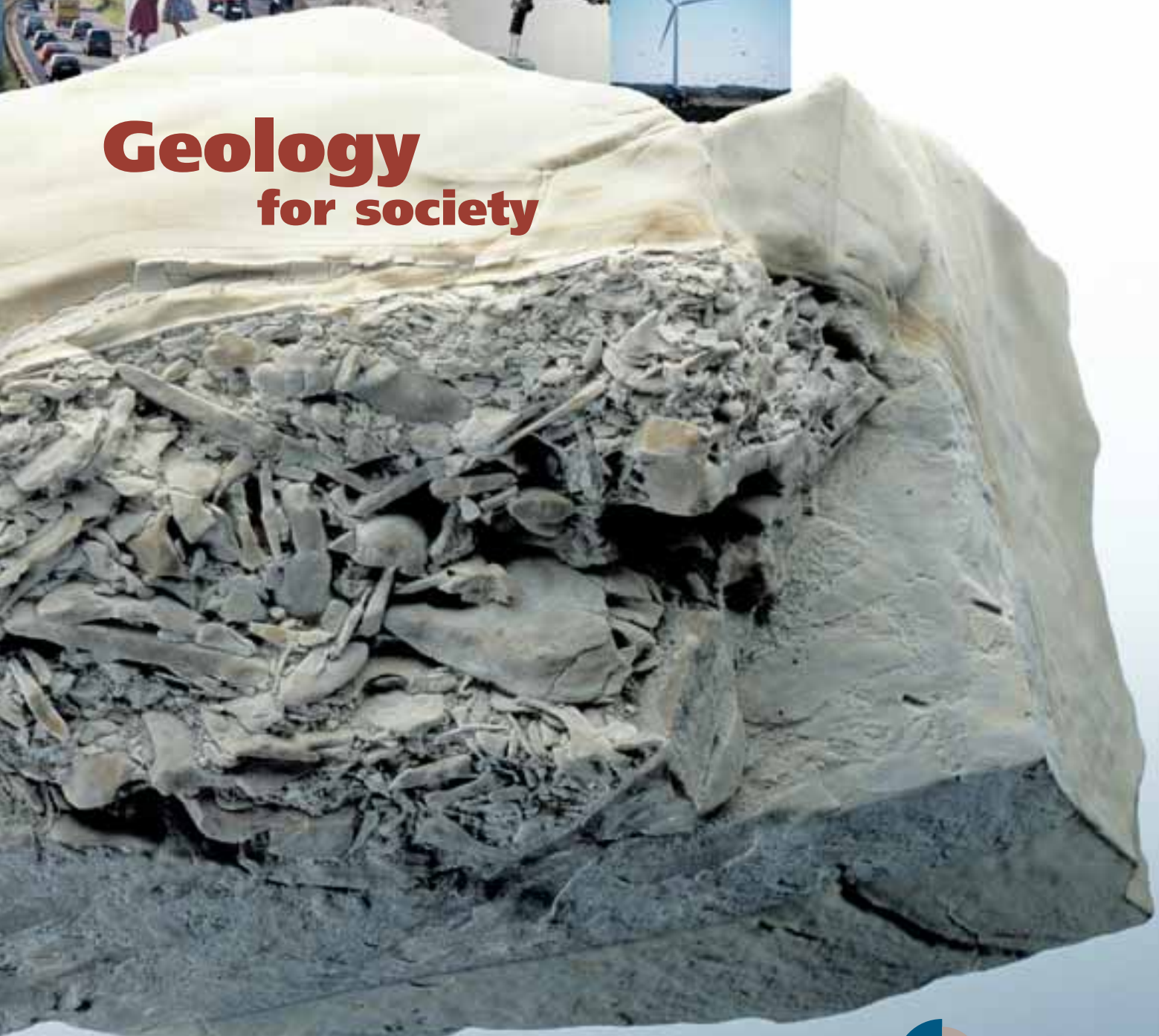




drinking water
energy
mineral resources
nature

Geology **for society**




Annual Report 2003

Geological Survey of Denmark and Greenland (GEUS)
Ministry of the Environment




GEUS



Research for welfare and balance New Strategies from GEUS

Drinking water, energy, mineral resources and nature are all essential building stones of society. In 2003, GEUS prepared strategies for its future work and they form a basis for the GEUS performance contract 2004-2007. The key elements of the strategies are geological research supporting continued possibilities for societal welfare and balanced use of nature. Thus, emphasis is placed on building geological knowledge that can be utilised in high-quality consultancy for authorities and business in Denmark and Greenland.

Denmark faces a real challenge with the management of the country's water resources. New European water directives lay down a framework, but they also entail great demands on development of new knowledge. GEUS is working on the development of geological and hydrological models and on building knowledge on the transport of substances in the aquatic environment. These are all areas of great significance for protection, monitoring and management of water resources.

For many decades from now, society will be dependent on oil and gas to meet its need for energy. In this connection, the reserves in the North Sea play an important role in that they contribute considerably to the Danish economy. GEUS continues to give a high priority to research in the subsurface with a view to making new finds and optimise utilisation of already known resources. Research also aims at utilising the subsurface for storage of the greenhouse gas CO² as well as utilising geothermal energy.

Nature and the environment have become ever more important. The extraction of raw materials in accordance with society's need for sand, gravel and clay for building and construction must be balanced

with nature and with people's need for recreational areas. Knowledge about the country's geology is crucial to achieving this balance. In this connection, GEUS will continue its geological research and mapping on land and at sea.

Access to mineral resources is also significant to the development of the Greenlandic society. Greenland has a clear objective of making the extractive industry one of the most important. One of the keys to achieving this objective is the presence of solid knowledge of the geology of Greenland. Therefore, GEUS plans targeted geological research in Greenland which is to help identify areas where there are possible oil, gas and mineral finds.

The nature of Greenland and the North Atlantic also play an important role in the understanding of global climate change which can alter conditions for life on Earth in the future. With a view to understanding the climate and assessing the effects of a changed climate, GEUS participates in international marine geological research and monitoring of Greenland's inland ice.

As regards data banks, GEUS aims to maintain its position as the geological memory of Denmark and Greenland. The data collections must be relevant and of high quality so that they can be used by stakeholders in the rest of society. GEUS intends to communicate the results of its research to an international forum as well as to the general public.

Finally, the strategies contain goals for GEUS' continued commitment in developing countries as well as its plans for organisational and staff development. GEUS' strategies can be read at www.geus.dk.



Foreword

Towards the end of 2003, the board of directors entered into a new performance contract with the Ministry of the Environment for the four-year period 2004-2007. The performance contract has its starting point in new strategies for the coming years which are prepared following thorough discussions amongst staff, managers at all levels, management and the board of directors and after consultation with cooperation partners. The financial framework that has been indicated for the coming finance acts is falling, but GEUS will try to cover the reductions in appropriations with extra external income from research councils, funds, the EU, public authorities and industry.

In Denmark, the areas of highest priority for the new strategies are research and consultancy with regard to securing clean drinking water in future and the oil and gas resources in the North Sea. On the other hand, it has been necessary to give lower priority to several topics within the programme area "Nature and the environment". The tasks in Greenland maintain their relative share of GEUS' basic appropriation and are given priority after consultation with the Greenland Home Rule.

In 2003, GEUS made a new calculation of Denmark's drinking water resources, and the work on the development of a method for mapping of areas with sandy soil which are particularly sensitive to leaching of pesticides to groundwater is about to be concluded.

Continued utilisation of hydrocarbon resources in the North Sea was on the political agenda in 2003. With its research, GEUS has contributed to the understanding of the processes leading to oil formation in limestone fields and has received international acknowledgment for this. With regard to Greenland, GEUS has, in cooperation with the Home Rule Government, made special efforts with regard to the international oil industry by marketing the hydrocarbon potential offshore West Greenland. A new licensing round is planned for 2004. In addition, GEUS has conducted the first year's collection of seismic data north of the Faeroe Islands and south of Greenland in the continental shelf project with a view to possibly asserting claims on areas beyond 200 nautical miles. In the

field of minerals, GEUS has also been actively contributing to develop mineral resource utilisation into a major industry in Greenland. In 2003, efforts were concentrated on geological mapping in West Greenland, compilation of relevant regional data for the promotion of exploration by companies, and documentation of geological processes that may lead to the formation of deposits of diamonds and gold. A successful signal to the international mining industry was the opening of a new gold mine in South Greenland in the end of 2003.

In the climate area, GEUS completed a large international research project which documents that geological potential exists in Denmark's subsurface for storage of large amounts of CO₂ if such a solution to the limitation of emissions of this greenhouse gas into the atmosphere should become part of the political agenda. On behalf of Greenland, GEUS prepared an application to UNESCO for the nomination of Jakobshavn Isbræ as a world heritage site. In Denmark, GEUS carried out geological mapping in Western Jutland with special focus on drinking water interests.

In the area of international assistance, GEUS has extended its work to several new countries. On behalf of the World Bank, GEUS assessed the chances for development of mining operations in the Lao People's Democratic Republic (the Lao PDR) and Kyrgyzstan. The cooperation with Vietnam has been continued and intensified, particularly with regard to the opportunities for the Vietnamese to explore for and exploit Vietnam's oil and gas reserves. In Ghana, GEUS completed its two-year consultancy project for the Nordic Development Fund with regard to organisation of Ghana's national geological survey.

Despite another round of redundancies in 2003, the staff at GEUS has managed to complete a number of important research and consultancy projects in Denmark and abroad and to meet almost all its objectives and performance indicators with a positive financial bottom line.



Per Buch Andreasen
Chairman Board of
Directors



Martin Ghisler
Managing Director



New key to data for billions

A new version of the comprehensive subsurface database SAMBA was introduced in 2003. SAMBA contains a myriad of information from deep wells and geophysics collected in connection with many years of exploration and production of oil and gas and other uses of the subsurface. Thus, SAMBA contains information about 365,000 km of seismic lines and geological information and log data from innumerable boreholes and it has cost billions of kroner to collect this information. This is where authorities can find information about oil production from wells, license information and reports from North Sea activities. Finally, SAMBA works as a registration system for cores samples and other geological material in GEUS' core sample storage which has more than 60,000 core boxes. The database, which is run in cooperation with the Danish Energy Authority, is an important key to subsurface data that society can draw upon in future in connection with continued oil and gas research and exploration as well as studies of the possibilities of exploiting geothermal energy and storage of CO₂ in the subsurface. Some of the information in the database is confidential, but a selection of geological and geophysical data is available at the GEUS website.



The North Sea and the readers in focus

The popular-science magazine, "Geologi - Nyt fra GEUS", was published in four issues in 2003. Three of those issues describe geological research in the North Sea and focus on oil geological surveys of the Valdemar Field and on marine geological surveys at the Jutland Reef and Horns Reef near Blåvands Huk. However, readers have also been able to read the story about the exciting geology in southern West Greenland which boasts the famous geological Ilimaussaq Complex where more than 225 different minerals have been found. Towards the end of 2003, GEUS carried out a reader survey with regard to "Geologi - Nyt fra GEUS" in order to measure reader satisfaction. An overwhelming response rate has provided a good basis for an analysis of reader satisfaction with the magazine.

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

Databanks, information and information to

232,000 wells available on the Internet

When Danish people want clean drinking water in their glass and gravel, sand, clay and limestone for building, industry and agriculture, they can get help from the Well Data Archive at GEUS. Since 1926, geological information has been archived here from more than 270,000 holes drilled in the top 5-250 metres of Denmark's surface. At the end of 2003, GEUS completed its work in making 232,000 of these wells available on the Internet. Many of the holes have primarily been drilled in search of water, but also to check the bearing capacity of the ground in connection with building and when exploring for mineral resources and contamination. Danes can now access information from the GEUS website about the geology in wells and information about groundwater pumping and placement of filters etc. The search among the many wells is carried out on maps where users can easily click their way to relevant areas and find information about wells. The information is then directly extracted from GEUS' electronic well database Jupiter. Through the years, the well archive has been an important source of information about Denmark's geology and groundwater in connection with water supply, the hydrogeological mapping of Denmark in the 1970's, and large-scale environmental research projects such as the landfill studies in the 1980's and the Danish Environmental Research Programme in the 1990's. Today, the archive data are, for example, used in the work with zoning and detailed mapping of Danish groundwater resources. The well archive is a result of legislation made with foresight. It appears from the first water supply act from 1926 that information about all water supply wells must be reported to GEUS. Since 1978, the Mineral Resources Act has also provided for a duty to report mineral resource wells. Well borers, regional authorities, water works, consultancy firms and producers of raw materials have all been important contributors to the building of the Well Data Archive.





technology the general public

Web communication of geology on the increase

To an increasing extent, information regarding GEUS' activities, publications, data and services is communicated through our website. Also in 2003, www.geus.dk scored top marks in the evaluation "Bedst på nettet" (best on the net), and the website was also among the nominees for the award "Bedst på nettet" in the category research, consultancy and training. The number of external visits to the website has risen from about 100,000 in 2002 to about 380,000 in 2003. More than half of these visits are from abroad. In cooperation with the Danish Forest and Nature Agency and regional authorities, GEUS has also participated with technical knowledge and financial support to the project "Geologi i Danmark" (geology in Denmark). Popular-scientific descriptions of more than 90 geological sites can be found at www.naturnet.dk. The project commenced by the Nationalkomiteen for Geologi (national committee for geology) is supported by the Danish Outdoor Council. The Midtsønderjyllands Museum (museum of central south Jutland) has prepared the descriptions.

Geological consultancy service

Again in 2003, many people have phoned the GEUS consultancy service with questions about geology. Most calls pertain to information about wells and come from many of GEUS' target groups, such as well borers, water works, consulting engineers, regional and local authorities and government agencies. However, sales of geological and hydrogeological maps as well as general geological consultancy are also in demand. Finally, many schools and citizens make use of the consultancy service to ask many types of geological questions.



New estimate of Denmark's drinking water resources

In May 2003, GEUS published a new estimate of Denmark's exploitable drinking water resources. The estimate shows that the resources are almost halved compared to the most recent national estimate from 11 years ago - from 1.8 billion m³/year to 1.0 billion m³/year. The estimate is based on model simulations of the hydrological cycle with the national water resource model - the so-called DK model. The primary explanation for this reduction is that the new estimate has detailed calculations for the entire freshwater cycle and that impacts on watercourses and nature limit the amounts extractable from groundwater. In addition, problems with water quality in the upper groundwater aquifers mean that parts of the resources will have to be written off for a number of years. Under these preconditions, the estimate shows excessive pumping around Copenhagen, Odense and Århus and on the light soils in central and western Jutland where the need for field irrigation is large. In most of these areas, the problem is that so much water is pumped up that the effect on watercourses is too severe. In other areas, the risk of drawing nitrate and pesticides down from the upper contaminated aquifers and the release of substances such as nickel from the subsurface are limiting the amounts possible to pump up. The groundwater charge in the deeper aquifers is too small compared to the current level of pumping. Experience with the DK model is valuable in relation to the resource estimate required nationally and from river basin districts in connection with the Water Framework Directive and the national monitoring programme, NOVANA. In addition, the model is an applicable tool for the assessment of the impact of climate change on the size of Danish water resources.

Patent on method for measuring the activity of bacteria

In July, GEUS filed a patent application for a method for improved measurement of bacterial activity. The method was developed in connection with research within the field of decontamination of soil. In the studies of bacterial processes in soil, there has so far been no tool to measure if bacteria are active with eg. degradation of foreign substances. It is well-known that very few bacteria are active when they are in soil and therefore this is only half the answer when we can see if the bacteria are there. By measuring messenger RNA it is possible to see directly if particular genes are expressed and whether the bacteria therefore create the process we are interested in. This invention makes it possible to reinforce the signal from mRNA without having to remove contaminated DNA from the sample.



**Procuring knowledge
for optimal management
of our water resources**

Water

Research on salt water in groundwater aquifers in limestone

Increasing problems are expected with regard to water quality from the many wells in eastern Zealand where water abstraction is carried out in the uppermost jointed limestone strata. In recent years, there have thus been attempts at finding deeper and better protected groundwater resources in the limestone. In some places, it has been possible to find deep-lying water-bearing fractures in the limestone that have good water quality. In other places, this has not been possible, either because of failing water flow in the deep-lying part of the limestone or because of problems with salt water. Wells and geophysical explorations have shown that the boundary between fresh and salt water in the limestone is not nearly as deep-lying as one would have expected on the basis of the traditional understanding of weight balance between fresh and salt water. It has been proved that the boundary is partly controlled by limestone's ability to let fresh water displace salt water and partly by diffusion of the salt water. With a view to making a regional strategy for utilisation of the deeper-lying part of the groundwater resources in limestone, the project studies whether the fresh water-salt water boundary is stable when pumping from deeper-lying parts of the aquifer and whether pumping will be able to draw younger contaminated groundwater further down. In addition, the project aims to elucidate how deep water-bearing fractures can be found in limestone and how great the groundwater charge is in the deeper-lying limestone aquifers. The project is being carried out with Environment & Resources DTU at the Technical University of Denmark and it is funded by Københavns Energi, Copenhagen County, Roskilde County and Frederiksborg County.





Research for a common European standard

The support for implementation of the EU Water Framework Directive was continued in 2003. In addition, GEUS is participating in European research projects working with problems related to the Directive. At the end of 2003, the project BASELINE ended with the submission of a report to the EU. One object of the project was to develop a joint European method of defining natural groundwater quality. The report describes the natural groundwater quality in 25 selected aquifers in Europe. In Denmark, reports have been prepared for three aquifers. These were Miocene and Pleistocene sand aquifers in Jutland and on Funen as well as Palaeocene limestone aquifers around Copenhagen. In addition, GEUS is managing the project HarmoniRiB which intends to develop models for assessment of the uncertainty of water data and water models as well as establishing a network of representative drainage areas in Europe, from which data with uncertainty levels can be freely available for other research projects. Finally, GEUS is participating in the project HARMONICA which intends to build a bridge between research and practical implementation of the Water Framework Directive in Europe. This will be done through workshops, seminars and other information exchange.

Progress in the work with pesticide sensitive areas

GEUS and the Danish Institute of Agricultural Sciences are working on the development of a method for mapping of areas which are particularly sensitive to leaching of pesticides to groundwater. The project - Koncept for Udpegning af Pesticidfølsomme Arealer (KUPA – Concept for Identification of Pesticide-Sensitive Areas) - has been concentrated on developing a method for sandy soil areas and on assessing the possibilities of developing a method for areas with clay soil. In 2003, the planned laboratory analyses and most of the interpretation were completed. The results of this work show that, to a great extent, it is possible to use simple easily accessible soil parameters for calculation of leaching. In this connection, GEUS is trying to determine whether it is possible to characterise leaching by means of the size of soil parameters. A further perspective of the work is that it is possible to identify areas that are particularly sensitive to leaching by means of a mapping of a small number of simple soil parameters. Furthermore, the project has shown that it can make sense to point out particularly sensitive areas even though they are only checked for a few pesticides.

resources



Jurassic heavy-weighter

A comprehensive book with 948 pages was published in 2003: "The Jurassic of Denmark and Greenland". The book describes the geological development in a period of the Earth's history that is of great significance to society today. The Jurassic strata are thus important source rocks and reservoir rocks for oil and gas and also constitute an important resource for storage of CO₂ and gas and for exploitation of geothermal energy. Through 28 articles, the reader is presented to the results of intensive Jurassic research in the late 1980s and the 1990s. This includes a detailed chronostratigraphic and biostratigraphic overview of the Jurassic in north-western Europe as well as a number of stratigraphic, sedimentological, structural and geochemical studies of the Jurassic strata in Denmark and East Greenland. The Jurassic strata in Danish territory are primarily found in the subsurface and research here is based on innumerable wells and seismic data collected over more than 30 years of oil explorations. In contrast to this, the Jurassic strata in East Greenland can be studied in impressive exposures along fjords or mountain sides, and East Greenland is regarded as a unique field laboratory, particularly among geologists working with exploration of the Norwegian shelf.



Article 76 - short text with far-reaching consequences

During the course of 2004, Denmark is expected to ratify the United Nations Convention on the Law of the Sea which makes it possible for coastal states to claim rights to the resources of the subsurface and seabed beyond the 200 nautical mile limit. Off the coasts of Greenland and the Faeroe Islands there are five areas where it may be possible to make such claims. The coastal state has 10 years from the time of ratification to document any claims by means of geodetic, bathymetric, geophysical and geological data. The Danish Finance Act has now appropriated funds to carry out these surveys, and in 2003, seismic data were collected at sea north of the Faeroe Islands and south of Greenland in order to explore the thickness of sedimentary rocks. Article 76 of the Convention on the Law of the Sea defines the conditions required for making claims beyond 200 nautical miles, and the occurrence of thick sedimentary rocks is one of them. A requirement for any claim is that there is a natural prolongation of the land territory beyond 200 nautical miles - a factor that can give rise to diverse geological considerations. Although article 76 is only one page of text, it will form the basis of one of the main initiatives for GEUS in the next decade.





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

Energy resources

New calculations of oil migration in the North Sea limestone

GEUS completed a project which, by means of model calculations, describes the processes when limestone reservoirs in the North Sea are charged with oil. It can take millions of years to fill the microscopic pores in the limestone, so the model is not only intended to calculate the migration of oil and water in the pores but also to take into account that, over many years, the reservoir will slowly sink further down into the subsurface under a continued compression. The project showed that, by means of simple and geological assumptions, it is possible to calculate the filling history for limestone reservoirs. Thus, it has been possible to calculate a hydrocarbon distribution in the Kraka Field and in the Dan-Halvdan Field system which has great similarity to the current hydrocarbon distribution data from oil wells. As a consequence of the constant subsidence of the area, water is being pressed through the limestone very slowly. This migration may move the oil towards the flanks of up-faulted limestone structures; places where oil is not normally expected to be found. Further model calculations may help identify new areas in the North Sea that have not previously been relevant in connection with oil. The project is funded by the Danish Energy Authority's Energy Research Programme.



Possible geological storage of CO₂

Storage of CO₂ in the subsurface is one method of reducing greenhouse gas emissions into the atmosphere. In 2003, GEUS completed the EU project GEST-CO which looked into the possibilities of subsurface storage of CO₂ in eight EU Member States. The studies show that in Denmark it is possible to store 16 billion tonnes of CO₂. The calculation only includes the most obvious geological possibilities, but the storage capacity nevertheless corresponds to more than 400 years of CO₂ emissions at the current level of coal and natural gas consumption. In addition, GEUS is participating in projects about storage of CO₂ in the United Kingdom and in the Canadian Weyburn oil field where it is not only environmental benefits that come from the CO₂ injection but also in terms of increased oil extraction from the field because of the thinning effect of the gas on the oil. Finally, GEUS is participating in the international research project SACS which monitors and models storage of one million tonnes CO₂ per year under the Norwegian Sleipner gas field in the North Sea. This corresponds to 3 per cent of total Norwegian CO₂ emissions. This project is currently the only one of its kind where CO₂ is stored in the subsurface merely out of environmental concerns.



New map of the limestone in Denmark

The limestone in the Danish subsurface is a very important reservoir rock for oil and gas, but in several places in Denmark, we also get drinking water from the limestone strata. In the North Sea, we find the limestone several kilometres down in the subsurface, and in eastern Denmark, the rocks are exposed, for example in the cliffs at Stevns and on Møn. In 2003, GEUS prepared a new detailed map of the top and depth of the carbonate rocks under the entire Danish territory from the central part of the North Sea to the easternmost part of Denmark. The map, which is prepared on a scale of 1:750 000, is the first collated record of rock types important to society, and it builds on a collection of comprehensive seismic data, previously published maps and information from oil and gas and water wells. The map covers the carbonate rocks and similar geological formations deposited in the period from the Cenomanian to the Danian.

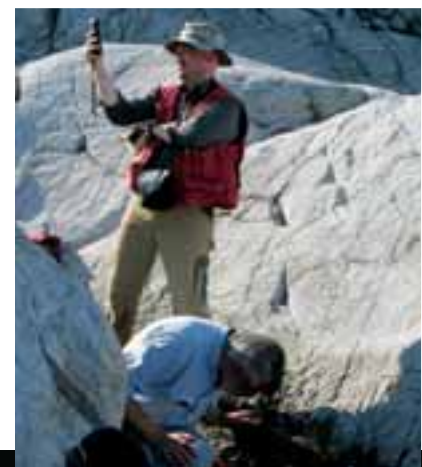


Initiatives for extended diamond exploration

With support from the Bureau of Minerals and Petroleum, GEUS continued its efforts to increase the interest of the mining industry in diamond exploration in Greenland. During the summer of 2003, geologists worked on mapping kimberlitic rocks which may be diamondiferous. At three selected sites, samples weighing tonnes were extracted from kimberlite dykes with a view to testing their diamond content and study the distribution, magnetic properties and chemistry of kimberlites. A comprehensive programme for dating kimberlites from West Greenland has been initiated in cooperation with University of Alberta, Edmonton. In addition the landscape between Maniitsoq and Kangerlussuaq was surveyed in order to map the distribution of large plains, valleys, and more alpine landscape elements. The surveys are to contribute to understanding why, and how much bedrock has been eroded by water, wind, and ice over millions of years. This work was conducted in cooperation with Stockholm University. Finally, a DVD was published with a comprehensive collection of existing data from the diamond exploration of the mining industry in West Greenland over 35 years and GEUS' own data collected in many years of geological research.

Geological maps of thousands of square kilometres

During the summer of 2003, GEUS completed a three-year mapping campaign in the area between Sisimiut and Disko Bay with a view to preparing new detailed geological maps which are in high demand in the mining industry. The coupling of the large amounts of geological data and the drawing of the new maps are in full swing. The summer field work also included studies of the fractures in the terrain between Sisimiut to Aassiaat in order to understand the development of a large fault structure that continues beyond the coast in this area, and has helped in the formation of large sediment basins that may contain oil deposits. Over the year, a geological map has also been published on a scale of 1:1 000 000 of the Caledonian fold belt in East Greenland between 70°N-82°N. The map, which covers an area of almost six times that of Denmark, is based on a compilation of five previously published maps on the scale of 1:500 000, and it collates geological knowledge from more than 30 years of mapping work in the remote East Greenland. Finally, a map was published with more than 130 km of geological profiles of the basalts on the Disko Island in West Greenland. The profiles contain detailed information about the individual lava flows and document the build-up of parts of the basalt province of West Greenland.





Creating a scientific basis for targeted and environmentally friendly exploitation of minerals in Greenland and Denmark

Two mountain ranges become one

New geological surveys show that about two billion years ago in West Greenland a large unbroken mountain range was formed which measured up to the Himalayas in width. The formation of the mountain range took place when two ancient continents collided, and today a deep cut in the now long eroded fold belt can be seen from the eastern part of Canada to Greenland and possibly all the way to Scandinavia. It has long been believed that central West Greenland was built up of two different mountain ranges, the so-called Nagssugtoqides and the Rinkian fold belt. However, new studies of folds and other structures in the rocks in the Greenlandic mountains and new datings of the rocks now indicate clearly that the entire bedrock area between Kangerlussuaq and Upernavik constitutes the roots of one giant ancient mountain range. The results shed new light over the early movements of the Earth's lithosphere plates, and the new large mountain range in West Greenland can be directly correlated with the Rae-Hearne province in eastern Canada, while the correlation to the east under the Inland Ice is uncertain. This work, which is supported by the Carlsberg Foundation, was carried out in close cooperation with research institutions in the USA, Australia and the UK.

Mineral resources and Greenland mapping

Gold for Greenland

We did it! The first gold bars were extracted from Greenland's first gold mine in the Nalunaq area in South Greenland, and some of the gold will be used to produce the rings for the wedding of the Danish Crown Prince and his fiancée. GEUS is involved in the production of a geological description of the gold deposit. This work is being carried out together with the Bureau of Minerals and Petroleum and the mining company, Nalunaq Gold Mine A/S, which has the license for the region. However, GEUS has also focused on minerals in the Nuuk area where chances of finding gold are good. Here, several Archaean greenstone belts are found which look like similar rock formations in other parts of the world with large finds of gold and nickel. This is documented in a comprehensive report from GEUS which sums up the known mineralisations and the geological development of the Nuuk area together with a presentation and interpretation of the existing geophysical and geochemical data. The report also contains a DVD with several reports on mining companies' previous activities in the area and a large amount of extra geophysical and geochemical data and geological field maps from GEUS' archives. The initiative for the report was taken by the Bureau of Minerals and Petroleum with a view to attracting the mining industry to the area.



The North Sea as supplier of raw materials

The North Sea contains other resources than oil and gas. Denmark needs raw materials for building and construction work, and the mineral resources in the seabed are now in play as a supplement to the resources on land. In 2003, GEUS worked with producing maps of the seabed sediments in the coastal parts of the North Sea between Hanstholm and Blåvands Huk, and determination of the raw materials potential in the area has started. The mapping builds on several years' collection of seismic data and data showing the surface and composition of the seabed. The mapping has been carried out in cooperation with the Royal Danish Navy, the Royal Danish Administration of Navigation and Hydrography and the Danish Coastal Authority, and the results are used by the Danish Forest and Nature Agency which has administrative responsibility of regulating the extraction of raw materials.

Perhaps Greenland's first World Heritage Site

The Ilulissat Ice Fjord and the area surrounding the ice fjord constitute a unique area, and in 2003 the Danish Ministry of Culture nominated it for inclusion in the UNESCO World Heritage List. In January 2003, GEUS completed the nomination report, and during the summer an inspection of the area was arranged for a UNESCO representative. The report describes the ice fjord's unique nature with photos, text and videos. The Jakobshavn Glacier terminates into the ice fjord, draining a large part of the Inland Ice and is one of the world's fastest ice streams. It moves at a speed of up to 1 metre per hour, and approx. 35 km³ icebergs are formed each year. Despite the harsh nature, the coasts of the ice fjord have been populated by humans for more than 4,000 years. A steering group consisting of representatives from the Greenland Home Rule, the municipality of Ilulissat and the Danish Ministry of Culture was behind the project, and the work was funded by the Danish Cooperation for Environment in the Arctic (DANCEA). In June 2004, a UNESCO committee meeting in Beijing will decide whether the site will be included in the World Heritage List.



Assessment of collapse at Møns Klint

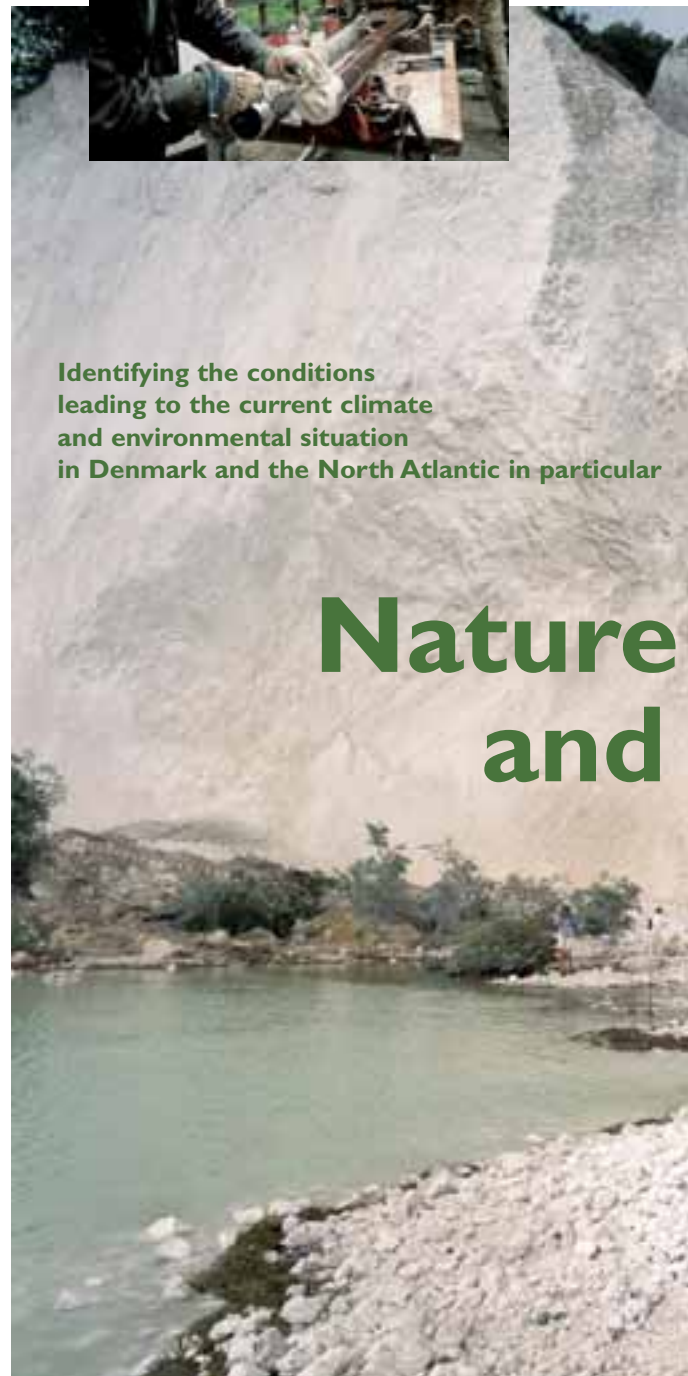
On the morning of Saturday 5 July, there was a loud rumble at Møns Klint when part of the "Store Stejlbjerg" cliff collapsed. Luckily, there were no casualties in the collapse, and the Danish Forest and Nature Agency cordoned off the area immediately. Shortly after, a GEUS geologist was on the spot to inspect the collapse and to give advice as to when it could be opened to visitors again. The collapse was surprising since the cliff is normally more stable in the summer, but the combination of a dry spring and extremely heavy rainfall a couple of days beforehand made the cliff collapse. In connection with assessing the danger of collapse along limestone cliffs, GEUS is participating in an EU research project with the object of developing concepts to predict collapses. The project entails testing the ability of different geophysical methods to predict collapses. This work is carried out in five research areas with limestone cliffs -two in the UK, one in France and two at Møns Klint.

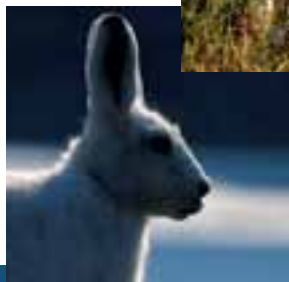
Geological maps of Denmark

In 2003, the geological mapping of Denmark was concentrated on mapping the areas southeast, east and northeast of Ringkøbing Fjord in western Jutland. The mapping for the geological map sheet, Skjern 1114 III was completed in the spring of 2003, and in the autumn it was finalised for printing. In the autumn of 2003, the field work continued with mapping of the central part of Skovbjerg Bakkeø, corresponding to parts of the map sheets 1114 I and 1115 II. The work in west Jutland was partly funded by Ringkøbing County in connection with the mapping of the county's areas with special drinking water interests. On the island of Lolland, the mapping of the map sheet, Maribo 1411 II, continued and this map sheet is expected to be completed in 2004.

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

Nature and





New map basis for Greenlandic national park

The North-East Greenland National Park is the world's largest of its kind. In connection with the increased interest in North and East Greenland, the Greenland Home Rule decided in 2001 that a strategic plan for the North-East Greenland National Park is to be prepared. The strategy will ensure a graduated protection of the region, and it will ensure that the area is included in regional development in Greenland. As a first step in this work, GEUS has compiled digital topographical data of the region from Scoresbysund in central East Greenland to the western North Greenland. These data are based on aerial photographs recorded in the period 1978-87. The data correspond to maps on a scale of 1:100 000 and contain information about the coastline, lakes, rivers, glaciers and show contour lines for each 100 metres. This work, which is funded by DANCEA, will be followed by a geological, biological and archaeological description of the region.

New theory regarding the formation of icebergs in the North Atlantic

The sediments on the seabed in the North Atlantic contain layers of ice-transported material, the so-called "Heinrich events", which originate from the melting and release of clay, sand and gravel in the bottom of icebergs. The layers show that large armadas of icebergs drifted around the Atlantic during the last ice age for brief, very cold periods. The icebergs particularly came from the earlier ice sheet over North America, but the ice sheets over Greenland and north-western Europe also contributed. Together with researchers from Germany, Sweden and the USA, GEUS collected new marine geological data at the Reykjanes ridge southwest of Iceland which shed new light over the mechanisms leading to Heinrich events. So far, it has been difficult to understand why the many icebergs were formed in cold periods. The new interpretations of data indicate that an increased transport of heat with the Gulf Stream to the north has led to the break-up of the ice sheets and the formation of the many icebergs. As the icebergs melted, large amounts of clay, sand and gravel were deposited on the seabed. However, the melting of the icebergs simultaneously led to the formation of a cold low-salinity layer on the surface of the North Atlantic which at first prevented further heat transport and heat exchange between the atmosphere and the highly saline, warm and heavy bodies of water in the Gulf Stream. This new interpretation, which was published by Elsevier in the magazine *Marine Geology*, has been the object of great interest amongst researchers. During 2003, the article was the second-most read article on Elsevier's website.

environment

Bustling activity on the international scene

Throughout the year, researchers from GEUS have made their mark in international publications. At the 6th Petroleum Geology Conference in London in October 2003, 12 articles were presented on subjects ranging from limestone reservoirs research in the North Sea to exploration on the Faeroe Islands and studies of sediment basins in Greenland. In the field of oil and gas, a longer article has also been published in the magazine *Petroleum Geoscience* describing the geological development of the Faeroese part of the North-East Atlantic Margin in the Tertiary period. The article elucidates the chances of discovering oil in the Faeroese subsurface. In October 2003, a special issue was published of the international magazine *Precambrian Research*, which describes the results of several years of surveys in the 3.7-3.8 billion year-old greenstone belt at Isua in West Greenland. The objective of these surveys, which were carried out by an international research group, was to map the early Archaean processes on Earth. GEUS contributed with three articles for this publication, and a GEUS researcher edited the publication together with two foreign colleagues.



Flashes of the year



Posters and photos for the Night of Culture in Copenhagen

Again in 2003, the citizens of Copenhagen had the chance of a geological experience in the Night of Culture. Many people went to the Geological Museum where GEUS, together with its partners at Geocenter Copenhagen, presented a photo symphony of Greenland's landscapes and a large collection of posters about our vital fresh water which was prepared by school classes from all over Denmark. The youngsters' knowledge and view of the water were compiled in connection with a poster competition staged by the Danish Water Resources Committee and the Ministry of Education to celebrate the UN International Year of Freshwater 2003. The winning class later received the first prize of DKK 70,000 at an event at Geocenter Copenhagen.

Prize for best article

At a symposium in Galveston, Texas in June, the Society of Professional Well Log Analysts, which has more than 2,500 members worldwide, revealed that senior researcher Peter Frykman from GEUS was awarded the prize for best article in their international journal *Petrophysics* together with his co-author Clayton Deutsch from the University of Alberta. The article describes how to best find a correlation between core and log data from wells in the North Sea by means of statistical methods and laws of scaling. The authors describe the theoretical background and show practical examples of how to combine data from different scales. The examples are selected from the Dan Field and the Harald Field where the geological strata sequence in the limestone and the shallow-marine sandstones respectively contains the variations in porosity which can be analysed with the scaling laws.

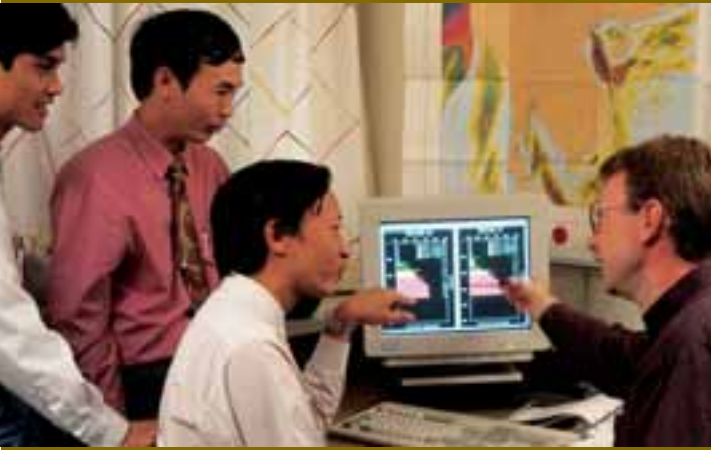
New newsletter for users

In 2003, GEUS introduced another newsletter called "Vand & Data" (water & data) to improve the communication of its activities within the field of groundwater and data. The initiative came from a study in 2001 where GEUS asked its users how satisfied they were with its services in the groundwater area. The newsletter contains information about new research projects, significant results, publications, services and databases. In 2003, two printed issues of Vand & Data were published, and here the users could read about a new method for stakeholder involvement in groundwater protection, results and objectives in EU research projects, methods for well logging, the national water resource model and additions to GEUS databases. The newsletter is also published electronically and can be read or downloaded in Danish from: <http://www.geus.dk/vand-og-data/vd-dk.htm>. You can also find links here to central water and data information from GEUS, including groundwater monitoring, groundwater modelling, databases, services and popular-scientific publications about water.

Danish Geology Prize awarded

In April 2003, GEUS awarded the Danish Geology Prize 2002 of DKK 25,000 to the director of the Danish Lithosphere Centre, Hans Christian Larsen. The prize, for which the Geological Society of Denmark nominates the winner, was awarded at a meeting of the Society where it was also possible to hear about the research at the Danish Lithosphere Centre. Hans Christian Larsen was awarded the prize for his great efforts for international research into the geological processes of the Earth's crust and the understanding of the dynamics behind the break-up and the plate-tectonic spreading of continents. Hans Christian Larsen's deep commitment to many international research projects has helped in placing Danish geology on the world map.





Speeding up oil training in Vietnam

In 2001, a cooperation project between the Vietnam Petroleum Institute (VPI) and GEUS was initiated to improve Vietnam's capacity to assess the country's oil and gas resources. Training, research and technology transfer are keywords in the project which is funded by the Danish International Development Assistance (Danida) ENRECA programme. The Geological Institute at the University of Copenhagen and the Hanoi University of Mining and Geology (HUMG) also participate in the project. A large number of project activities were carried out in 2003. Eight students are following the MSc programme at the HUMG according to plan. Concurrently with their studies, they are working with different scientific subjects related to an oil geology research programme in the Phu Khanh basin. This work includes research tasks within different geological and geophysical disciplines and the preliminary results have been presented at local and international conferences. Following these activities, Danish and Vietnamese researchers have been invited to participate in a new research partnership under the international Integrated Ocean Drilling Program (IODP) which is planning offshore research drilling in the area. Five MSc's, who receive support from the ENRECA project, have visited Denmark where they have been in job training at GEUS and received teaching at GEUS and the University of Copenhagen. Danish researchers have held open training courses at the HUMG. In October 2003, GEUS and the VPI held the annual project workshop in Hanoi where results of the research programme were presented to researchers and representatives from the oil industry who are active in Vietnam. Finally, technology has been transferred to the VPI. This includes computers, software, an advanced microscope and sample preparation equipment, and the VPI library has been supplied with relevant literature. The project is exchanging experience and data with other ENRECA projects active in the Danish Water Sector Programme Support in Vietnam.

Small-scale mining - where and how in Kyrgyzstan

Small-scale mining is an important basis for life for many millions of people around the world. Mainly gold mining creates the many jobs in small, remote societies. However, gold mining can also create environmental and health problems if it is not managed correctly. In 2003, GEUS worked in Kyrgyzstan with a view to determining how many people work in small-scale mining, which methods they are using and which health problems are related to the industry. Part of this work was carried out in cooperation with a local NGO group. The project was concluded with a training programme for small-scale miners in a remote mountain community and in the capital Bishkek where workers were trained in the best methods of extracting gold without harming the environment and human health. The project was funded by the World Bank.

**Knowledge building
in developing countries
through research
and consultancy services**

GEUS around



Possible funds from mining for schooling in the Lao PDR

GEUS has been on a mission to the Lao PDR (the Lao People's Democratic Republic) on behalf of the World Bank to help the government of the Lao PDR identify possible new business activities that can procure money for more schools in the Lao PDR. The objective is to get all the children of the Lao PDR to school in 2020. According to the future vision of the World Bank for funding of increased schooling in the Lao PDR, mining is a possible source of income for the country. During the course of the project "Sources of growth in the Lao PDR", GEUS assessed which major mines could possibly be established after 8-10 years and 15-20 years respectively. This work included a calculation of how many people could potentially be employed in the mines and of the size of the potential income to the state from taxes etc. GEUS assessed that it would be possible to open one gold/copper mine, one phosphate fertilizer mine and one sapphire mine within the desired time horizon. This work also points out that it is essential for the Lao PDR to initiate targeted marketing of its geological potential in order to attract investments from international mining for exploration.

Agricultural influence on groundwater in Latvia

Like Denmark, Latvia is dependent upon its groundwater for drinking water supply. As opposed to Denmark, however, there is very limited knowledge in Latvia about groundwater quality in shallow aquifers. Through support from DAN-CEE, GEUS is in the process of mapping the degree of contamination in the upper aquifers and assessing the extent of future problems with groundwater quality in different areas of Latvia. During the course of 2003, about 120 shallow wells have been drilled and a large amount of water samples have been extracted for chemical analysis. In this connection, technology has been transferred to Latvia in the form of drilling equipment and a laboratory vehicle. The groundwater will be analysed for different pesticides, nitrogen compounds, macro-ions and a long range of different trace elements. Some of the analyses are carried out on ICP-MS equipment. This is a method with great potential for future monitoring of groundwater. The method only requires small water samples and is competitive with regard to price, and it has a relatively high sensitivity to a wide range of substances.

the world



Geological knowledge for Ghana

In 2003, GEUS completed a two-year project in Ghana with a view to assisting the Geological Survey Department (GSD) in acquiring knowledge, tools and facilities to make the GSD more capable of handling tasks related to the utilisation of Ghana's mineral resources. The project included transfer of knowledge within systematic geological mapping, analysis of geological data and establishment of archives and databases. For several periods, geologists from GEUS have been posted in Ghana, and Ghanaian geologists have visited GEUS in connection with the establishment of databases and have participated in GEUS' geological mapping of Greenland. The project is funded by the Nordic Development Fund.

Key figures

More detailed key figures for GEUS' activities are found in "Årsrapport 2003" Report and Accounts 2003 available in Danish from GEUS and on www.geus.dk

Number of employees: 319, including the Danish Lithosphere Centre (21)

ACCOUNTS 2003*

Amounts in million DKK.

Revenue	227.0
Net figures (appropriation)	113.5
Operating revenue	96.3
Aktstykkemidler** brought forward from 2002	17.2
Expenditure	224.5
Salaries	131.3
Other operating expenditure	93.2

* The accounts include the Danish Lithosphere Centre - a research centre financed by the Danish National Research Foundation.

** Supplementary funding appropriated by the Danish Finance Committee.

PRESENTATION ACTIVITIES

Long-term knowledge building

Articles in international scientific magazines/publications	79
Articles in own scientific series	30
Other scientific publications	32

Ongoing scientific task solution, consultancy and presentation

Publicly available reports	108
Confidential reports	16
Memoranda, opinions, reviews, etc.	86

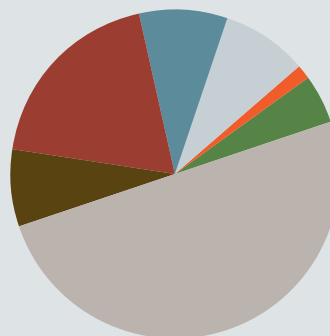
General presentation

Institution reports (annual report, etc.)	7
Popular science articles	39
Lectures, exhibitions, etc.	42

TRAINING OF SCIENTISTS

PhD students	28
PhD graduates	5
Master's students	45

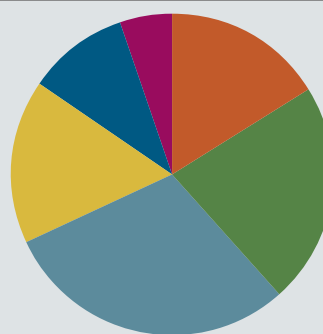
Revenue broken down by sources of revenue



Amounts in million DKK.

Budget appropriation:	113.5
Aktstykkemidler brought forward from 2001:	17.2
Programme and external funds:	43.3
Other co-financed contract research:	19.7
Commercial contracts and sale of data:	19.2
Other revenue:	3.2
Danish National Research Foundation to the Danish Lithosphere Centre:	10.9

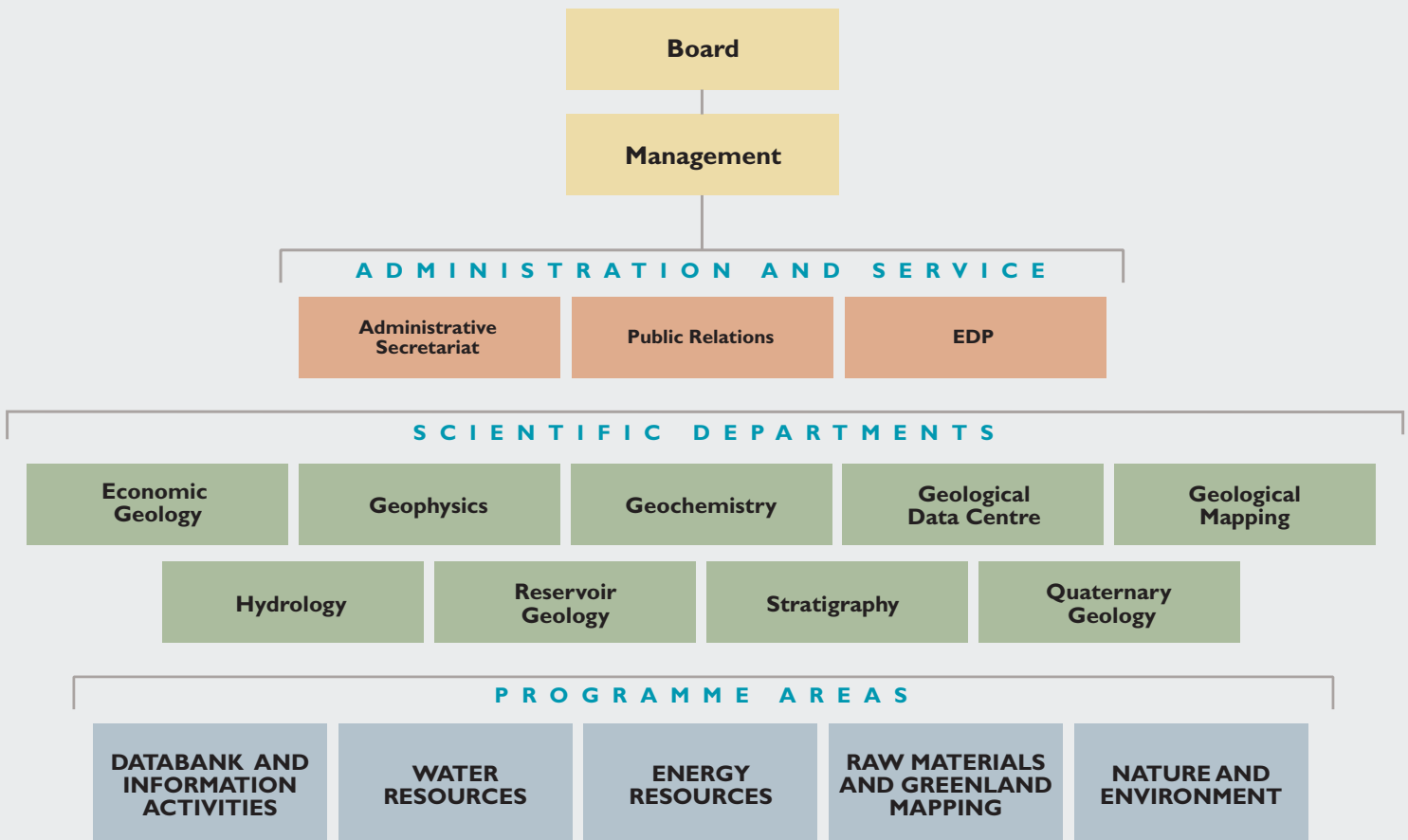
Expenditure broken down by programme areas



Amounts in million DKK.

Databanks, information technology and information to the general public:	36.2
Water resources:	50.0
Energy resources:	66.7
Mineral resources and Greenland mapping:	37.0
Nature and environment:	22.9
Danish Lithosphere Centre:	11.8

Organisation



Due to cuts in appropriations, further staff cuts were foreboded in 2003, so that at the beginning of 2004 a total staff cut since 2002 of 60 employees will have been completed. In 2003, GEUS had nine research departments and three administrative/service departments. In addition, the Danish Lithosphere Centre (DLC), under the Danish National Research Foundation, is administratively attached to GEUS. Scientific activities are conducted in five programme areas, where tasks are carried out in project groups in a matrix structure.

Programme area:
Databanks, information technology and information to the general public

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 cooperation 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 and Greenland mapping

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.

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