

Knowledge about the earth that sustains us



Water
Energy
Mineral resources
Nature



Annual Report 2005

GEUS
MINISTRY OF THE ENVIRONMENT



GEUS

GEUS' major research fields

Knowledge about the earth that sustains us

The earth sustains us and provides us with energy and natural resources, and we get our all-important drinking water from it. Our growth is dependent on the raw materials available for industry and building, and for many years, we will remain dependent on oil and gas for heating, industry, and transport. Pollution can spoil our drinking water, and clean drinking water is a scarce resource in many places around the world. Geological research is therefore an important key to our continued ability to find and manage our resources wisely and sensibly. This is reflected in GEUS' major research fields.

In May 2005 the Danish Council for Research Policy notified Danish research institutions about a hearing to identify especially promising research fields to be appointed high priority. At the request of the Council, GEUS submitted three current major research fields and two up-and-coming research fields.

Current major research fields:

The Precambrian basement of Greenland

Greenland's Precambrian basement is one of the largest coherent masses of the oldest rock types on earth. It holds important mineral resources, and geological studies can inform us about the earth's major geological processes where continents break and come together again

Oil geology in Denmark, Greenland and the Faroe Islands

Denmark is still self-sufficient in oil and gas and Greenland is in the process of finding these much-coveted energy resources. Geological research is an important precondition for making new finds and for exploiting existing hydrocarbon resources most efficiently.

Water resources

Clean drinking water is still a matter of course in Denmark, but pollution and unsound use of this resource may put an end to this. Knowledge about groundwater and the water's cycle are essential for continued good monitoring and management of this very important resource.

Up-and-coming research fields:

The formation and development of the Labrador Sea, the North Atlantic Ocean and the Arctic Ocean

Great geological processes controlling the formation of oceans have made their mark in the North Atlantic Ocean and the oceans around Greenland. Geological knowledge about what happened is an important prerequisite for assessing the origin of the oceans and what resources might hide below the seabed.

Geomicrobiology

The life and activities of microorganisms in the ground and groundwater sediments play an important role in the breakdown of pollutants. Geomicrobiological research concentrates on mapping the lives of microorganisms and the role they play in depollution.

Read the full description of GEUS' major research fields at www.geus.dk (only available in Danish).



Foreword

2005 turned out to be a good year for GEUS, including yet another great number of exciting projects within a wide range of work tasks, and a political decision to stabilise the Ministry of the Environment and GEUS' financial appropriations in the coming years. Following staff cuts in previous years, this means that peace and quiet to work have now been re-established along with renewed enthusiasm and optimism among employees.

One of the year's memorable events was a visit to GEUS' activities in Greenland by the Danish Minister for the Environment, Connie Hedegaard. The Minister first visited the Glacier in Bredefjord (Sermilik) in South Greenland where the results of climate change can be witnessed at first hand. Over a period of 20 years the tip of the glacier has retreated 7 km and the rocks 200 metres high above its current surface bear signs of the glacier's previous thickness. GEUS demonstrated its automatic equipment, which measures the melting of the ice and submits data via satellite to GEUS on a regular basis. The Minister had just hosted a meeting in Ilulissat for environment ministers from 24 countries. At the meeting, the ministers had discussed the effects of climate change and the visitors were able to see for themselves how the world's fastest moving glacier has shrunk considerably in size.

The Minister then went by helicopter to the Storøen island where Nuna Minerals is drilling for gold, and to some of GEUS' geology field camps in the mountains. Here the geologists were able to show the Minister their recent find of carbonatite, which suggests that other types of mineral deposits may be found in the area. The Minister thus got an impression of GEUS' many and varied field surveys, which cover geological mapping as well as targeted exploration for mineral resources, and the importance of these activities to efforts by the Greenland Home Rule to develop the mineral resources sector into a leading industry for Greenland. GEUS in Copenhagen, along with the other institutions under the Ministry of the Environment, took part in

the implementation of the new local and central government structural reform. On 1 January 2007, the Ministry of the Environment will be welcoming about 750 new employees transferred from the counties. This will also affect GEUS in that a new department will be established in Aarhus. Furthermore, GEUS will be playing an important role in the establishment of Denmark's Environmental Portal. The office in Aarhus will be in charge of coordinating the future fee-financed survey of Danish water resources, whereas GEUS' Geological Data Centre will be in charge of receiving, quality assuring, and processing data from municipalities, regions and environmental centres in the new structure, as well as making them available to public and private stakeholders.

GEUS and the University of Copenhagen intensified their collaboration in 2005. Never before has GEUS had so many PhD and Master's thesis students linked to the institute. At a common Geocenter Day, employees from the Geological Institute, the Geographical Institute, the Geological Museum, and GEUS debated joint research projects and the development of joint facilities. A number of initiatives were taken to further increase the synergies from constructive collaboration in Geocenter Copenhagen. GEUS wants to expand its collaboration with the university environment to cover the University of Aarhus. GEUS recruits its researchers from both Aarhus and Copenhagen Universities. Due to a coming generational shift, GEUS will need to ensure the recruitment of well-qualified candidates within many different scientific disciplines in the next 5-10 years.

In this annual report we draw a picture of GEUS' many activities in research, education, consultancy, and communication through a number of examples. These are only a small selection of the almost 500 projects that GEUS carried out in 2005.



Per Buch Andreasen
Chairman of the Board



Martin Ghisler
Managing Director



Photo: Danish Minister for the Environment Connie Hedegaard flanked by Buch Andreasen, Chairman of the Board (right), and Martin Ghisler, Managing Director (left), in front of the Sermilik glacier northeast of Narsaq in South Greenland.

Harmonisation of data from Danish counties

Danish counties and municipalities are under restructuring so that by 1 January 2007 Denmark will consist of 98 municipalities and five large regions. It is important that the new municipalities, regions and state environmental centres, from the start, have the best possible data basis for managing the environment, drinking water and natural resources. Today, Danish counties have independent databases, which are managed and updated differently and therefore vary considerably with regard to content. GEUS worked closely with the counties during 2005 to harmonise data, so that in future all data will be available in one place and in the same format. The data in question are geological data from drillings and data on groundwater resources and water chemistry. All the data will be included in the Danish Regions' Environmental Portal, planned for launch in 2006. The groundwater section of this portal is GEUS' national Jupiter database, which contains data on: drillings, drinking water and groundwater quality, groundwater resources, and groundwater level. Work in 2005 also covered a survey of new data from the counties which have not previously been registered. This is data on e.g. photos and other records from drillings, sample data from pumping tests in selected aquifers, as well as sedimentary-chemical analyses, age determination of groundwater and printed drilling reports, which are scanned into the database.

Expansion of databases and online access

In 2005, GEUS expanded two national databases: the Jupiter database, which holds information about groundwater and drillings, and the GERDA database, which contains geophysical data for the environment and raw materials area. Jupiter was expanded to make it integratable with the Danish Region's Environmental Portal. The database was set up so that it can now receive a series of new data types from the counties, such as data on water extraction licenses, and so that data can be transferred automatically to the Environmental Portal. Furthermore, it is possible to record historical data on fixed points and coordinates for drillings, while scanned copies of original drilling reports from the counties are available for some areas. Towards the end of 2003 information about the 240,000 drillings in the database was made available via the Internet, and the public has made ample use of this online access to geology and groundwater information. In 2005 access to the Jupiter database was expanded, which means it is now possible to find groundwater chemistry information and see graphic illustrations and tables of raw-water analyses. The GERDA database contains different geophysical data, mainly from regional mapping of areas of special drinking water interest, as well as GEUS well-logging data from water wells. GERDA was expanded in 2005 to include the possibilities of extracting data in different spatial referencing systems and storing helicopter electromagnetic (HEM) data. GERDA was developed in close cooperation with the University of Aarhus, Aarhus County, the Danish Forest and Nature Agency, and consultancies.

Databanks and information



mation

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

NR. 4



GeoKnowledge – a new magazine for upper-secondary schools

2005 saw the launch of a new popular science magazine called "Geoviden – Geologi og Geografi" (GeoKnowledge – Geology and Geography). The magazine is published by GEUS in cooperation with the Geocenter partners: the Geological Museum, the Geological Institute, and the Geographical Institute, all of which belong under the University of Copenhagen. The magazine was published in four issues, in both printed and electronic form, dealing with themes about the mineral resources of Greenland, the formation of Danish landscape in the Ice Age, the coasts of Denmark, and earthquakes and processes in the earth's interior. The magazine aims at readers with an interest in nature and it is targeted especially at teachers and students at Danish upper-secondary schools. The first issue of the magazine was well received and the number of subscribers of the printed version went up during 2005 from 3500 to more than 4000. Interest in the magazine is also reflected in a tripling in visits to the Geocenter's website, where GeoKnowledge can be read or downloaded.

Geology "on the air"

Several GEUS employees participated in TV and radio programmes during 2005, explaining their work and contributing with expert knowledge. In "Naturesyn" (Nature vision), a radio show broadcasted by the Danish Broadcasting Corporation (DR), listeners could hear the story of Greenland's first World Heritage site Ilulissat Icefjord, and they could hear facts on Greenland's geological development and accounts from geological field work in Greenland. On television, the popular-science series "Viden om", also broadcast by DR, allowed viewers to follow researchers' hunt for groundwater as well as their hunt for methane in the seabed that, if released, can affect the climate. Furthermore, GEUS researchers contributed knowledge and interviews to a theme section on earthquakes on DR's website "Viden + IT" (knowledge + IT), a website with information about the natural sciences, IT and technology. The theme section in question include the webpages: "Farvel Californien" (Goodbye California!); "Jordskælv giver ny viden om vores planet" (Earthquakes – a source to new knowledge about our planet); and "Kan det ske i Danmark?" (Could it happen in Denmark?) You can hear or see these programmes in Danish via the GEUS website under the Danish menu title "Geologi for alle."

Almost four million years of geology on paper

GEUS published a comprehensive popular science book in 2005 called: "Grønlands geologiske udvikling – fra urtid til nutid" (The geological history of Greenland – from the prehistoric to the present). The rocks and mountains of Greenland tell the story of the earth's geological development going back 3800 million years. The book takes us all the way back in time and around the world's largest island. It summarises the results of more than 60 years of geological surveys on land on the continental shelf off the coast of Greenland, explaining the geological processes and shedding light on the economical resources present in Greenland's rocks. The book was well received by critics. The Danish newspaper Berlingske Tidende wrote: "How was the world's greatest island created? What is it made of? And what are the powers that formed its mountains, rocks and highlands? A unique new work on Greenland's geology gives us the answers to all of these questions. Surely, this is the ultimate book about Greenland! 270 pages, illustrated lavishly and in large format, about the creation of the largest island in the world". Since its publication in mid-October last year, interest in the book has been great – not only in Denmark, but also in Greenland, Norway and Sweden.

New national hydrological model

Water is necessary - for humans, as well as for fish and fowl living in and by watercourses and lakes. A national hydrological model is one of the tools for good water resource management. In 2005, GEUS and the counties began joint work on national modelling of the water balance and groundwater formation. This work will continue until 2009 and will be carried out under the programme for national monitoring of the aquatic environment and nature - known as NOVANA. The National Water Resources Model, the so-called DK-model, which GEUS used as basis for its most recent statement of potential drinking water resources in 2003, also forms the basis for the new DK-model of NOVANA. Work will include adapting the DK-model to the new water districts under the structural reform and bringing up to date the model with data from regional mapping of areas with special drinking water interests. The NOVANA DK-model is a large-scale model, which is to provide an overall picture of the water balance as well as the size and utilisation of groundwater resources, taking into account factors such as climate change, land use, and water extraction strategy. However, the project also aims at creating a consensus about the overall hydrological interpretation and data used, so that the model will have general acceptance in national management of groundwater resources. Finally, the project is to ensure uniform interpretation of the model across administrative borders.



Predicting future sources of groundwater contamination

The use of new industrial chemicals or changes in the use of known chemicals can lead to new groundwater contamination. Denmark wishes to keep its groundwater clean. On behalf of the Danish EPA, GEUS therefore had a look at which substances other countries have found to be potentially threatening to groundwater. This work included extensive research of international literature and contact to European and US knowledge centres working with groundwater quality. The objective was to determine what the international scientific society deems to be potential future sources of groundwater contamination. Future contamination could not only come from new substances which industry has put into use, but also substances or microorganisms which could not previously be detected or substances whose use or occurrence in products was hitherto unknown. The substances and microorganisms predicted to be likely future contamination are described in the report "Emerging contaminants in Danish groundwater". These are substances and microorganisms which are not currently included in the national monitoring programmes. Furthermore, in the report GEUS recommends that research and monitoring should be instigated with regard to: new break-down products from pesticides, oestrogen from farm animals, disease-causing viruses, bacteria or single-celled animals, medicinal products and antibacterial agents, as well as certain synthetic musk compounds.

Water

Procuring knowledge
for optimal management
of our water resources

Break-through in BAM research

BAM, a breakdown compound from the pesticide dichlobenil, is the most frequently occurring pesticide component in Danish groundwater. For a number of years, GEUS has worked on several problems related to BAM. In 2005, a project was completed which developed a cheap and quick analysis method for determining pesticides in groundwater, including BAM. Project efforts included the development of anti-substances for pesticides with which it is possible to measure the presence of pesticides in a water sample. The method was implemented on a microchip platform allowing for the analysis of concentrations ten-times lower than previously possible, and it is possible to analyse water with regard to concentrations of two different pesticides on the same platform. The method was developed in collaboration with Statens Serum Institut, Exiqon, and the Department of Micro and Nanotechnology and the Institute of Environment & Resources at the Technical University of Denmark. The project had support from the SUE programme (programme on the collaboration between sector research, universities, and enterprises and industry) under the Danish Agency for Science, Technology and Innovation. During the project it was ascertained that BAM can be broken down using a special type of bacteria which the project's scientists succeeded in isolating at a later stage of the project. The special type of bacteria is being patented and in 2005 two new research projects were launched. These projects experiment with the use of the special type of bacteria to remediate soil and groundwater that have been contaminated with BAM. One project is aimed at developing microbiological filters for use in connection with contaminated water wells and in-situ remediation of BAM-contaminated soil under farmyards. The two projects are supported by the Danish Research Council for Technology and Production Sciences and the Danish EPA, respectively.

resources



Better quality in modelling work

The EU Water Framework Directive, which entered into force at the end of 2000, sets out requirements for management of national water resources. Hydrological models linking groundwater and surface water are used in resource management, and there is increasing demand for quality assurance of the use of these models. Since 2002, GEUS has taken part in the EU-funded research project HarmoniQuA. This is a project to establish procedures for how to achieve better quality modelling work. The project has concentrated on providing guidance on state-of-the-art modelling practices, creating dialogue between water-resources managers, modellers, reviewers and stakeholders, and ensuring transparency to a degree that will enable outsiders to understand the modelling process in detail and, thus, to discuss the modelling work. During the project a quality assurance tool was developed in the form of a software programme, MoST. MoST supports quality assurance within a number of fields such as groundwater, surface water, water quality, ecology, and economy. GEUS hosted a workshop in 2005 where the project and the functionalities of MoST were introduced. GEUS also manages the EU project HarmoniRiB. This project is working to develop methods to assess the uncertainty of water data and water models, and to establish a network of representative European upland areas through which data on uncertainty levels can be made freely available for other research projects.

Model for deep aquifers in Jutland

Sand layers from the Miocene period make up some of the most important aquifers in Jutland, and several counties in Jutland therefore stress the importance of these layers in the assessment and protection of Danish groundwater resources. GEUS and the counties are collaborating on the preparation of a three-dimensional geological model of the sediments. Several methods must be put into play in order to map these old, primarily fluvial, sediments. Geologists examined the content of fossils in six new boreholes in the counties of Ringkøbing and Vejle, and five boreholes in Sønderjylland County, in order to more fully understand the structure of this series of strata. Geophysical data are also being used to map the layers, and the sediments are being examined in coastal cliffs and quarries where the layers, in some places, have been exposed. An adjustment of the dating of the Salten Profile in the County of Aarhus revealed that a revision of the entire Miocene series of strata in the northern part of central Jutland is required. A PhD programme was commenced in 2005 with the aim of establishing a geological model for the Jutland Miocene aquifers. The model will be used for subsequent calculations of groundwater flow.



Greenland's oil – a new area to play with

The Bureau of Minerals and Petroleum (BMP) under the Greenland Home Rule is preparing an upcoming licensing round for an offshore area west of Disko-Nuussuaq in North-west Greenland. In this context, GEUS has been working together with the BMP to evolve an exploration strategy and has been participating in marketing efforts aimed at the international oil industry. New geophysical data reveal the presence of deep basins and large geological structures in the area not far from the sites on the island of Disko and the peninsular Nuussuaq where oil is seeping from the rocks. In 2005, geologists from GEUS continued the work on interpretation and analysis of data from the area. Seismic and other geophysical data need to be interpreted in order to adjust the geological models and analyses of source rocks, reservoir rocks, and oil seeps. Finally, GEUS has commenced conversion of all relevant exploration data from the area, so that they can be made available for GIS systems in the future.

Another licensing round in the North Sea

The 6th licensing round for exploration and extraction of oil and gas in areas in the North Sea began on 20 May 2005 when the Danish Energy Authority announced the terms of the new concessions. By the deadline on 1 November 2005, the Danish Energy Authority had received 17 applications from twenty oil companies. Companies included some that have not previously had concessions in Denmark. In connection with the licensing round, GEUS marketed a comprehensive series of geodata from the North Sea and offered special data compilations to industry. In 2005 GEUS also evaluated the quality of the work programmes of applicants, preparing memos hereon for the Danish Energy Authority.



Energy



Danish-Canadian collaboration on delimitation of the continental shelf

Denmark and Canada will work together to collect the data necessary to support possible claims for expansion of Canada and Greenland's continental shelf beyond 200 nautical miles into the Arctic Ocean north of Ellesmere Island and Greenland. This was the content of a memorandum signed by representatives of the Earth Sciences Sector (ESS) of Natural Resources Canada and GEUS in 2005. Both countries have ratified the United Nations' Convention on the Law of the Sea which allows coastal states to make claims on subsurface and seabed resources beyond 200 nautical miles. However, seabed depth and geology must live up to a number of conditions described in article 76 of the Convention. The Arctic Ocean is an area which is difficult to access and the ESS and GEUS have therefore agreed to collaborate on the efforts to collect and process data, so as to make work as efficient as possible. The preliminary joint work programme covers the collection of refraction-seismic, gravimetric and ocean-depth data in 2006 from the submarine Lomonosov Ridge which stretches into the Arctic Ocean north of Ellesmere Island and Greenland. In connection with these activities in the Arctic Ocean, GEUS collected data from three seismic stations onshore in Northeast Greenland in 2005. The purpose was to document the composition of the earth's crust. Furthermore, GEUS collected and processed data from two other areas where there is potential for making claims. These include an area northeast of the Faroe Islands where ocean-depth data were collected, and an area southwest of the Faroe Islands where, during the course of 2005, seismic data were interpreted and borehole samples from the seabed were subjected to chemical analysis. These activities are being funded by the Ministry of Science, Technology, and Innovation with contributions from the Faroese Home Rule Government, and are a collaboration between GEUS and other institutions from Denmark, the Faroe Islands, and Greenland.



resources

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



CO₂ storage in a European perspective

In 2005, GEUS took part in a number of EU-funded international research projects to clarify the possibilities for subsurface storage of CO₂, thus reducing emissions of this greenhouse gas to the atmosphere. At Ketzin near Berlin, researchers have been working to establish a geological model of the sand layers where CO₂ storage will be commenced in 2007. This will be the world's first plant for storage of the greenhouse gases from a power plant. This work is part of the project CO₂SINK, and activities in 2005 also included seismic surveys for planning boreholes for injection of the CO₂ and two observation boreholes. GEUS is moreover part of the CASTOR project, which is to examine the storage capacity in eight Eastern European countries, and of the ULCOS project, the objective of which is to develop methods for halving the CO₂ emissions from the European steel industry. In both projects, researchers have been working to identify suitable sedimentary basins for CO₂ storage near power plants and industrial plants in Eastern Europe and near the four largest steel works in the EU. Information and collaboration within international activities take place in a number of formal networks. GEUS participates in several European networks and is a representative in the global Carbon Sequestration Leadership Forum together with the Danish Energy Authority. In November 2005, GEUS hosted a workshop in the European Network of Excellence on Geological Storage of CO₂ (CO₂GeoNet). The purpose of this network is to strengthen Europe's scientific and technological positions within CO₂ storage through pooling resources and expertise.

New oil/gas resources in the North Sea

Oil and gas from the North Sea have supplied Danish society with energy for many years and large quantities of hydrocarbons are still hidden in the limestone. The oil is pumped up from highly porous layers in the limestone and knowledge about the structure and composition of the limestone is therefore of great significance when identifying new areas where oil may be found. In 2005 GEUS concentrated on an area around the Gorm Field and the Dagmar Field which already yields oil, and which could be holding more oil. The area covers several subsurface basins from the late Cretaceous with individual stratigraphical characteristics and development. During the course of the year, geologists carried out work to update the stratigraphy of the area in order to gain insight into the possible presence of hitherto unknown, highly porous layers. Work also included identifying possible zones in the limestone with enhanced porosity using seismic data. The continuous subsidence of the limestone in the North Sea causes the oil to flow in a very complex pattern, which in turn means that the oil can be found outside and on the flanks of upfaulted limestone structures too, places where one would normally not expect to find oil. In recent years the oil industry has had its eyes on these flank potentials and in 2005 GEUS carried out modelling work to estimate oil saturation in the flanks of the South Arne field in collaboration with an international oil company.

On-line access to Greenland's mineral occurrences

In early 2005, GEUS opened its new web service "Greenland Mineral Occurrence Map (GMOM)", which gives the mining industry and others access to information about hundreds of mineral deposits in Greenland. Users can search via an interactive map and the web service moreover allows you to see occurrences of minerals together with other types of cartographical data, such data on coastlines, rivers, lakes, and digital terrain models. Furthermore, the GMOM contains a series of geodata, for example airborne geophysical measurements and geochemical data made available as background maps. The user can combine the different data types with maps of mineral occurrences and create plots and files for own use. The user also has access to PDF files with GEUS interpretations of the occurrences of mineralisation mapped, including images and special maps for areas where this type of data is available. All depictions contain an overview of publications and company exploration reports. GMOM was developed in collaboration with the BMP in Greenland and covers the area between 66°N and 70° 15'N in West Greenland. Mineral occurrences often occur in special geological environments, and in the latter part of 2005 GMOM was expanded to include a search option on main types of geological environment throughout Greenland and a view option showing these together with selected occurrences of the minerals associated with the environments.

Mapping and new geological find

Detailed geological maps are in great demand by the mining industry and constitute an important basis for commercial exploration activities. In 2005 GEUS published a geological map of North Kangersuneq ("Kangersuneq, 68V.2 Nord") in the scale of 1:100,000, and a map containing geological profiles of the basalts on Disko Island in West Greenland. The profiles include detailed information about the individual lava flows and document the build-up of parts of West Greenland's basalt province. During the summer, geologists continued the detailed, 1:100 000 scale mapping of Greenland. GEUS is concentrating the detailed mapping on areas where mineral-resources interest is greatest, and in 2005 geologists mapped areas around Kapisillit at the bottom of the Godthåb Fjord. During this survey, a hitherto unknown occurrence of carbonatite, a volcanic rock, was discovered. Furthermore, dikes and rocks of lamprophyres were found in the vicinity of the carbonatite, and these are interesting in the context of diamond exploration. Carbonatites are in some places known to hold economically significant minerals. However, the economical potential of the new find is still unknown. GEUS has instigated examinations of samples collected in order to determine the age and formation of the carbonatite and lamprophyres.



Mineral res

Creating the scientific basis for targeted and environmental friendly exploitation of minerals in Greenland and Denmark





ources



New gold mineralisations

The Nuuk area in West Greenland was once more the target of geologists' efforts to explain the geological history and map the processes of nature that have led to concentrations of gold in the mountains. In particular the geologists have had their eyes on the so-called Precambrian supracrustal rocks, because these rocks are typical host rocks for gold mineralisations. In connection with geological examinations of ore in the field, GEUS in 2005 developed statistical models in order to describe the special characteristics of e.g. gold mineralisation on the basis of different types of data, including magnetic, gravity, and geochemical data. Results from the models are used as guidelines for exploration of the field and help promote an understanding of why mineralisation occurs in the given geological environments. During the summer of 2005 several new gold mineralisations were discovered and better understanding of the relationship between occurrences and the different types of supracrustal environments was achieved. Finally, new magmatic formations in the Fiskefjord area were discovered revealing a potential for platinum group mineralisations in the area.

Strengthened collaboration across the Baffin Bay

Greenland and the eastern part of Canada were linked many million years ago and their geology is therefore very similar. Throughout the years institutions working with geology and minerals exploration on either side of the Baffin Bay have collaborated. In 2005 GEUS and the BMP in Greenland hosted a workshop with the purpose of developing and expanding the collaboration and network among institutions and researchers working in the area. The workshop dealt with themes of common interest within geological correlations, geological environments, and mineral resources. GEUS subsequently published a report presenting abstracts and results from the workshop. Moreover, there was agreement among participants that a similar workshop be held in 2007 hosted by Canada.

Status on optimistic diamond hunt

The opening of diamond mines in Canada has intensified the mining industry's interest in West Greenland because the geology here and in Canada are the same and the 1990s saw large-scale exploration for these lucrative precious stones. Several mining companies have maintained interest in the area, and in 2005 a Canadian mining company uncovered the biggest diamond found so far in Greenland. In recent years, GEUS has followed up mining company efforts with a scientific survey of kimberlites, a rock type that can contain diamonds. In 2005, focus was on processing and analyses of samples collected in the previous years. Geochemical analyses of the minerals in the kimberlite samples show there is cause for optimism as results confirm the presence of classical kimberlites in Greenland. The outcome of five years of research efforts was presented at a workshop in Copenhagen in November, hosted by GEUS and the BMP in Greenland. The workshop was visited by 40 Danish and foreign researchers and representatives from exploration companies with knowledge from diamond provinces throughout in the world, exchanging experience and discussing future efforts within diamond exploration in Greenland.

New data from the warm Cretaceous sea

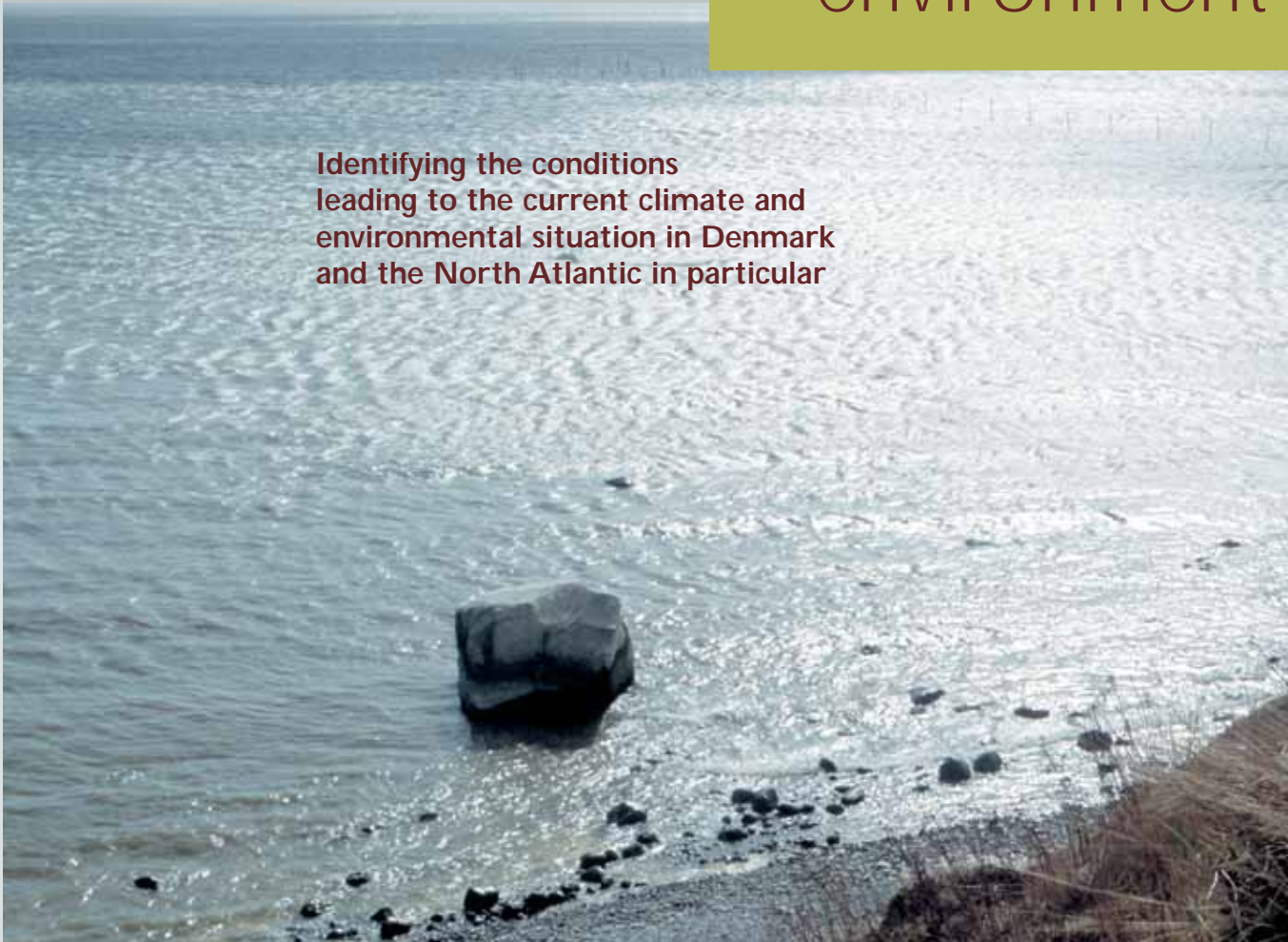
The period from late Cretaceous to Danian from 90-60 million years ago represents a prolonged period with a greenhouse climate, which differs considerably from the present with regard to oceanography, ecology, and geological sedimentation. At this time enormous areas of the continents were covered by sea, and in the vast sea covering north-western Europe, mainly limestone sediments were deposited, which today can be seen in the characteristic cliffs on Møn and Stevns in southern Zealand. In 2005 borings were drilled through the chalk at Stevns in order to study the climate fluctuations, marine currents, sedimentology and ecology of this interesting period in the earth's history. The 450 and 350-metre-deep boreholes represent the first complete series of strata through the chalk from the Maastricht period in eastern Denmark, and data from the boreholes will be included as an important part of clarifying the environment which formed the characteristic chalk layers. However, the prospects of the research project reach further. Most of the oil in the Danish sector of the North Sea is in limestone of the same age, and a large proportion of the drinking water pumped up from the subsurface originates from these rocks. The work is taking place in collaboration between two of the partners in the Geocenter Copenhagen, the Geological Institute, and GEUS, and it is being funded by a centre grant from the Danish Natural Science Research Council.

Relationship between prairie fires and the climate

New studies show that there is a relationship between outbreaks of prairie fires in America and the climate. Over the past 4,500 years, there has been a cyclical shift between dry and more humid periods in the central regions of North America. The phenomenon has been studied in lake sediments which form a natural archive of past changes in the environment. The sediments are characterised by changes between high and low content of chalk, grass pollen and charcoal. During humid periods there was a widespread covering of grass, which nurtured extensive fires, while during dry periods the grass cover was so thin that only small fires could break out. Dating the sediments shows that each cycle lasts about 160 years. A similar cycle has been found in ice cores from Greenland, about 4,000 km away, showing that this is not a local phenomenon. Other data indicate that it is cyclicity in solar activity, which controls these brief changes in the earth's climate. The work is being funded by the US National Science Foundation.

Nature and environment

Identifying the conditions leading to the current climate and environmental situation in Denmark and the North Atlantic in particular



Geological maps of Denmark

Geological maps are the foundation of both planning and many technical and administrative tasks. GEUS is carrying out geological mapping of several areas of Denmark, and the work has been organised so that, to a great degree, it provides the geological data currently required by Danish society. In 2005 field work concentrated on mapping the region near Ringkøbing, where the county is currently designating areas of particular interest for drinking water, and on Lolland Falster, Møn and in Rold Skov. Geological map sheet 1114 IV Ringkøbing was completed and printed in 2005. Work on mapping Rold Skov has been part funded by the Danish Forest and Nature Agency, and it will form part of the preparations for reforestation after the storm in January 2005.



Thematic map and data for the National Park in Greenland

In August 2002 the Greenland Home Rule agreed to prepare a strategy plan for the National Park in North and North-East Greenland and in the Scoresby Sund area to ensure differentiated protection of the region and to ensure that the area is included in regional development in Greenland. As a basis for the plan, GEUS compiled digital topographical data for the region and assembled selected geological theme data. The topographical data contains information on place names and coastlines, lakes, rivers, and glaciers as well as contour lines for each 100 metres. The geological theme data includes geological 1:250 000 maps and maps with associated descriptions of selected geological locations of special scientific interest, as well as maps of selected locations of interest in oil/gas contexts, or locations containing economically interesting mineralisations. Finally, a map has been compiled of the area which collates geophysical and geochemical data. The work is being funded by DANCEA funds from the Danish EPA.



Balanced nature protection for the Baltic Sea

The vulnerable habitats of the Baltic Sea are exposed to many threats from sand pumping, fishing, tourism and pollution, and conflicting interests give rise to difficult problems. Therefore it is important that countries bordering the Baltic Sea agree on a coordinated management plan to relieve the problems. However, there is a great lack of data, and data is often in different formats which makes it difficult to exchange between countries. Therefore, the BALANCE project was started in 2005. The object of the project is to integrate the available data which can be used by administrations in all the Baltic countries. The BALANCE activities cover the whole Baltic, Kattegat and the Skagerrak, and focus on four pilot areas across borders. Within these areas a habitats map will be made on the basis of integrated data on sediments, bottom fauna, fish etc. Part of this work will involve developing a protocol for habitat mapping. The project is being funded by the EU, it is headed by the Danish Forest and Nature Agency and involves a large number of institutions in the Baltic countries. GEUS is coordinating the integration and organisation of the geological and physical data for the marine landscape maps and habitat maps for the whole of the Baltic region. The project is also helping MariNet activities, in which Danish authorities and research institutions exchange information and coordinate cooperation in order to ensure better utilisation of national marine efforts.





Geologists make their stamp

In 2005, Danes could meet geologists from GEUS pry into their research. In June Post Greenland issued a new stamp to mark completion in 2004 of the geological mapping of Greenland by GEUS, after forty years' scientific work. To mark the occasion later in the year researchers from GEUS gave a taste of the work in Greenland at the largest stamp fair in northern Europe "Frimærker i Forum", where almost eight thousand philatelists went through the turnstiles. On 12 May the gates opened for "Forskningens Døgn" (24 hrs in the name of research) with a large number of events throughout Denmark where the public could meet researchers and hear about what they do. Researchers from GEUS were ready with their "order a researcher" concept where companies, libraries, schools and associations could order a researcher to visit and tell some exciting tales from the world of research. In October GEUS held a "Copenhagen Night of Culture" event at the Geological Museum in cooperation with partners from Geocenter Copenhagen, where Copenhagen residents could taste Danish groundwater, simulate their own earthquake and hear about ice research in Greenland. 2005 also saw geological research reported in the public space through a large screen outside the Geological Museum building, operated by Geocenter Copenhagen.

Research and innovation in society

In spring 2005, the Danish Council for Strategic Research called for ideas for research areas which could be profitable to invest in and which could promote innovation in society within a relatively short time horizon – the Innovation Accelerated Research Platforms. GEUS helped in designing two proposals for the water area. From more than 200 proposals, the Council for Strategic Research has pointed out ten research platforms. One of these is to promote strategic research in the water area; an area where Denmark is an international front runner. Characteristic for the area is high research intensity, and it has a high potential for innovation and development of new solutions to Danish businesses. Subsequently, in collaboration with other players, GEUS took initiative to hold a thematic day for Danish stakeholders in the water area. The objective of the day was to establish networks and to identify needs for research and development of technology within the water area. In October 2005, the Danish Council for Strategic Research allocated money to enhance strategic research in the water area.





Good progress in educating young researchers

GEUS takes part in the education of graduates and researchers at PhD level in cooperation with a number of universities in Denmark and abroad. GEUS helps with teaching, advice, tasks, data and workplaces. Twenty GEUS employees teach at five universities, but most of the work is in advising Masters and PhD students linked to the institution with a permanent work station within research areas either where GEUS has a special interest in ensuring researcher recruitment, or where GEUS has special expertise, which is not available from the universities. In 2005 employees at GEUS tutored 45 PhD students and 73 Masters students, of whom 17 are employed at GEUS and 38 have a workstation at the institution. Almost half the students are from the University of Copenhagen, the rest are from the universities in Aarhus and Roskilde as well as the Technical University of Denmark and the Royal Veterinary and Agricultural University. There are also students from universities in Sweden, England, Scotland, Ireland, Germany, Australia, Thailand and Vietnam. The students are attracted by the social significance of the tasks from GEUS as well as the broad research expertise and modern research facilities. An article in a students' magazine published by the Danish Association of Masters and PhDs in 2005 described how two Masters students working at GEUS were extremely happy to be writing their theses at this particular institution. GEUS also helps train researchers through participation in a number of researcher schools in cooperation with universities and other sector-research institutions. These are the four schools of research COGCI, FIVA, SedBas and RECETO in the areas climate, water resources, resources in sediment basins and environmental chemistry.

Courses in groundwater modelling

In 2005 GEUS held two well-attended courses in advanced groundwater modelling aimed at county personnel working with administration of water resources and staff from consultancy firms and water utilities. Mathematical models which describe groundwater flow are routinely used in the administration of Danish water resources and the results from the models are very important when decisions are to be made on action plans for the protection and exploitation of the groundwater. Therefore, the courses focussed in particular on how best to set criteria for the accuracy of the models and assess the uncertainty in calculations connected to this work. The courses were held in cooperation with the Geological Institute at the University of Copenhagen, and were a combination of lectures, practical exercises in modelling on computers and exchange of experience. The course materials primarily comprised a manual on groundwater modelling which is published (in Danish) by GEUS. Compared with previous editions, the manual has been expanded considerably, including new sections on methods of assessing uncertainty and on quality assurance in connection with groundwater modelling.

New research professor

In 2005 Ole Valdemar Vejrbæk took up the position of research professor in applied geophysics at GEUS in order to strengthen research into oil and gas in the limestone in the North Sea from which Denmark extracts energy worth billions of DKK. He has added significantly to knowledge of the Danish subsurface through a number of mapping projects, and in 1996 he received the Danish Geology Prize with Peter Britze for work which resulted in a national map of the deep Danish subsurface. In 2001, with Lars Kristensen, he received the prize for the best scientific article which appeared in the international journal *Petroleum Geoscience* in 2000. The article described a new method of mapping oil deposits in the limestone in the North Sea.





GEUS around the world

Knowledge building in developing countries
through research and consultancy services

Kick-off for continued oil education in Vietnam

In 2005, phase 2 kicked-off of a cooperation project between GEUS and the Vietnam Petroleum Institute (VPI), aiming at enhancing Vietnam's ability to assess its oil and gas resources. The project is being funded by the Danida ENRECA programme and it will focus on oil-geological research in the Malay – Tho Chu basin, with a view to understanding the geological structure of the basin and assessing the potentials for oil/gas. Phase 2 not only aims at capacity-building at VPI, but also at improving cooperation with universities in Vietnam and Denmark. With participation from teaching resources from the Geological Institute at the University of Copenhagen, joint MSc/PhD programmes will be completed for younger researchers and students from VPI, Hanoi University of Mining and Geology (HUMG) and Hanoi University of Science (HUS). The programmes also include introducing Vietnamese lecturers to modern teaching techniques such as those used at the Geological Institute in Copenhagen. The education programme was well under way in 2005. Nine Vietnamese students have completed their admission exams for the MSc/PhD programmes, after taking a series of preparatory courses, and three PhD students have completed longer courses in Copenhagen with great success. They have taken the oil-geological courses at the University of Copenhagen and have had work experience at GEUS. In Vietnam, geological fieldwork was completed on the island of Phu Quoc, in preparation for a new drilling as part of the oil-geological assessment of the basin and to train the students. At the end of the year, a contract was signed with a drilling company for the ENRECA-2 drillings.



Oil pollution service in Kenya

The coast of Kenya is a golden chain of natural areas with coral reefs, sandy beaches, mangrove forests and rocky shores. A large part of the oil for Europe and the US is transported from the Persian Gulf along the coasts of Kenya, and an oil spill from one of the large tankers could have grave consequences for the environment and commerce along the coast. A Danish-Kenyan project, KenSea, worked in 2005 to map and assess the vulnerability of the coast to oil pollution so that the authorities could set priorities for their action against possible pollution. The result is 16 maps of the entire coastline which show where the coast is sensitive and states where to take first action in the event of an accident. The assessment of the coasts included the various types of coast and animal life as well as human activity such as fishing and tourism. The project was organised in collaboration with the users and the people who could be affected by pollution, and the work has involved contact to local shipmasters and fishermen as well as volunteers and state organisations. The KenSea project is led by GEUS with participation by the companies GeoQuest and AquaSim as well as the National Environmental Research Institute of Denmark and the DEPHA organisation from Kenya. The Project is being funded by Danida (Danish International Development Assistance) via the United Nations Development Programme (UNDP).





Preparations for oil exploration in Uganda

The government of Uganda is busy getting ready for the possibility that the country may become an oil-producing nation. The geological conditions look promising. Oil seeps have been found on the surface, and drillings have been made in the Albertine Graben area in the west of the country on the border with the Democratic Republic Congo. In 2005 GEUS worked with capacity development at the Petroleum Exploration and Production Department (PEPD) under the Ministry of Energy and Mines in Uganda, so that in the future they have sufficient knowledge and facilities to administrate expected oil exploration and extraction in Uganda in a sustainable manner. Work has involved identifying and advising on the laboratory facilities which will be needed, as well as training staff in laboratory practice and analysis techniques, interpretation of data and reporting results both within oil exploration and environmental monitoring. Researchers from GEUS have visited Uganda, and staff from the PEPD have taken part in laboratory courses in Copenhagen, where lectures and practical training have taught them about modern laboratory methods. The project is being funded by Danida (Danish International Development Assistance) via the United Nations Development Programme (UNDP).



Knowledge and capacity development in Ghana

The minerals sector is an important industry in Ghana. Ghana was previously known as the "Gold Coast", as a considerable proportion of the country's revenues came from gold mining. Today minerals account for about 38 per cent of Ghana's exports. In 2005, GEUS won two international tendering rounds for projects to support the mining sector in Ghana.

The first project is to develop the capacity of the Geological Survey Department of Ghana (GSD); a key institution in the minerals sector. Over the next two-and-a-half years GEUS is to help build up knowledge, tools and facilities so that the institution is better able to carry out the tasks linked to exploitation of mineral resources in Ghana as well as other geological tasks. The work will include assessing the current organisation of the institution in relation to the requirements placed on the institution and training of geologists in geological mapping and a number of key geological disciplines such as geochemistry, petrology, sedimentology, palaeontology and stratigraphy. GEUS will also help with operating laboratory facilities and developing digital databases and GIS tools as well as production of high-quality geological maps and reports.

The second project is to assist in developing knowledge about the geophysical conditions in Ghana. Work involves quality control of geophysical data from the Volta basin which is to be part of a longer evaluation of the basin's economic potential. Up to 2008, GEUS will ensure the quality of the aeromagnetic, radiometric and electromagnetic data, collected by the geophysics firm Furgro Airborne Geophysics, and in collaboration with Danish Space Center carry out similar work for gravity data. The work will also include teaching employees at GSD in quality assurance of geophysical data and about the underlying theories.

The projects are being funded by the Mining Sector Support Programme (MSSP), and they are part of a larger European EU package of support projects for Ghana from the European Development Fund.



Key figures 2005

More detailed key figures for GEUS' activities can be found in *Årsrapport 2005 (Report and Accounts 2005)* and in *"GEUS' virksomhed i 2005 - Faglige resultater"* (*GEUS activities in 2005 - scientific results*), both available on request from GEUS or at www.geus.dk

Number of employees at end of 2005: 283

Number of scientific projects: approx. 500

ACCOUNTS 2005

Amounts in million DKK

Revenue:	221,0
Net figure (appropriation):	126.9
Operating revenue:	94.1
Expenditure:	227.2
Salaries	122.2
Other operating expenditure:	105.0

PRESENTATION ACTIVITIES

Long-term knowledge building

Articles in international scientific journals/publications	105
Articles in GEUS' own scientific series	36
Other scientific publications	8

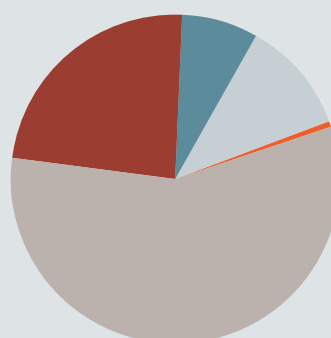
Ongoing scientific task solution consultancy and presentation

Publicly available reports	75
Confidential reports	46
Memoranda, opinions, expositions, etc.	74
General presentation	
Institution reports (annual report, etc.)	6
Popular-science articles	34
Popular-science lectures	48
Visits on www.geus.dk	1.100.000

Researcher training

Current PhD students with GEUS tutors	45
Completed PhD degrees at GEUS	5
Masters students with GEUS tutors	73

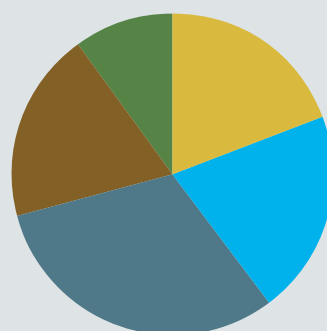
Revenue broken down by resources of revenue:



Amounts in million DKK

Budget appropriation:	126,9
Programme and external resources:	52,1
Other co-financed contract research:	16,8
Commercial contracts and sale of data:	24,5
Other revenue:	0,7

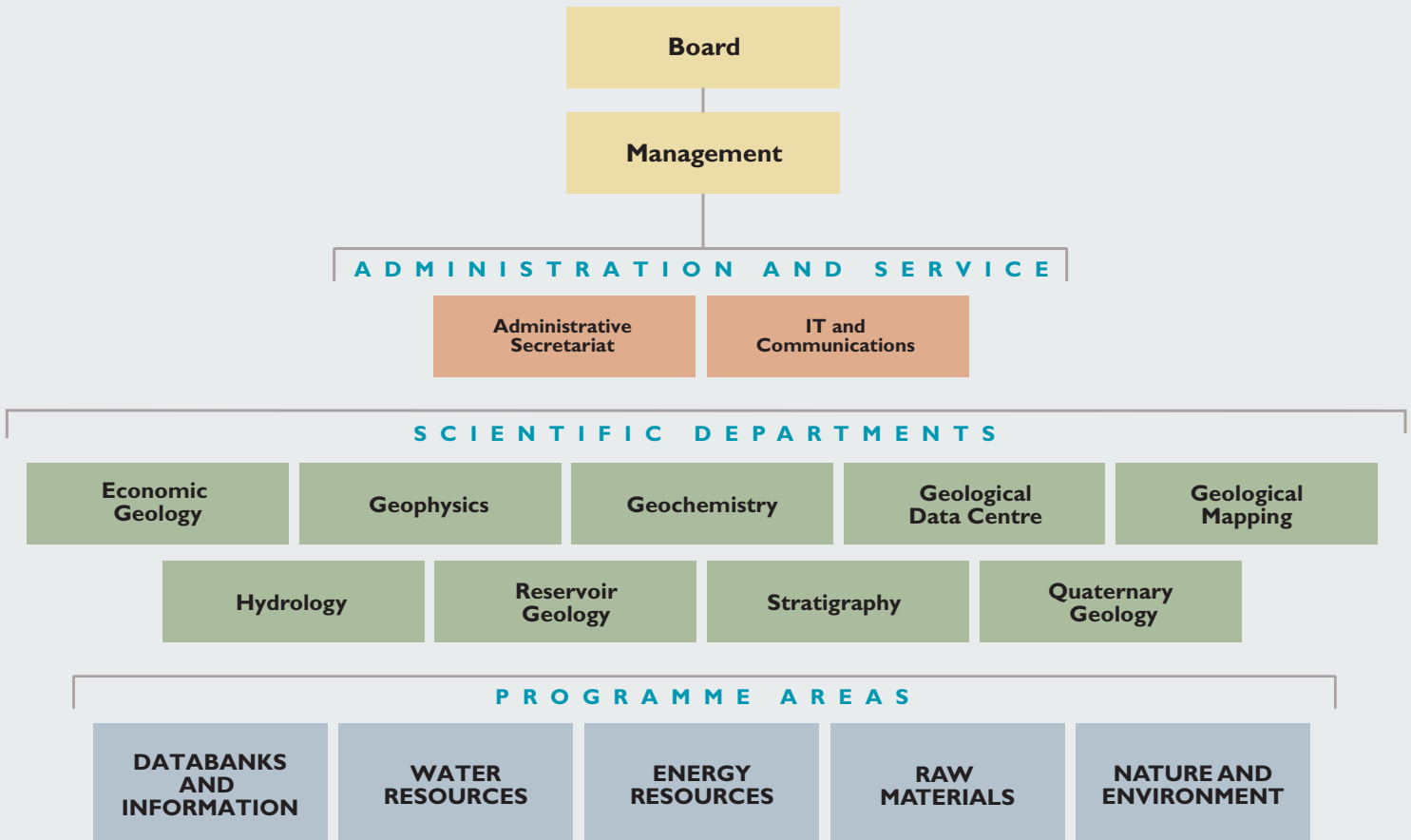
Expenditure broken down after programme areas:



Amounts in million DKK

Databanks and information:	44,1
Water resources:	46,2
Energy resources:	71,1
Mineral resources:	43,1
Nature and environment:	22,7

Organisation



In 2005, GEUS had nine 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. Activities form the basis of consultancy services to government and local authorities.

**Programme area:
Energy resources**

Procuring and contributing 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 environmentally 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 environment**

Defining the processes in time and space leading to the current climate and environmental condition 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.

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