

# RESOURCES...

for life



**water**

**energy**

**minerals**

**nature**

**ANNUAL REPORT 2007**

**GEOLOGICAL SURVEY OF DENMARK AND GREENLAND  
MINISTRY OF CLIMATE AND ENERGY**





B.K. Jensen J. Fredericia F. Getreuer Christiansen

## New Board of Management

### Johnny Fredericia, Managing Director

Johnny Fredericia comes from within GEUS, where he had been Deputy Director since 1998, and before that he was a state geologist for eight years, responsible for the Department of Quaternary Geology. He is a qualified geologist from the University of Copenhagen and has a PhD degree in hydrogeology from the Technical University of Denmark.

### Bjørn Kaare Jensen, Deputy Director

Bjørn Kaare Jensen comes from a position as international manager of Obicon. He is a graduate in microbiology from the University of Copenhagen and has extensive experience in the soil and groundwater areas. He worked for 10 years as a researcher at the Technical University of Denmark and after that he was head of research at the Vandkvalitetsinstituttet (VKI - institute for water quality) and later the Dansk Hydraulisk Institut (DHI - Danish hydraulic institute) for 12 years.

### Flemming Getreuer Christiansen, Deputy Director

Flemming Getreuer Christiansen comes from positions within GEUS. From 1992 he was a state geologist and head of the Oil Geology Department in the old Geological Survey of Greenland (GGU), and later became head of the Department of Stratigraphy at GEUS. He graduated in geology from the University of Aarhus where he also held a scholarship.

## New framework, new name, new top management and a new department

The year 2007 was an eventful year for the Geological Survey of Denmark and Greenland (GEUS) with new frameworks and many new faces. A new Act for GEUS entered into force on 6 June, as a consequence of the Government's reorganisation of the Danish research landscape, where the majority of sector research institutions were integrated into Danish universities. Due to the special nature and tasks of GEUS, it was decided to establish the institution as an independent, self-governing research institution with its own legal basis and a new board of directors representing the interests prescribed by the Act. This new Act also led to a new Danish name (De Nationale Geologiske Undersøgelser for Danmark og Grønland), but the old English name and the abbreviation GEUS were kept. Later in the year, the Government appointed a new board of directors, with Dr. Per Buch Andreasen being reappointed as chairman. In connection with the new Government after the general election in the autumn, GEUS moved from the Ministry of the Environment to the new Ministry of Climate and Energy with Connie Hedegaard as minister.

GEUS has also welcomed many new employees in 2007. In connection with the municipal structural reform, GEUS established a new department for Groundwater Mapping in Aarhus in 2007. With this establishment GEUS is now focusing on the national groundwater mapping to be implemented by the Ministry of the Environment's new environment centres in the years to come. Finally, a new board of management was appointed in 2007. On 1 April Johnny Fredericia took up the position as the new Managing Director and in December GEUS announced that Bjørn Kaare Jensen and Flemming Getreuer Christiansen will take up their positions as Deputy Directors in early 2008.

## New department for Groundwater Mapping

The Groundwater Mapping Department has 14 employees with state geologist Richard Thomsen as the head of department. The department is located in the old Amtsgård in Højbjerg together with Environment Center Aarhus. The majority of employees are geologists from groundwater offices of the counties, however, there is also specialist staff from GEUS in Copenhagen. The department leads specialist coordination of the national groundwater mapping and assists the Agency for Spatial and Environmental Planning and the Environment Centers with specialist coordination, advice and guidance for the groundwater mapping.







## Introduction

Annual report 2007 provides a brief insight into an exceptionally eventful year, which has been epoch-making in the 120-year history of GEUS.

As a consequence of the government's decision to reorganise the Danish research landscape in 2006, GEUS is now subject to its own act, Act no. 356 of 6 June 2007, which was adopted unanimously by the Danish Parliament. GEUS became one of three national research institutions and changed its Danish name, although the English name remains the Geological Survey of Denmark and Greenland (GEUS).

In 2006 the government also decided to establish a national geocenter, Geocenter Denmark, as a part of the focus on the research area. In 2007 the Center's statute was approved by the University of Aarhus, the University of Copenhagen and GEUS. Geocenter Denmark will be an important instrument in reaching the government's goals in the geo-scientific area.

GEUS' department in Aarhus opened on 2 January and has now become an integrated part of GEUS, carrying out tasks within groundwater mapping and groundwater monitoring in close cooperation with the new environment centres and the Agency for Spatial and Environmental Planning.

With the formation of the new government after the general election in November 2007, a new Ministry of Climate and Energy was established, and GEUS was transferred to the new Ministry from the Ministry of the Environment. GEUS already had a large portfolio of tasks in the energy and climate area which fell within the new Ministry's field of responsibility, and GEUS is also continuing its work for the Ministry of the Environment. This work has therefore been included in GEUS' new performance contract, which commenced in January 2008 and runs until the end of 2011.

In 2007 the common public-sector data solutions for the environment area were implemented, and GEUS' extensive databases on geology and groundwater became a daily tool for state, municipalities and regions.

Combating climate changes and adapting to those we cannot avoid have created a need for solutions requiring GEUS know-how in areas such as geothermal energy, CO<sub>2</sub> storage, impacts on the water cycle and leaching of nutrients and pesticides to the groundwater, flooding, coastal erosion and developments in the melting of the Inland Ice in Greenland. GEUS is well prepared for this interdisciplinary challenge. GEUS anticipates new uses for geological knowledge and a new understanding of the importance of our climatic past, as well as a great need for knowledge of geological processes and natural resources.

Fossil energy sources will continue to be an important part of Denmark's energy supply for many years to come, and a source of considerable revenues for the Danish society. Focus on the climate must therefore be combined with an open-minded understanding of the values of subsurface resources. Rapidly increasing oil prices have resulted in enormous demand for knowledge about oil/gas resources - also at GEUS.

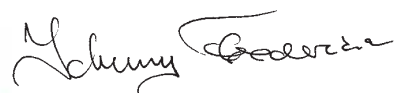
Interest in geological natural resources of oil/gas and minerals in Greenland is greater than ever, where strategically it constitutes an important aspect in Greenland's endeavours to create a self-sufficient economy. Therefore, the Home Rule Commission has considered the role of GEUS, and both Denmark and Greenland want GEUS to continue as the institution from which the authorities can seek geological advice.

The ownership of potential resources below the offshore area of the Faroe Islands and Greenland received much press coverage in 2007. This is reflected in the continental shelf project, under which a large expedition was carried out in difficult ice conditions north of Greenland using two ice-breakers.

With an eventful year behind us, a performance contract in place until 2011, a common understanding of the model for future Denmark-Greenland cooperation and a high demand for GEUS knowledge, we are already well into an exciting 2008.



Per Buch Andreasen  
Chairman of the Board



Johnny Fredericia  
Managing Director





# Databanks and

## Drinking-water data on the internet

In 2007 GEUS opened a new web portal, where people can retrieve information on the quality of the water supplied by waterworks. The water's hardness and content of various bacteria are just some of the information, which can be obtained together with information on content of selected substances such as nickel, which may be interesting to people with allergies. For people who are especially interested, it is possible to retrieve information on all the substances for which drinking water is screened, and it is also possible to see how drinking-water quality has varied over time. The information is based on data reported to GEUS by analysis laboratories, municipalities and the former counties. The reports go through automatic quality control to detect a number of errors before the data are loaded into the database.

Drinking-water quality in the database is stated for the individual waterworks. In larger towns, drinking water is mixed from many different waterworks in the water supply network before it reaches consumers, so the information on the website is only accurate for the households receiving water from one specific waterworks.

## Access to knowledge about world-class ice in Greenland

During the year, GEUS opened the new website 'Knowledge about the Ilulissat Ice Fjord'. With a few clicks, school pupils, teachers and the public can search for knowledge of the unique World Heritage site - the Ilulissat Ice Fjord in Greenland and experience the beauty and the enormous powers of ice through videos, photographs, animations and texts. In 2004 the Ilulissat Ice Fjord was admitted to the prestigious list of UNESCO World Heritage Sites of unique culture and nature. The ice fjord is a picturesque area, where icebergs from one of the world's fastest moving glaciers form beautiful and dramatic sceneries. For thousands of years, the harsh nature has created a rich basis of life for humans and animals, and this area has attracted many adventurers and researchers for centuries. At the website, you can also read about the Inland Ice and the climate and find out about human life in this area over a thousand years. The website has videos from the ice fjord, and if you are adventurous you can go on an animated flight through the magical landscape or lean back and meditate to the beautiful pictures in a slideshow by the well-known Greenland photographer Jakob Laurrup.



## Electronic access to peer-reviewed publications

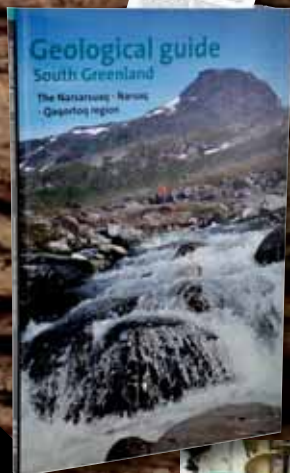
In 2007 GEUS' peer-reviewed series of publications 'Geological Survey of Denmark and Greenland Bulletin' became fully accessible in electronic versions. Now, all 14 issues since the beginning of 2003 can be downloaded as PDF files from [www.geus.dk](http://www.geus.dk). The series contains groups of specialist articles, larger comprehensive works and the annual 'Review of Survey Activities' with short scientific articles providing a general view of the GEUS' ongoing research. The first group includes the 950-page-long publication 'The Jurassic of Denmark and Greenland', which through 28 separate articles provides comprehensive knowledge of Jurassic strata in the entire North Atlantic area. The strata are important source rocks and reservoir rocks for oil and gas and also well suited for storage of CO<sub>2</sub> and gas, as well as for exploitation of geothermal energy. In the long term, electronic access will also include GEUS' earlier scientific series of publications, of which several issues from 1995-2002 can already be downloaded.





# information

Storage, quality assurance and presentation of geological knowledge and data



## Guide to the interesting geology of South Greenland

'Geological guide - South Greenland' is the title of a new popular science book in English, published by GEUS in 2007. The book is a guide to the unique geology in the Narsarsuaq - Narsaq - Qaortoq area in South Greenland with several world-famous mineral sites. The area comprises the Ilimaussa complex, which is one of the world's most fascinating intrusions due to its extreme richness of rare elements and correspondingly large numbers of rare minerals. The target group is tourists and other visitors, who are interested in geology or who want to know something about the rocks, glaciers and landscapes in which they travel. The book describes a wide range of sites worth visiting because of their fine minerals, mottled rocks or fantastic shapes, and because they give a good general idea of the geological processes that took place more than 1100 million years ago some kilometres below the volcanoes, which covered the face of the earth at that time. The guide is richly illustrated with colour photographs, graphics and many topographical and geological maps, and it has a handy A5 format, so it is easy to take on your trip to the mountains.

## Stable access to national drilling and water data

GEUS' Jupiter database is the joint public-sector database for drillings, groundwater and drinking-water data, and with the launch of the municipal structural reform in 2007, Jupiter now serves as a tool for employees working in the raw materials, groundwater and drinking-water areas in municipalities, regions and state-owned Environment Centers. The database is frequently used, and in 2007 the number of displays of information about drillings and waterworks more than doubled. There has been a large increase in extracts and updates through the so-called web services, where users work online on the database with groundwater systems such as Rambøll's GeoGis and KMD's Struktura. Jupiter is part of the Danish Nature and Environment Portal together with other national databases with nature and environment information, and during the year the first phase of a joint public-sector user management system was put into operation. This is to make it easier for users to access and update the many different kinds of data in the portal. Furthermore, GEUS entered into an agreement with the Danish Nature and Environment Portal to ensure optimal access to data from Jupiter during the daytime and to ensure various requirements for response time from the database. Finally, in close cooperation with users, GEUS has, optimised and streamlined the database, so it can better manage the large amounts of new data from the former counties which were loaded in 2006.





# Water re

## National groundwater mapping

With the launch of the new municipal structural reform in 2007, the state-owned Environment Centers have taken over administration of national groundwater mapping, and work on action plans has been transferred to the municipalities. The work of the Environment Centers includes mapping areas with special drinking-water interests and catchment areas for water-works outside areas with special drinking-water interests. GEUS manages the specialist coordination of groundwater mapping and assists the Agency for Spatial and Environmental Planning and the Environment Centers with coordination and advice, so that, as far as possible, national groundwater mapping is carried out more uniformly. In 2007 there were comprehensive activities on the structure and organisation of the work. An overall structure has been defined and experience groups for geophysics, geological and hydrological modelling, water quality and potential mapping have been set up. During the year GEUS has been busy setting up geological-hydrological models at basin level and has quality assured the models together with the Environment Centers. Furthermore, a number of development projects have been initiated, which include further development of the helicopter-borne geophysical method SkyTEM with focus on mapping geological structures close to the surface. Finally, GEUS has arranged a wide range of courses and team days for the employees at the Environment Centers and, where relevant, also for employees from private consultancy firms participating in the work.

## New methods for adaptive management of water resources

The world's water resources are under increasing pressure, and there are greater demands for management of resources, which can take into account both people's and nature's needs for water. There is a need for holistic solutions counterbalancing uncertainties such as changes in needs and the effects of climate change. Water operators must solve complex problems, where the interests of agriculture and industry conflict with demands to conserve the best possible aquatic environment and it is difficult to assess the consequences of a proposal for balanced management. During 2007, GEUS participated in the EU-funded research project NeWater, which is currently developing methods and tools to help make the right decisions. The project is working in seven basins in Europe, Asia and Africa. GEUS has participated in the testing of new methods for adaptive management of intensively exploited groundwater aquifers in the Guadiana river basin in Spain. Among other things, the work has tested the decision tool known as Bayesian Belief Network, which has turned out to be very useful for researchers as well as practical water operators in elucidating the problems of the area and in identifying and weighting the necessary decisions and initiatives which can solve the water conflict. The results from the NeWater project support implementation of the EU Water Framework Directive and the EU Water Initiative, and during the project the experience and methods will be included in a "guide book" and a portal for water operators containing guidelines, training material, experience from the seven river basins, and tools for adaptive water management.



## International research evaluation

GEUS ensures ongoing evaluation of the quality of the institution's scientific work. In 2007 the quality of GEUS' research within the Water Resources programme area was subject to a thorough check by an international panel appointed by the Danish Council for Strategic Research. In a report, the panel concludes that GEUS' research is of a high quality and singles out research within pesticides, soil contamination and hydrological modelling. It also concludes that the institution provides advice of high quality and relevance to society. GEUS' board of directors has subsequently expressed its satisfaction with the report and has decided that an action plan is to be prepared on the basis of the panel's recommendations for improvements.



# sources

Procuring knowledge to permit optimal management of our water resources

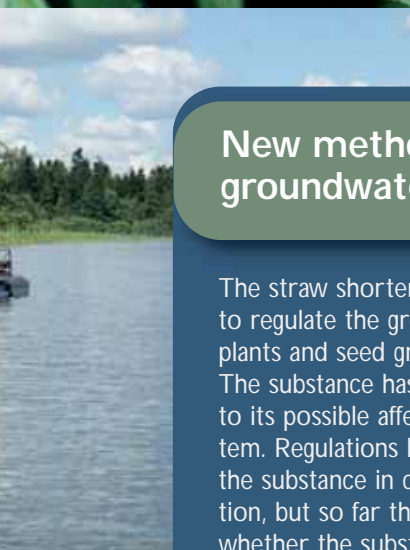


## The water cycle under a changed climate

In 2007 GEUS examined the effects of future climate change on the fresh water cycle. With help from the national hydrological DK-model, calculations have been made for West Jutland by using two climate scenarios from the Danish Meteorological Institute. The survey, which was carried out on behalf of the Danish Water and Waste Water Association (DANVA) and Københavns Energi, follows up on a similar national study in 2006, but this time with the incorporation of the consequences of changes in land use and increase in sea levels. Calculations show that climate change can affect the hydrological system in West Jutland significantly with large seasonal and geographical variations. The expected severe winter precipitation will result in increased groundwater levels and a significantly larger run-off into watercourses, particularly during the winter period. Furthermore, a higher sea level will result in increased groundwater levels in a zone of 2-10 kilometres from the coast. Both can result in water-logged areas or flooding, which can create problems for farmers far into the spring. The groundwater level will generally rise, but drying-out can be expected of the upper aquifers in the late summer, which may result in less run-off into watercourses in August-September. The consequences not only depend on the climate, but also on the need for field irrigation and the type of dominant crop. For example, a doubling of forests will only result in a marginal reduction in the average groundwater recharge, although it is likely that the groundwater recharge will be reduced noticeably in the late summer in areas dominated by forest. The survey has analysed isolated scenarios for changes in land use and sea level and can therefore not give answers to the exact size of the changes, but the work has identified a number of important consequences for future land-use planning and water abstraction strategy.

## New method for soil and groundwater screening

The straw shortener, chlormequat, is often used to regulate the growth of corn, ornamental plants and seed grass in Denmark and abroad. The substance has received great attention due to its possible effects on the reproduction system. Regulations have been introduced on using the substance in connection with food production, but so far there has been no focus on whether the substance will leach into the groundwater and there have been no methods of analysis for the substance's presence in soil and water. For years this has worried Danish waterworks, which have not been able to test whether chlormequat is a problem for drinking water. GEUS and Københavns Energi took up this challenge, and now there is a usable analysis method as well as the first test-sample results of analysis of groundwater from some of Københavns Energi's wells. The analyses were all negative and the study indicates that extensive use of the substance does not pose a serious risk to the groundwater quality in the five wells examined. With a view to a more general conclusion of the substance's fate in Danish soil, more detailed field studies in the Danish Pesticide Leaching Assessment Programme have been initiated, where three test fields in Denmark were treated with chlormequat in April 2007.



## Opportunities for CO<sub>2</sub> storage in Europe

There is an international desire to reduce CO<sub>2</sub> emission, as described in the Kyoto Protocol, but the goals can be difficult to reach as the world continues to thirst for energy to create growth and wealth. Capture and storage of CO<sub>2</sub> in the underground is one of the methods which can be implemented to limit emission of greenhouse gases into the atmosphere. For several years Europe has been focusing on the so-called CCS technology (Carbon Capture & Storage) through many EU-financed international research projects to clarify the possibilities of geological storage of greenhouse gasses. GEUS is participating in several of these projects. These include the GeoCapacity project, which aims at updating and extending the basis for geological storage of greenhouse gasses in Europe, and the DYNAMIS project, which is to pave the way for future European gas or coal power stations producing hydrogen and electricity without CO<sub>2</sub> emission. Geological storage of greenhouse gasses is based on techniques used in extracting oil and natural gas and underground storage of natural gas. In 2007 work included surveys of storage possibilities in deep saline aquifers, empty or almost empty oil- and gasfields, as well as coal-bearing layers. Finally, GEUS is part of the COACH project to transfer competences within geological storage of CO<sub>2</sub> from the EU to China. The storage possibilities in Denmark were addressed in a now completed EU project, and in 2007 GEUS published a report which assesses the possibilities of storing greenhouse gasses in the Havnsø geological structure north-east of Kalundborg, which is near the two large CO<sub>2</sub> point sources at Asnæsværket power plant and the Statoil refinery. Surveys show that the Havnsø structure is probably the most suitable place to store CO<sub>2</sub> in Denmark and perhaps even one of the best places in Europe, and the report recommends a number of initiatives, which should be initiated before making a final decision on whether the structure is suitable for CO<sub>2</sub> storage.

## Hunt for geothermal energy

The world's climate problems call for new energy solutions to reduce CO<sub>2</sub> emission to the atmosphere. Heat from the core of the earth in the form of geothermal energy is one of the energy sources available. Geothermal energy is used in many places in Europe, and Denmark uses geothermal energy in installations on the Island of Amager outside Copenhagen and in Thisted in Jutland. Hot water is collected from water-bearing sandstone layers 2-3 kilometres down in the subsurface. For many years, GEUS has worked on developing geological models to describe and predict where there are geological layers in the subsurface with hot water in sufficient amounts and which can be pumped up to the surface. In recent years, GEUS has worked with DONG Energy on interpreting seismic data and data from drillings in order to build geological models of the subsurface under a number of Danish towns. One of these areas is in the densely populated North Zealand, where the geothermal potential is currently being examined. In parallel with this work, preliminary surveys, quality assurance and interpretation have been carried out of new seismic data from Sønderborg, where DONG Energy and Sønderborg Fjernvarme are planning to establish Denmark's third geothermal plant.

Procuring of knowledge for continued exploration and exploitation of energy resources in Denmark and Greenland

# Energy res

## Increased oil abstraction using a climate-friendly method

The Danish National Advanced Technology Foundation has launched a number of projects combining research-related and business-related challenges with the potential to create new growth industries. One of these projects is to examine the possibilities of increasing oil extraction in the North Sea by pumping CO<sub>2</sub> from power plants down into the oil reservoirs. CO<sub>2</sub> dilutes oil and makes it flow more easily towards the production wells. This solves two key problems at the same time: CO<sub>2</sub> emission to the atmosphere are reduced and oil extraction from existing fields is increased. During 2007, GEUS developed an experimental apparatus in the laboratory to examine how an oilfield will react to CO<sub>2</sub>. The project is to work with sample material from chalk formations in the North Sea, and researchers from GEUS have also been busy selecting and describing the sample material to be used in their own laboratory and in laboratories at several of the project partners, which include DONG E&P, DONG Energy Generation, DTU Chemical Engineering, DTU Aqua and Danish Geotechnical Institute GEO.



# Sources

## Great interest in oil exploration in Greenland

In recent years, the oil industry's interest in Greenland has increased, and it peaked during the licensing round in 2006 for offshore areas west of Disko-Nuussuaq in West Greenland. During 2007 and in early 2008, eight new exploration and exploitation licences were issued. Today there are ten oil/gas licences in Greenland, and there are seven companies involved: Cairn Energy PLC, Chevron, DONG Energy, EnCana Corporation, ExxonMobil, Husky Energy and NUNAOIL A/S. In the course of the year, GEUS has advised the Bureau of Minerals and Petroleum in connection with administration of the many applications for licences, and researchers from the institution have been busy compiling and publishing the oil geological knowledge collected during the most recent research projects in West Greenland. The year 2007 also saw the USGS publish new figures on oil resources in Northeast Greenland in connection with American assessments of the entire Arctic area. The new assessments, some of which are based on cooperation with GEUS, reduced the expected oil/gas resource in relation to a previous assessment from 2000, but at the same time increased the probability. Northeast Greenland is still attractive in relation to hydrocarbons, and GEUS is planning several research projects in this area for 2008 and onwards.



## The Continental Shelf Project - underpinning possible national claims

As a project manager of the Danish Continental Shelf Project, since 2003 GEUS has been busy surveying the continental shelf in five areas off the coast of Greenland and the Faroe Islands, where it is deemed that there may be claims to extend the continental shelf beyond 200 nautical miles in accordance with the United Nations Convention on the Law of the Sea. Any resources under on the seabed will be assigned to the coastal state. The five areas involved comprise one area in the Arctic Ocean, two off Northeast Greenland and South Greenland and two areas northeast and southwest of the Faroe Islands. In 2007 the seabed was surveyed in the area southwest of the Faroe Islands, but the largest activity took place during the LOMROG expedition in the Arctic Ocean. Here, researchers surveyed the seabed and acquired seismic data and gravity data under very difficult ice conditions. The activities were carried out with the Swedish Polar Research Secretariat using the Swedish ice-breaker, Oden, as a platform and with the powerful Russian ice-breaker, 50 let Pobedy, as an auxiliary vessel during difficult parts of the expedition. In parallel with the current data acquisition, researchers have been busy processing and interpreting data from previous years' data acquisition. During 2007 interpretation of the data acquired in 2006 from the sea ice north of Greenland was completed, as well as interpretation of data from the area off Northeast Greenland. The Continental Shelf Project is being financed by the Ministry of Science, Technology and Innovation with contributions from the Faroese government and the work is done in a cooperation between GEUS and other institutions from Denmark, the Faroe Islands and Greenland.





## Testing of a new stable, self-consolidating concrete

The demand for concrete has grown in recent years due to the great activity in the construction sector, and there is a shortage of additives such as fly ash and microsilica, which are mixed with the concrete to give it greater strength and good casting properties. The concrete industry is therefore looking for alternatives. During 2007 GEUS worked together with the industry to test a new type of high-quality concrete, which uses a cheap fibre-like clay mineral as an additive. The concrete is self-consolidating, which means that it does not have to be vibrated when casting, and it can be pumped up to, for example, casting moulds, even under high pressure. It also has viscose-elastic properties, which ensure good coating of the reinforcing, and high stability so it does not separate in water and in the powder phase. It is the clay mineral Palygorskite with its unique fibre structure that provides the concrete with these good properties. It comes from Spain and was originally used to manufacture cat litter. This new concrete was developed through an EU research project, and GEUS has a European patent on the invention.

## Resource evaluation and geological mapping

In recent years, interest in mineral mining in Greenland has increased significantly. Two mines are already in operation and the Bureau of Minerals and Petroleum constantly receives new applications for exploration licences. In the course of the year, GEUS advised the Bureau of Minerals and Petroleum in connection with the many licence applications, and together with the Bureau geologists from GEUS have monitored the activities in the Seqi olivine mine in West Greenland and the Nalunaq gold mine in South Greenland. The year 2007 also saw completion of four years of ore geological investigations by GEUS near Godthåbsfjorden to assess the potential for mineral resources in the area. Activities are focusing on the Precambrian supra-crystalline rocks, which can hold mineralisation of precious metals and base metals, and several reports from the surveys have been published during the year, the final series alone comprises at least 14 reports. The work in the area also included detailed geological mapping to support the ore geological surveys, and over the summer geologists completed field work for a new 1:100 000 geological map of the Kapisillit area in Godthåbsfjorden.



# Mineral res

Creating the scientific basis for targeted and environment-friendly exploitation of mineral deposits in Greenland and Denmark



## Many new maps of Greenland

In 2007 GEUS published a number of printed topographical and geological maps in the scale 1:250 000 of Greenland's most deserted and inaccessible areas. The maps cover land and glacier areas 10-times the area of Denmark, from 80 degrees north in western North Greenland over the northern point of Greenland at Kap Morris Jesup and all the way south to Scoresby Sund in central East Greenland. The 53 topographical maps contain information on coastlines, lakes, rivers and contour lines every 100 metres. The maps are based on compilations completed by GEUS as part of the exploration of the area during the past 30 years, and the printing of the maps now gives researchers, as well as others with interest in this area, access to new topographical data. Geological maps in 1:500 000 of this area have previously been printed. The 49 new geological maps contain somewhat more detail, and nomenclature as well as map units have been harmonised across map boundaries. The maps also exist in a seamless digital version, which can be searched in an interactive map on the GEUS website. Printing of the map sheets is being financed by Aage V. Jensens Fonde.

## More new diamond finds

Deposits of diamonds in West Greenland have been well-known for several decades, but it was not until the opening of the diamond mines in Canada that the mining industry became seriously interested in West Greenland. In the 1990s there was a comprehensive search for diamonds, and in recent years enterprises have been making more and more finds of the much sought-after precious stones, in particular in the diamond area at Maniitsoq in West Greenland. In 2007 GEUS continued several years' scientific surveys and mapping of the diamondiferous kimberlite rocks as a follow-up to work by companies, and in recent years geologists have identified new areas with diamond potential. One of these areas is the Disko Bay in West Greenland, where GEUS in 2006 reported finds of indicator minerals and micro diamonds in old river sediments on Disko Island. During 2007 the area was surveyed by the company Avannaa Resources Ltd, and in early 2008 the company announced the finding of 1 macro diamond and 101 micro diamonds on the mainland east of Disko. International interest in Greenland for diamonds continues, and GEUS is preparing several activities at the 9th International Kimberlite Conference in Germany, in August 2008.

# ources

## Web-based report database for industry

For many years, Greenland's mineral resources have been marketed by GEUS and the Bureau of Minerals and Petroleum at annual mineral fairs in Canada and through the issue of the newsletter MINEX as well as the theme magazine Geology and Ore and the fact sheets Exploration and Mining in Greenland. This service for the industry has now been extended with a new online portal to geoscientific publications and data through the database DODEX (Geoscience DOcuments and Data for EXploration in Greenland). This facility, which was developed by GEUS and the Bureau of Minerals and Petroleum, is targeted at professionals in the international exploration and mining industry. DODEX will provide easy access to all company reports available to the public and received by the authorities. The database will contain full references to the reports, which can be downloaded as PDF files, and searches in the database can be made through text search and geographical criteria. In 2007 GEUS worked on programming the database, and digitalisation and scanning of reports are in progress with a view to opening the database in spring 2008. DODEX is scheduled to be completed during 2009, when it will contain all company reports, relevant GEUS publications and information on available data.





## Reduced sea ice cover in the Arctic Ocean

In recent years measurements from American submarines and satellites have shown that the sea ice in the Arctic Ocean has been reduced significantly in thickness and area, and model prognoses show that perhaps the entire ocean will become ice-free during a future warmer climate. In 2007 researchers from GEUS and Norway presented results from the first studies of seabed cores from the most inaccessible parts of the Arctic Ocean north of Canada and Greenland. Using studies of foraminifera in seabed sediments, researchers have proved that the sea ice cover was reduced in this heavily ice-covered area in the last interglacial period, which was warmer than today. The results are the first of their kind from this part of the Arctic Ocean, where the most severe ice conditions of the area are found today, and in future these results will help make more reliable model prognoses of the future developments of the sea ice in this area. The studies are part of the research project, Greenland Arctic Shelf Ice and Climate Experiment (GreenICE), which was financed by the EU.



# Nature and climate

Identifying processes leading to the current climate and environment situation in Denmark and the North Atlantic in particular





## Richer marine environment in previous warm period

During the warm period in Roman times, from around the birth of Christ to 300-400 years after, there were significant changes in the marine environment in inner Danish waters. The seawater became more salty and surveys of seabed deposits from Horsens Fjord and Tempelkrog at the end of Isefjord show that the marine environment became more productive. Geologists from GEUS, the University of Aarhus and Loughborough University in England have studied the incidence of mussels, snails and foraminifera in drill cores from the seabed and have found species requiring other living conditions in order to survive than those we have today. The increased salinity and productivity in the inner waters can be explained by a larger inflow of seawater with high salinity from the North Sea. Other surveys of marine environment of the past also show that there was a significantly increased inflow, which has impacted the marine conditions in the central part of the Baltic Sea. The surveys are part of a current project, which aims at studying the development of the Danish coastal environment over the past 9000 years. The work is supported by the Danish Research Council for Culture and Communication, the Danish Research Council for Nature and the Universe as well as by funds from Loughborough University in England.

## A new tool for better nature protection in the Baltic Sea

The EU-funded research project, BALANCE, was completed in 2007. One of the results is the development of marine landscape maps for the Baltic Sea, Kattegat and the Skagerrak. The maps classify the seabed in various types of landscape on the basis of information on sediment, salinity and light conditions, which are important parameters for describing living conditions on the seabed for plants and animals and identifying habitats. Habitats of the Baltic Sea region are under threat from sand dredging, fishing, tourism and pollution, and the many often conflicting interests create problems, which call for common solutions from the Baltic countries. The marine landscape map is an important tool for making a common management plan for the area, which can create a balance between nature and human activity. The maps are based on existing geological and physical data from all the Baltic countries, and during the project GEUS was responsible for compiling data and producing the maps that are all now available through the project's data portal. Nineteen institutions from nine Baltic countries took part in the project, which was managed by the Danish Forest and Nature Agency.

## Addressing the world's environment and resource problems

More than fifty geological surveys have undertaken to prepare a digital geological map of the entire world on the scale 1:1 000 000. The OneGeology project is perhaps one of the largest and most ambitious international mapping projects ever. Geological maps are important for knowledge of nature and resources, and the project contribute to a better understanding of the world's environment and a global solution to environmental and resource problems. Data will be available on a web portal as a dynamic geological map, which is constantly updated when new data are received from all over the world. GEUS is contributing with digital geological map data from Denmark and Greenland. OneGeology is a joint contribution from the geological surveys to the UN International Year of Planet Earth 2008, activities of which will be carried out from 2007-2009. In a press release before the project's launch in England in March 2007, Ian Jackson from the British Geological Survey said, "All geologists know well that geology and rocks don't respect man-made political frontiers. Nor do the environmental problems and natural resources that go with them. With our changing climate, there is even more urgent need for good quality and more complete data about our environment to be available for those who need it. By contributing to OneGeology, each nation can do something locally to make a huge difference globally."

## A digital map of valuable geological areas

Denmark's almost 500 valuable geological areas are currently being collated on a digital map. These are all areas which tell an important story of how Denmark came into existence. The map, with associated geological descriptions, is primarily for municipalities and regions in their planning and work to protect geologically interesting areas in the open landscape, but it will also benefit anyone interested in geology. Two examples of valuable areas which best illustrate Denmark's oldest history are Møns Klint, which tells us about the time when Denmark was a chalky ocean occupied by sharks and cuttlefish, and Jyske Ås which tells us about the time when the ice during the Ice Age stretched from Vendsyssel over Kattegat to North Zealand. On the map, there are both point areas and large landscapes. Hollerup Kiselgurgrav west of Randers is one of the point areas with layers from the entire Eem interglacial period and with the oldest certain traces of human life. Faldborgdalen and Skalsådalen are large landscapes with important parts of the history of Gudenåen. The map is produced in cooperation between the Agency for Spatial and Environmental Planning and GEUS, and is completed region by region. The map of the Region of Central Jutland was completed in 2007, and maps and geological descriptions from 130 areas can now be accessed on the Internet.





## Doctorate and assigned professor

Research professor Jens Christian Refsgaard from GEUS received a doctorate in natural science in 2007. On 1 June he defended his doctoral thesis 'Hydrological Modelling and River Basin Management' at the University of Copenhagen. The thesis presents the benefits of using hydrological models to describe the aquatic environment and it assesses the uncertainties associated with the use of these models in practical management of water resources. In the same month, senior researcher Jens Aamand from GEUS became attached to the Department of Ecology at the University of Copenhagen as assigned professor, where he will teach and participate in enhancing research into microbiological degradation of foreign substances in water and soil.



# Glimpses of the year

## The world meets to make more reliable water models

In September, Geocenter Copenhagen hosted the international ModelCARE conference, where researchers from all over the world gathered to discuss how to develop more reliable models to describe the flow of groundwater. Today, mathematical models are essential tools for managing groundwater resources and there are ever greater demands that the models make accurate calculations. Both international and Danish interest in the conference was great. More than 180 researchers from 32 countries participated in the conference, including the world's leading experts within groundwater modelling. About 50 Danish experts came from universities, research institutions, consulting companies, water companies and environment centres. One of the driving forces of the organisational committee - research professor Jens Christian Refsgaard from GEUS said at the conference, "Water is one of the world's most important resources, which we must manage in the best possible way. The development of more reliable models for calculating our groundwater is an important step towards sustainable exploitation and good management of groundwater resources".







## Groundwater award for visionary efforts

On 1 November, state geologist Richard Thomsen from GEUS received the G.O. Andrup Groundwater award for his life-long work to secure the groundwater and his contribution to the development of new methods for groundwater protection. The Groundwater award of DKK 60 000 was presented by Erling Bonnesen - member of the Danish Parliament's Environment and Regional Planning Committee at an event in Odense Congress Center. Richard Thomsen is the first recipient of the new G.O. Andrup Groundwater award, set up by Odense Water Ltd. The prize, which is to put groundwater and drinking-water quality on the agenda, is named after the former director of Odense Water Ltd, who was a devoted environmental debater and an ardent advocate of groundwater protection. At the presentation Erling Bonnesen said among other things, "Over a life-long career Richard Thomsen has worked to secure groundwater, and he has demonstrated that this is possible by contributing to and initiating the development of new methods. He has a visionary eye for the possibilities in research and has the ability to create an appreciation of - and thus realisation of - unique groundwater protection efforts, which are currently being implemented in Denmark".

## Opening of mobile exhibition on Greenland's geology

To present geology to a larger public in Greenland, together with the Aasiaat Museum GEUS has set up an exhibition on geological research and Greenland's geology. The exhibition opened at Aasiaat Museum in the autumn and has since received many visitors. The exhibition, which is in Danish and Greenlandic, describes the main features of Greenland's geological development. With examples, it tells us about the work methods of geologists, Greenland's minerals and the possibilities of finding oil and gas. It is a lightweight exhibition, which can be easily set up, packed away and sent off so that during the forthcoming years it will be exhibited all around Greenland. So far the exhibition will be displayed at Narsaq, Paamiut, Sisimiut, Qeqertarsuaq and Qaqortoq in 2008.

## Support to young Greenlanders with a feeling for oil

In early January, the INUTEK Technological Society of Greenland implemented the internet-based oil exploration game, OILSIM in cooperation with the Faroese e-learning firm Simprentis and the Bureau of Minerals and Petroleum. More than 100 high-school students from all over Greenland competed for two days in this virtual game, where you have to find as much oil and gas as possible. The first prize of DKK 5000, donated by DONG Energy, was presented in Nuuk to Agathe Møller and Kista Høegh, together with a cheque for DKK 21 000 from GEUS for their trip to England, where they participated in a similar international virtual oil hunt at Chevron's offices in London on 27 January. Here, winning teams from Denmark, the Faroe Islands, Greenland, Norway and Scotland competed, and Agathe and Kista came second before contestants from oil countries such as Norway and Scotland, only to be outdone by the Danish team from the Esbjerg Statsskole (high school). On their way back, there were more experiences and challenges for the two high-school girls, when they visited GEUS to hear about how real-life geologists search for the black gold. "We hope that their visit to London and their time here at GEUS will sharpen their interest in geology, so we can recruit more young people to this profession. There is a great need for this," said Kai Sørensen, deputy director of GEUS, after the visit.





## Capacity building in Ghana

In the course of the year, GEUS has continued its work over many years on building capacity in Ghana within the water area and the mineral sector, which are both important for the country. At the University of Ghana in Accra, capacity building is taking place within the specialist area hydrogeology and hydrology. In 2007 work included helping Ghanaian PhD students to carry out hydrogeological surveys of the palaeozoic Voltaian sediments, which amount to 40 per cent of Ghana's subsurface, and which may contain important groundwater resources. The activities are taking place in cooperation with the Geo-center partner, the Department of Geography and Geology at the University of Copenhagen, and they are being supported by Danida's ENRECA programme. In the area of minerals, work has included capacity building in connection with the geological survey in Ghana - Geological Survey Department (GSD), which is a key institution in the mineral sector. Mineral resources amount to approx. 38 per cent of Ghana's exports, and the activities aim to build knowledge, tools and facilities, so the institution can better manage work linked to exploitation of the country's mineral resources and to other geological work. The work included training geologists in geological mapping and a number of geological key disciplines such as geochemistry, petrology, sedimentology, paleontology and stratigraphy as well as helping operate laboratory facilities and build digital databases and GIS tools. The project, which is being financed by the Mining Sector Support Programme (MSSP), is part of a larger European package of support projects for Ghana from the European Development Fund.



## Building oil-geological knowledge in East and Southeast Asia

The intergovernmental organisation CCOP (Coordinating Committee for Geoscience Programmes in East and Southeast Asia) works to promote geo-scientific research programmes in East and Southeast Asia to improve the economy and quality of life in this region. In 2007 several CCOP countries completed an oil-geological project with support from the Danish International Development Agency (Danida) and with GEUS as a Danish partner. Since the beginning of 2005 the project has been very successful in stimulating oil/gas-related research cooperation and geological knowledge-building. Oil/gas is a vital sector for the development of the economy in this region, but the majority of revenues go to private oil companies, for example because of inadequate competences in public oil/gas institutions. There are several interesting deposits of hydrocarbons in geological basins across national borders, and over the years CCOP has been an important organisation in promoting cooperation in this region, where lurking conflicts between countries on ownership of oil/gas resources are ever present. The project has focused on hydrocarbon surveys in two geological basins - the Song Hong-Yinggehai basin between China and Vietnam and the Sulu Sea-East Sabah basin between Malaysia, the Philippines and Indonesia. The project has attracted great attention at government level in the individual countries and has been able to provide goodwill and extra support for the work. For the first time, in partnership it was possible to produce a number of geological maps of the two basins across national borders. The work has created a much better geological basis, which can increase interest in investments from the international oil industry, and it has created trust and confidence between the countries in this region. In parallel with case studies, the project has addressed the technical geological problems facing the individual countries in joint seminars, workshops and field trips, where experts from the region and GEUS have been heavily involved as resource persons and facilitators.



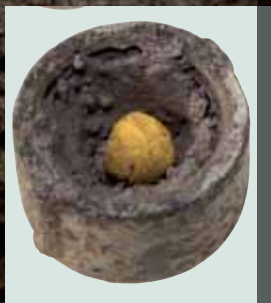
# GEUS around the world

Knowledge-building in developing countries through research and consultancy



## Sustainable small-scale mining

In recent years GEUS has worked on behalf of the World Bank in several developing countries to map the scope of small-scale mining and provided advice on more environment-friendly practice in this type of mining. Small-scale mining is an important basis of life for nearly 100 million people throughout the world. Gold mining creates the majority of jobs in small communities. Gold miners use mercury to extract gold, and this creates great environmental and health problems, if not handled correctly. In 2007 there were activities in both Asia and Africa. In two areas of the Philippines, where around 5 tonnes of mercury is discharged annually, courses have been arranged for gold miners and their families on the use of a small simple instrument called a retort, where the mercury is reused during gold extraction. During work at Luzon, it was observed that a few small groups of gold miners used a previously unknown and simple method to extract the gold, by using the chemical borax. The method, which is harmful to neither the environment nor health, has now been introduced in the further process of the project on an equal footing with the retort, and GEUS is planning to introduce the borax method in other parts of the world, where the institution is involved. The go-ahead was also given for a project in Zambia with the aim to build capacity at the Environmental Council of Zambia (ECZ) to improve conditions for small-scale mining both production-wise and environmentally in the Copperbelt, Southwestern and Eastern Provinces in Zambia. The project is being financed by Danida through the United Nations Development Programme (UNDP) and is being implemented together with Obicon A/S. Finally, GEUS signed a cooperation agreement with the Geological Research Authority of the Sudan, aiming at advising on small-scale mining, building laboratory facilities and establishing joint research projects.



## Building African oil expertise

In recent years, there has been a great interest in the East African oil potential. The Sudan already produces oil, and Uganda found oil in 2007 and is expected to become an oil-producing nation by 2010. The Western Rift Zone in East Africa, in particular, is interesting in relation to oil, stretching from Lake Tanganyika and through Uganda into the Sudan. GEUS has previously been engaged in the building of oil expertise at the Petroleum Exploration and Production Department (PEPD) under the Ministry of Energy and Mines in Uganda, and in 2007 a similar project was launched in the Sudan. The project is to train petro-chemists from the Central Petroleum Laboratory (CPL) in the Sudan Ministry of Energy and Mining, and to facilitate the exchange of knowledge and cooperation between CPL and PEPD to increase knowledge of the geological conditions and the oil potential in the Western Rift Zone. So far this work has included analyses of oil samples from wells in southern Sudan and Uganda and analyses of source rocks from the rift zone between the two countries. The project is being financed by Danida through the United Nations Development Programme (UNDP).





# Key figures 2007

More detailed key figures for GEUS' activities can be found in 'Årsrapport 2007' (Report and Accounts 2007) and in 'GEUS' virksomhed i 2007 - Faglige resultater' (GEUS activities in 2007 - scientific results), the latter in Danish only, available on request from GEUS or at [www.geus.dk](http://www.geus.dk)

Number of employees: 304

Number of scientific projects: approx. 500

## ACCOUNTS 2007

Amounts in million DKK

<b>Revenue:</b>	<b>273.7</b>
Net figure (appropriation)	132.9
Operating income	140.8
<b>Expenditure</b>	<b>279.5</b>
Salaries	137.2
Other operating expenditure	142.3

## PRESENTATION ACTIVITIES

Long-term knowledge building

Articles in international scientific journals/publications	104
Articles in GEUS' own scientific series	37
Other scientific publications	9

Ongoing scientific task solution, consultancy and presentation

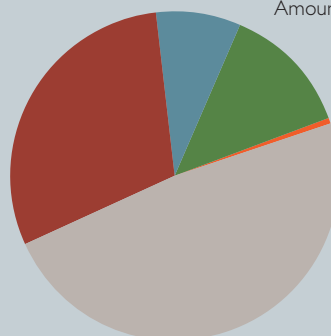
Publicly available reports	70
Confidential reports	36
Memoranda, opinions, expositions, etc.	49
General presentation	
Institution reports (annual report, etc.)	4
General and popular-science presentations	109
Visits on <a href="http://www.geus.dk">www.geus.dk</a>	2 270 000

## RESEARCHER TRAINING

Current PhD students	49
Completed PhD degrees	2

## Revenue broken down by sources of revenue

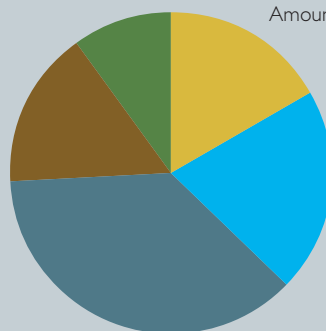
Amounts in million DKK



Budget appropriation:	132.9
Programme and external resources:	82.1
Other co-financed contract research:	22.4
Commercial contracts and sale of data:	35.5
Other revenue:	0.8

## Expenditure broken down after programme areas

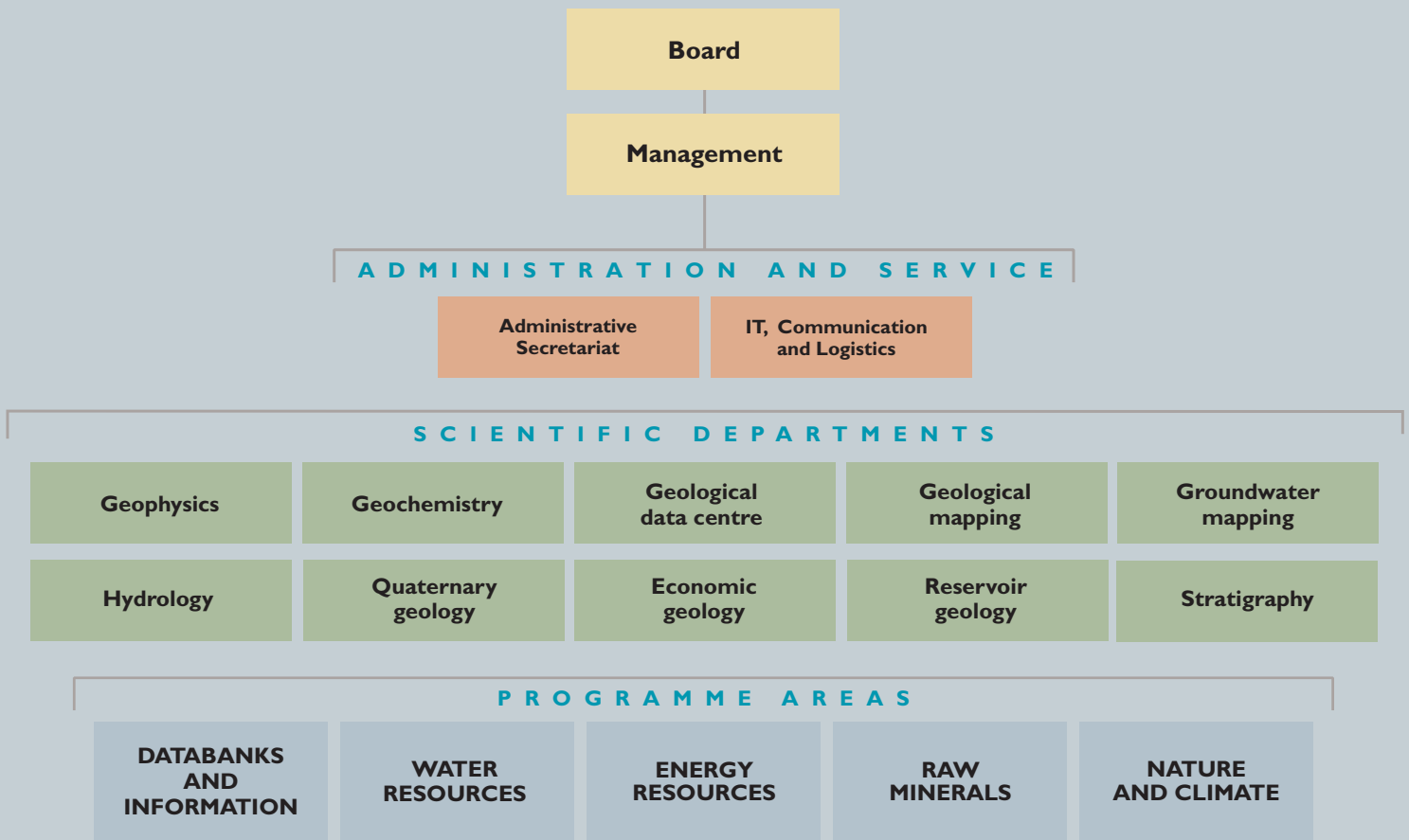
Amounts in million DKK



Databanks and information:	47.1
Water resources:	57.7
Energy resources:	102.8
Mineral resources:	44.5
Nature and climate:	27.4



# Organisation



In 2007, GEUS had ten research departments and two administrative/service departments. Scientific work takes place 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 geo-data to GEUS. The objective is to ensure that data and sample collections are on a quality level allowing them to be used to implement projects in the areas of monitoring, emergency preparedness, consultancy and research. In addition, the programme area includes IT projects to develop efficient and modern IT tools for GEUS and presentation of data to the scientific community and the public.

**Programme area:**  
**Water resources**

Procuring the necessary basis on which to manage our water resources. Activities are aimed at water circulation, the volume and quality of water resources,

groundwater protection and transportation of substances injurious to the water environment with special emphasis on groundwater. The activities form the basis of consultancy services to government and local authorities.

**Programme area:**  
**Energy resources**

Procuring and contributing to the basis for continued exploration and sustainable exploitation of the energy resources of Denmark and Greenland. Activities include own research projects and international co-operation in the areas of oil/gas and alternative energy. The knowledge retrieved forms the basis of GEUS' consultancy services to government and local authorities and to some extent projects carried out for the corporate sector.

**Programme area:**  
**Mineral resources**

Procuring the scientific basis for targeted exploration and environment-friendly exploitation of raw materials and minerals in Greenland and Denmark.

Activities include geological mapping and exploration of mineral resources in Greenland and official processing and consultancy services for Greenland Home Rule. In addition, studies are conducted regarding raw materials and construction work in Denmark and internationally.

**Programme area:**  
**Nature and climate**

Identifying the processes in time and space leading to the current climate and environmental situation in Denmark and the North Atlantic region in particular. One objective is to improve the prospect of distinguishing between natural and man-made environmental changes. This programme area also includes mapping of onshore and offshore geological conditions, as well as earthquake research and monitoring.



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

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](mailto:geus@geus.dk)  
Homepage: [www.geus.dk](http://www.geus.dk)



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