure continued development of geological knowledge in Greenland. 2014 was a busy year for GEUS geologists in Nuuk, who held several large events. In January they hosted the Culture Night in Nuuk, at which no less than 924 inquisitive citizens dropped by the GEUS offices at the Greenland Institute of Natural Resources. How do geologists determine whether there are valuable mineral resources in an area? How are different minerals extracted? What minerals are everyday objects made of? These were just some of the questions to which guests could get an answer. In September GEUS held a workshop in Nuuk with the Canada-Nunavut Geoscience Office at which information was exchanged between Nunavut, Greenland, Canada and Denmark about geology, mineral resources and geoscience in general. The workshop was part of endeavours to build up geological competences in both Nunavut and Greenland, in which it is intended to benefit by cultural and climate similarities. In October, GEUS and Asiaq presented the consequences of the melting ice sheet for 200 pupils at Midtgrønlands Gymnasiale Skole (GU), a high school in Greenland. This was the first Climate Change Teaching in Greenland Day and it took place at the Greenland Institute of Natural Resources. Finally, GEUS was at the Education Day at GU in Nuuk in November where students could hear about geology and geography education programmes.

Two new adjunct research professors

In 2014, the Section for Geology at the Department of Geosciences and Natural Resource Management at the University of Copenhagen appointed five professors and two adjunct professors who are to strengthen the four research groups at the Section. The two adjunct professors, Jochen Kolb and Torben Sonnenborg, come from GEUS. Jochen Kolb has been a research professor at GEUS since 2011, and he took up the position as adjunct professor in the research group for geochemical, mineralogical and petrological processes. Torben Sonnenborg has been a senior researcher at GEUS since 2005 and he took up the position as adjunct professor for the research group on water resources. As head of the Section for Geology, Professor Karsten Høgh Jensen explained: "We expect that the new professorships will strengthen the institute and our cooperation across Geocenter Denmark. It will lead to increased focus on geology which we expect in turn will lead to an increase in the number of students applying for programmes here, as well as new, larger research activities".

Prizes for two GEUS employees

Two GEUS employees received awards for their work in 2014. In March, Bjørn Kaare Jensen, deputy director, received the ATV Jord og Grundvand award for his many years of committed, innovative and visionary contributions to the development of the work with water resources in Denmark and abroad. "As a deputy director at GEUS, you have a broad foundation for your work, and in recent years, with the Ministry of the Environment, you have made great efforts, through visits abroad or as a host in Denmark, to demonstrate to the world the strong water competences Denmark has built up," said the chairman of the ATV Jord og Grundvand foundation, Ida Holm Olesen, during the award ceremony. In May, Sofia Ribeiro received the Schibbye'ske Præmie 2014 from the Danish Natural History Society for her research work in the borderland between geology and biology and for her contribution over the years to the study of climate and environmental change in the sea.

An autumn with geology

More than 60 events throughout Denmark lured Danes out of their homes during Geology Days coordinated by the Geological Society of Denmark, the National Committee for Geology, the Natural History Museum of Denmark and GEUS. In the weekend 20–21 September, geologists, nature guides, members of amateur geology associations and many others were ready to host tours, demonstrations and exhibitions. Each event offered a glimpse into Denmark's geological history over 1.5 billion years, from the granites of Bornholm to chalk cliffs and moler cliffs in the south and north, to Ice Age landscapes and modern active coastal formation.

In October, the Ministry of Climate, Energy and Building opened its doors during Culture Night and invited visitors from the Copenhagen area to hear about the green solutions of the future. The public met employees from the Ministry, the Danish Building and Property Agency, the Danish Energy Agency, the Danish Meteorological Institute and GEUS. More than 2500 made their way to the event, and at the GEUS stand, guests could have a guess at what minerals are used for making cars and mobile phones. They could learn about the hot water in the subsurface and ice melt in the Arctic, and they could see how GEUS works to combat mercury pollution from small-scale gold mining around the world.

Key figures for 2014

More detailed key figures for the activities of GEUS are available in Årsrapport – Regnskabsåret 2014 (Report and Accounts 2014), and in Faglige resultater 2014 (the latter in Danish only). Both of these are available at www.geus.dk – publikationer – institutionsrapporter.

Number of employees: **338**
Number of scientific projects: approx. **692**

ACCOUNTS 2014

Amounts in million DKK	
Revenue	**293.7**
Net figure (appropriation)	134.7
Operating income	159.0
Expenditure	**297.0**
Salaries	178.7
Other operating expenditure	118.3

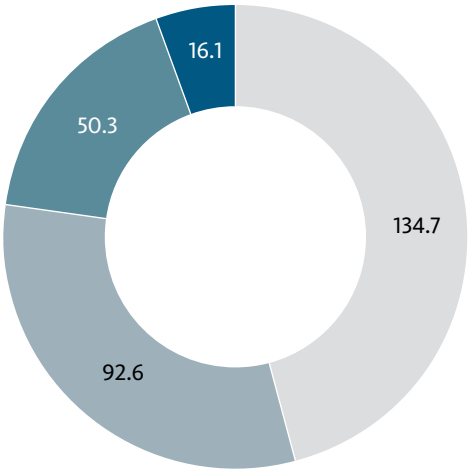
INFORMATION ACTIVITIES

Long-term knowledge building	
Articles in international scientific journals/publications	172
Other scientific publications	13
Conference contributions with abstracts or posters	201
On-going scientific tasks, consultancy and presentation	
Publicly available reports	59
Confidential reports	50
Memoranda, opinions, expositions, etc.	59
General information	
Institution reports (annual report, etc.)	5
General and popular-science presentations	143
– including popular-science lectures	82
Use of GEUS web	
Visits to www.geus.dk	514,000
Use of GEUS' web map services	2.4 mio.

RESEARCHER TRAINING WITH GEUS TUTORS

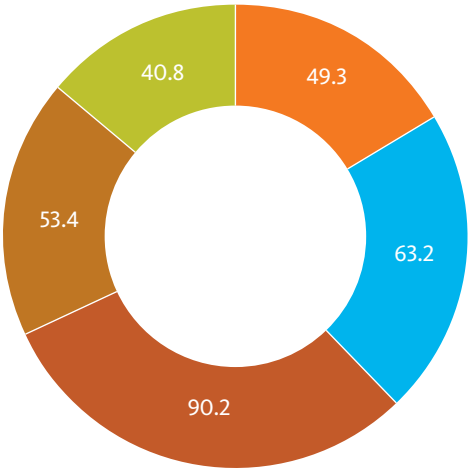
Current PhD students	63
Completed PhD degrees	19

Revenue broken down by sources of revenue in million DKK



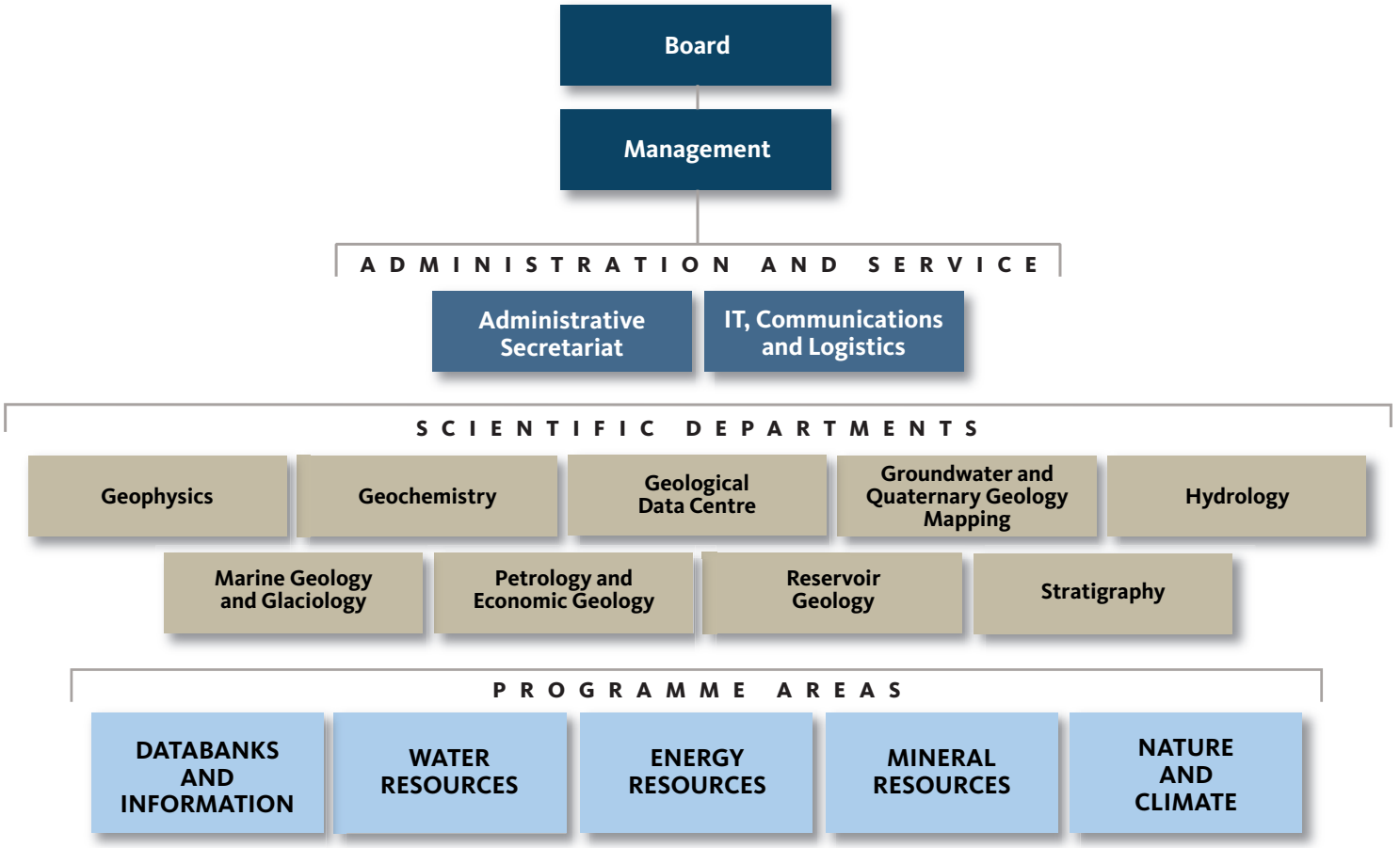
National budget and supplementary government appropriations:	134.7
Programme and external resources:	92.6
Other co-financed contract research:	50.3
Commercial contracts and sales of data:	16.1

Expenditure broken down by programme area in million DKK



Databanks and information:	49.3
Water resources:	63.2
Energy resources:	90.2
Mineral resources:	53.4
Nature and climate:	40.8

Organisation



In 2012 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

Storage, quality assurance and presentation of geological knowledge and data. The aim is to establish a level of quality of data and sample collections which helps work on monitoring, emergency management, advisory service and research. In addition, the programme area comprises operation and development of GEUS' IT infrastructure as well as communication to the scientific community and the public.

Water resources

Knowledge to optimise the management of Danish 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 in Denmark and abroad.

Energy resources

Knowledge for exploration and exploitation of energy resources in Denmark and Greenland. This work comprises own research projects and international cooperation with 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.

Mineral resources

Scientific basis for targeted and environmentally sound exploitation of 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 Government of Greenland. In addition, surveys are carried out in connection with raw materials and construction work in Denmark and internationally.

Nature and climate

Knowledge about the past and present climate and environment in Denmark and the North Atlantic area. The objective is to improve the prospects of distinguishing between natural and human-induced environment and climate changes. The programme area also includes a mapping of onshore and offshore geological conditions, as well as earthquake research and monitoring.

ISBN 978-87-7871-411-4

Water
Energy
Minerals
Nature
Climate

Geological Survey of
Denmark and Greenland (GEUS)
Ministry of Climate and Energy and Building

Øster Voldgade 10
DK-1350 Copenhagen K
Denmark

Telephone: +45 38 14 20 00
Telefax: +45 38 14 20 50
E-mail: geus@geus.dk
www.geus.dk