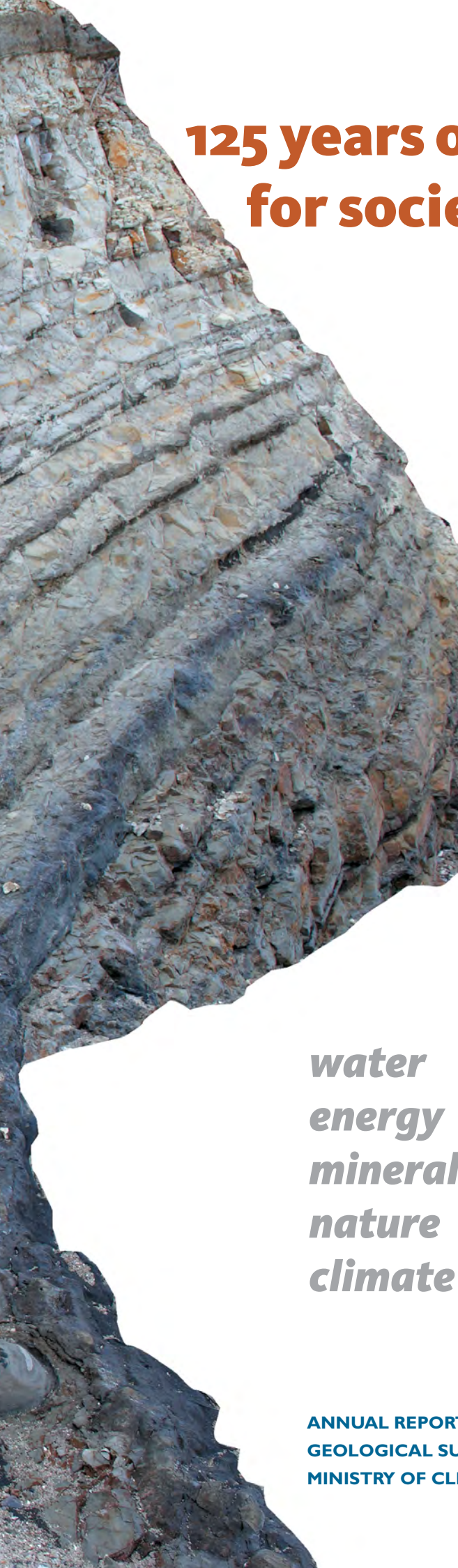


# 125 years of geological research for society



*water  
energy  
mineral resources  
nature  
climate*

ANNUAL REPORT 2013  
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND  
MINISTRY OF CLIMATE, ENERGY AND BUILDING



# GEUS celebrates its 125th anniversary

On 4 April 2013 the Geological Survey of Denmark and Greenland celebrated its 125th anniversary. As the first geological survey for the Kingdom of Denmark, the Geological Survey of Denmark was established in 1888, while the Geological Survey of Greenland was established in 1946. In 1995 the two surveys were merged to form the Geological Survey of Denmark and Greenland (GEUS); and in 2007 the Danish Parliament passed a special act for GEUS.

Throughout its 125 years of existence, GEUS has provided knowledge to society that has helped ensure clean drinking water and a clean environment and that has encouraged cost-effective and sustainable exploitation of building materials, minerals, oil, gas and geothermal energy from the subsurface.

GEUS' tasks have varied over time. While the subsurface remains fairly unchanged, the technological possibilities and society's demand for geological knowledge are constantly changing. In GEUS' early years, marl, lignite, peat, clay and gravel were important mineral resources. Today, drinking water, energy resources, industrial minerals and climate change set the agenda. Regardless of changes in the nature of its tasks, the challenge for GEUS remains the same. As the national geological survey, GEUS is responsible for seeking out answers to the most pressing geological questions for society.

GEUS celebrated its anniversary together with colleagues, collaboration partners, stakeholders, and other guests invited from Denmark and abroad. The event included a number of geological talks, and the Danish Minister for Climate, Energy and Building, Martin Lidegaard, also spoke at the event. More than 200 people heard the 11 talks that dealt with subjects in GEUS' core business areas: energy, mineral resources, water, nature and the climate. The talks were delivered by GEUS employees as well as by specially invited external speakers.





# Preface

2013 was a milestone year for GEUS, which celebrated the 125th anniversary of the Kingdom of Denmark's first geological survey. The anniversary was marked by celebrations in April 2013. Broad European participation and talks by speakers from e.g. Canada demonstrated that GEUS is well on its way to realising its ambition of greater internationalisation set out in its 2012 Strategy.

The year was very productive and the goals in GEUS' performance contract were almost all met. At the same time, GEUS was successfully able to deal with the more intensive performance management that permeates the entire central government administration. In 2013, GEUS further intensified its expert knowledge building in two core business areas: groundwater mapping and mineral resources.

The on-going tax-financed groundwater mapping is planned for completion in 2015, and GEUS has been keen to bring this new expertise into use in new assignments. This was achieved already in 2013, when, in collaboration with Aarhus University and Danish companies, GEUS was able to win assignments in Asian countries which see Denmark as a role model in the area of water management.

In the mineral resources area, interest has never been greater, and GEUS has contributed with specialist knowledge both via expert assessments and via participation in a number of working groups. This work will form the basis for future political decisions and downstream legislation throughout the Danish Realm. Special focus has been on the exploitation of uranium and rare-earth elements. As a response to the increasing demand for knowledge about minerals, security of supply and access to resources, as well as about future requirements on industry, in 2013 GEUS established Center for Minerals and Materials (MiMa).

Another milestone event was the opening of the GEUS office in Nuuk, Greenland. With the new office in Nuuk, GEUS now has a permanent presence and representation in Greenland. The welcome was overwhelming, and the communication effort which the office has already delivered has been much appreciated. If GEUS can help encourage young people to take training and education in the geosciences, this would be an important step in developing Greenland and its natural resources.

Activities have been equally high in all other GEUS business areas. Climate research has received much attention, and the condition of the Greenland ice sheet and the changed weather conditions have occasioned assessment and modelling of the impacts of climate change in Denmark and globally. During the year, GEUS has performed a number of assignments in collaboration with stakeholders responsible for Danish infrastructure.

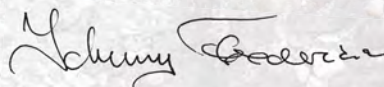
In the area of energy, many new projects on the exploitation of geothermal energy have seen the light of day, and GEUS has provided advice for the vast majority of these projects, in so doing contributing to the Danish transition to renewable energy.

Finally, GEUS has provided the foundation for yet another submission regarding extension of the Danish Realm's continental shelf (North-East Greenland) under the United Nations Convention on the Law of the Sea.

2013 was a year brimming with new initiatives that have formed a strong foundation for GEUS' future.



*Minik Rosing*  
Chairman of the Board



*Johnny Fredericia*  
Managing Director



### Large expansion of national borehole database

GEUS' Jupiter database is the national common public database for geology, groundwater and drinking water. The database, which contains data from more than 240 000 boreholes, is a part of the Danish Natural Environment Portal, which also includes other national databases with environmental data. The database is used every day by employees from municipalities, regions and agencies working in groundwater, environment and mineral resources management. In 2013, work was carried out to expand the Jupiter database, so that public authorities will have the option of filing data that are not covered by the duty to report, e.g. data from pollution surveys and geotechnical borehole data.

This expansion includes developing web services so that users can report and read data on the boreholes themselves and on their composition, atmospheric chemistry and sedimentation, as well as upload and extract data from mixed samples collected from the surface. This expansion of the Jupiter database also includes information about orders and exemptions under the Danish Water Supply Act, as a part of the DIADEM project under the Ministry of Housing, Urban and Rural Affairs. The DIADEM project is to provide easy access via the internet to public data required for sale and purchase of real estate. Finally, GEUS developed web services that provide the GeoScene3D software access to data from Jupiter. GeoScene3D is a modelling tool used e.g. in groundwater mapping.



### European resources and common infrastructure for geological data

In recent years, GEUS has been working on several EU-funded research projects to promote the exchange of geodata across European borders. These projects support the EU INSPIRE Directive on the establishment of a common European infrastructure for spatial information to enable easier exchange of data across national borders. Two of the projects were completed in 2013. The EuroGeoSource project has harmonised data on energy and mineral resources and made them accessible via a common data portal. The data are on oil and gas as well as data on the occurrence of metals, industrial minerals and building materials such as sand, gravel and clay. These are all important resources for Europe and the objective of the data portal is to help stimulate investment in sustainable use of them.

Another project, Geo-Seas, harmonised geological and geophysical data from European marine areas and made them accessible via a data portal. Information about depths and seabed topography and geology is indispensable to environmental protection, offshore raw materials extraction and for establishing for instance offshore cables, pipelines and wind farms. The new data portal will make it easier to access the many marine data that today are filed at national geological surveys and marine research institutions throughout Europe. Furthermore, GEUS is taking part in the EGDl-Scope project, which is preparing a pan-European infrastructure for geological data. This project will develop a plan for implementation of the common structure, which could also serve as the common framework for results from previous and on-going geodata projects.



## Seamless geological map of Greenland - 1: 500 000

In connection with GEUS' 125th anniversary, on Thursday 4 April a seamless geological map of Greenland on a scale of 1:500 000 was published. The map is available in digital format via the GEUS website. The map is based on 14 1:500 000-scale maps published by GEUS over the period 1971 to 2004. The new map integrates the geology into a single harmonised legend covering a total of 443 rock types. The web-based map makes up a platform for different field data types, such as oblique photographs, scanned field maps, published maps and profiles. Furthermore, it incorporates information from GEUS' databases. The map is a part of GEUS' contribution to the global One-Geology project to create a digital geological map of the Earth. On the day of the anniversary, the map was presented in full scale as a 5,5 m × 3,5 m mega poster. The background for producing the map was presented at a miniature symposium on Friday 5 April, at which also the many options available for the web-based map were demonstrated.

## Book about 125 years of research into the subsurface

In connection with its 125th anniversary celebrations, GEUS published the book, *Vi, de jordbundne – Glimt af GEUS gennem 125 år* (We – the people down-to-earth – Glimpses of GEUS over 125 years). The book tells the story of GEUS' 125-year-long exploration of the subsurface, initially in Denmark, and later also in Greenland and the Faeroe Islands. The various assignments that GEUS has helped deliver are placed in a societal context. Managing director Johnny Fredericia writes in the preface: "With this book, we want to provide insight into our organisation and into the societal significance of GEUS in the past and in the present, including its possible contribution to addressing future challenges for society when it comes to the Earth we live on and live from. The book concentrates on assignments in a broad societal context rather than in a narrow institutional context. The subtitle, 'glimpses of GEUS over 125 years', is intended to indicate that the book does not cover each and every aspect of GEUS' history throughout all of its 125-year existence.



### Climatic change increases the risk of low-dose pesticides leaching

Climate change will not increase the leaching of many pesticide types into groundwater. However, for low-dose herbicides, expected climate change is likely to cause increased leaching. This is the result of a study based on model calculations of pesticides leaching to groundwater and the aquatic environment, using data on scenarios for future climate, crop choices and pesticide use. Changes in agricultural patterns due to future climate conditions have been assessed on the basis of studies of agriculture in southern Germany and northern France; regions that today have climates similar to the expected Danish climate in around 2050. These are the main findings of the PRECIOUS research project completed by GEUS, Aarhus University and the Danish Meteorological Institute. The project was funded under the Danish EPA's pesticides research programme.



### Better calculations of climatic impacts on the water cycle

Calculations show that climate change will affect the water cycle in Denmark considerably. It is likely that there will be both flooding and, periodically, more water shortages. In 2013, GEUS concluded the HYACINTS project aimed at developing better tools to assess the extent of these impacts both nationally and locally. The purpose of the project was to couple meteorologists' climate models directly with the hydrological model that calculates water flows in the subsurface and on the surface, as well as to assess the uncertainties associated with these calculations.

The fundamental elements include the regional HIRHAM climate model from the Danish Meteorological Institute as well as GEUS' national hydrological model, the DK model, which can now perform coupled calculations, making it better at describing a reality in which the surface and the atmosphere constantly influence each other.

The other part of the project assessed the uncertainties linked to the calculations, so that it is now possible to assess how realistic forecasts are. This work has included analysis and assessment of the uncertainties throughout the entire chain of calculations spanning from calculations in the global climate model to the groundwater flow in which local soil parameters are a controlling factor. The results show that uncertainties depend largely on what the model is for. The uncertainty in the climate model is of greater significance than the uncertainties in the groundwater model when performing water-balance calculations, such as calculating the water flow in a given stream. However, the opposite applies if the model is used to calculate from where the water flows to a specific groundwater well, for example in connection with a contaminated catchment area. Several Danish research institutions, consultancy firms, water utility companies and authorities took part in the HYACINTS project, which was headed by GEUS and received funding from the Danish Council for Strategic Research.





## Hydrological short-term forecasts soon a reality

More extreme weather events such as cloudbursts and subsequent flooding have created a need for short-term weather forecasts and real-time warnings. GEUS has therefore launched a project to expand the national hydrological model, the DK model, so that it can continuously calculate developments in surface water and groundwater throughout Denmark. The model keeps account of groundwater levels, degree of soil water saturation, and runoff to watercourses. For example, the consequence of a cloudburst depends largely on whether the soil is dry or whether it is saturated with water. During the year, GEUS established an agreement with the Danish Meteorological Institute on the delivery of short-term weather forecast data to a pilot project aimed at developing tools for handling this type of data in the hydrological model. Furthermore, a user survey was performed among municipalities, water utility companies, consultants, farmers and other stakeholders to identify the types of hydrological data in demand and the format in which to deliver these data.

## Basis for new water plans

In 2013, GEUS helped develop the national water resources model, the DK model, in connection with preparation of new water management plans by the Danish Nature Agency. The Danish water plans outline how Denmark will achieve the Water Framework Directive's target of a 'good status' for watercourses, lakes, coastal waters and groundwater. Developing the model included expanding its watercourse network to enable more detailed calculations of how manmade or natural changes affect runoff in watercourses.

Furthermore, a method was developed to use the model to delineate groundwater bodies and thus couple model calculations with current groundwater quality measurements in order to assess the status of the groundwater. The DK model is a key element in the development of a new nationwide model to describe nitrogen transport and turnover. The new model will be used in connection with the water plans to assess how optimally to regulate nitrogen runoff and leaching to the aquatic environment. This work is being performed in collaboration with Aarhus University and DHI.





## Delimitation of the continental shelf around Greenland

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

During 2013, GEUS completed work to document the area offshore North-East Greenland, and on 26 November the Danish government and the Government of Greenland submitted their scientific documentation for their claim to the continental shelf in this area to the UN Commission on the Limits of the Continental Shelf (CLCS). The area in question is an approx. 62 000km<sup>2</sup> area outside the 200-nautical-mile limit between Greenland and Svalbard. Documentation for a claim to an area of the continental shelf offshore South Greenland was submitted in 2012 and for areas north-east and south-west of the Faeroe Islands in 2009 and 2010, respectively. The Continental Shelf Project is being funded by the Danish Ministry of Science, Innovation and Higher Education, with contributions from the Faroese government, and work is being carried out as a collaboration between GEUS and several other institutions from Denmark, the Faeroe Islands and Greenland.

## New appraisal of Danish shale gas potential

A new appraisal of the Danish shale gas resources was published by the US Geological Survey (USGS) at a meeting held at GEUS in early December 2013. GEUS provided geological knowledge for the calculations in the study, while the USGS carried out the actual appraisal of the Danish shale gas resources. The USGS used the same appraisal methodology as they use to appraise shale gas resources in the US and other countries. According to USGS calculations, potential Danish shale gas resources amount to 186 billion Nm<sup>3</sup> (normal cubic metres); 119 billion Nm<sup>3</sup> offshore and 67 billion Nm<sup>3</sup> onshore. The appraisal by the USGS concerns technically extractable shale gas resources, i.e. the amount of gas that can be extracted with the technology currently available. Therefore, the appraisal does not consider whether extracting the gas is commercially viable.

The uncertainty of the appraisal is +/- 100%, from 0 billion Nm<sup>3</sup> gas to 356 billion Nm<sup>3</sup>. The large uncertainty reflects the complex geological conditions of the subsurface and the fact that, as of yet, no shale gas has been found in drillings in Denmark. Having said that, we are still in the early stages of exploration and knowledge building, and new knowledge from exploration drillings, in particular, is needed to reduce the uncertainty of the appraisal.





## Enhanced oil recovery with CO<sub>2</sub>

Although the techniques to extract oil from the North Sea chalk have improved over the years, the expected oil recovery from Danish chalk fields is still only around 30% of the oil actually there. Research is being done into new techniques that can enhance oil recovery from the low-permeability chalk in the North Sea, e.g. by injecting CO<sub>2</sub> into the reservoirs. CO<sub>2</sub> makes the oil less viscous so that it can flow more easily to the production wells. GEUS is taking part in a project headed by Maersk Oil. The project is examining how CO<sub>2</sub> affects the flow of oil and water in fractured chalk, which is common in chalk reservoirs. During the year, GEUS' geologists performed flow experiments in the laboratory at pressures and temperatures identical to those present in a North Sea reservoir. Towards the end of the year, geologists started to establish a new trial set-up in which similar flow experiments can be carried out on larger cores with fractures. The project is being carried out in collaboration with the Norwegian company PERA and is funded by the Joint Chalk Research programme which is run by a group of oil companies with activities in the North Sea.

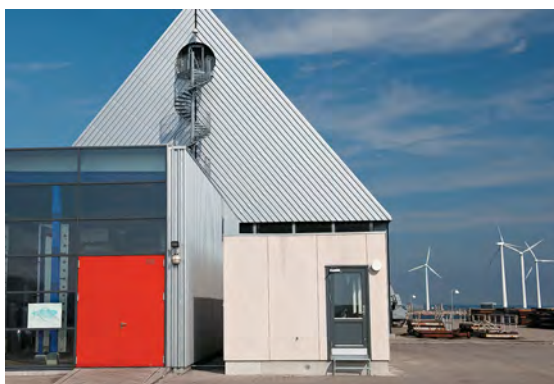


## Deep and shallow geothermal energy

Climate change calls for new energy solutions which can reduce emissions of CO<sub>2</sub> to the atmosphere. The goal is for Denmark to be independent of fossil fuels by 2050. The Danish subsurface contains a large green energy resource of geothermal heat exploiting temperature differences in deep reservoirs at depths from 1 to 3 km and in shallow boreholes in the top 100–200 m of the subsurface.

In order to contribute to the exploitation of deep geothermal energy, in 2013 GEUS analysed the distribution and transformation of deep-lying reservoir sandstone, so that we can gain a better understanding of its geothermal potential. GEUS' geologists are continuing their work to collect relevant geological data in a geographic information system to show areas with excellent potential for establishing geothermal plants. Thermal maps are being prepared of geological key parameters and aspects of significance for geothermal production properties. Furthermore, geologists are working to develop a prospect and risk analysis tool to appraise deep geothermal resources.

With regard to shallow geothermal energy, GEUS measured the thermal properties of soil samples and the temperature in selected boreholes. GEUS also compared information on surface-near geology with the thermal properties of the soil. Furthermore, geologists performed model calculations of groundwater and heat flows in the subsurface to assess environmental impacts and to be able to establish cost-effective and optimally functioning plants. Finally, a user-friendly database of relevant data from surveys of shallow geothermal resources and a web application were developed with which well drillers, administrative officers and consultants can extract information about geology and thermal properties for use in planning new shallow geothermal plants.





## Center for Minerals and Materials

The world's resources and raw materials are under increasing pressure due to population growth and an increasing middle class with millions of new consumers. In May 2013, GEUS opened its Center for Minerals and Materials (MiMa), the objective of which is to analyse whether there will be adequate mineral resources available for society in the future. MiMa uses GEUS' research-based knowledge and capacity in the mineral resources field and draws on existing professional networks. Knowledge about mineral resources supply and possible shortages will be made available for Danish and Greenlandic authorities, decision-makers, companies and NGOs.

“The size of the middle class is exploding worldwide and this is obviously putting huge pressure on the world's resources, which are not unlimited. It is therefore good news that GEUS is opening a new knowledge centre to help give an overview of the world's resources and the access of companies to the raw materials they need in their production,” said Minister for Climate, Energy and Building, Martin Lidegaard, in connection with the opening. MiMa performs its own surveys and analyses of the raw materials value chain, from exploration to production. MiMa also performs assignments on request from the authorities, industry and consultancy firms, if they are relevant for society.



## Critical minerals for important industries

Economic growth in new regions means increased global demand for minerals, both critical minerals for high-tech use and other minerals. In 2013, GEUS focussed on critical minerals through field studies in Greenland and through collaboration projects with industry and other research organisations, e.g. in a European context. GEUS completed ore geology, petrology and mineralogy surveys in the Gardar Province in South Greenland to assess and understand the formation of several deposits of critical minerals, including rare earth elements (REE), niobium and tantalum. The project is being carried out with prospecting companies active in the Gardar Province and the aim is to establish incentives for further investment in exploration and mining operations. At EU level, GEUS is also a part of the EURARE project to develop the foundation for an industry to ensure the future supply of REE and REE-related products to important European sectors, such as the automobile, electronics and chemicals industries. This work includes identifying REE resources in the EU and developing eco-friendly and efficient extraction and refinery technologies.





## Surveys of Greenland's mineral resources

In 2013, GEUS carried out several activities to appraise the mineral resources of Greenland. GEUS geologists collated geological and mineralogical data from South-East Greenland collected in the field in the period from 2009 to 2012. From June until September, the area around Tasiilaq underwent airborne aeromagnetic surveys. Processing of data focussed in particular on changes in the Earth's crust and ore-forming processes in bedrock and intrusions in the Skjoldungen region. In the southern part of Peary Land in North Greenland, geologists examined a series of locations with sedimentary deposits of zinc, which is in high demand globally, and on Trail island and in the Hurry Inlet area in central East Greenland, geologists collected data to check airborne hyperspectral measurements that were acquired in the area in 2012 in connection with mineral exploration activities. Finally, in December GEUS hosted an international workshop at which a panel of experts from research and industry evaluated the tungsten potential in Greenland. Several of the activities in 2013 were financed by the Government of Greenland through the Ministry of Industry and Mineral Resources.

## Mapping marine raw materials

In Denmark, mineral resources are excavated onshore for building and construction. In some areas, the increase in extraction conflicts with the desire to preserve landscapes and nature. GEUS is therefore working to find suitable mineral resources offshore which can be exploited sustainably. GEUS performed a detailed comparison of existing geophysical and geological data for a number of prioritised areas in Danish coastal waters for the Danish Nature Agency. The objective was to map the occurrence of marine raw materials and to gain information about type of raw material, formation, quantities and limitations in terms of extraction. In the large potential marine resource area at Kriegers Flak in the Danish sector of the Baltic Sea, a detailed interpretation was performed of the distribution, formation, quantity and quality of possible raw materials deposits. This interpretation was based on a highly comprehensive data set from Energinet.dk collected in connection with preliminary surveys for a wind farm. The raw materials have been assessed to make up the potentially largest future resource of quality raw materials for the greater Copenhagen area.

GEUS also launched a web-based marine raw materials database for the Danish Nature Agency, which contains up-to-date information about marine areas with raw materials in Danish waters. The database will be part of GEUS' marine geological database, MARTA, which contains several types of data, such as raw materials survey reports, marine geological metadata and information about seabed samples. Furthermore, GEUS prepared a report on mapped sand resources in Danish coastal waters for the Danish Coastal Authority for planning future coastal protection. Finally, GEUS performed a raw materials survey of the North Sea for the raw materials industry.



## Website collects knowledge about the ice in the Arctic

The effect of global warming is considerable in the Arctic, and in recent years snow and ice melt in this region has reached new records. The Greenland ice sheet is shrinking year by year, and melt water is contributing to the rise in sea level. The sea ice in the Arctic is becoming thinner and its extension is decreasing, so that, in the summer of 2012, the distribution of sea ice was the lowest ever recorded. Greenland and Denmark have a special interest in monitoring the condition of the large masses of ice in the Arctic, and in 2013, a new website, Polarportal.dk, was launched to enable the public to follow what is happening with the ice, almost in real time. The website shows how the Greenland ice sheet is changing in size week by week. This is put in a global context by also showing the degree to which melting of the ice sheet has contributed to the rise in global sea level.

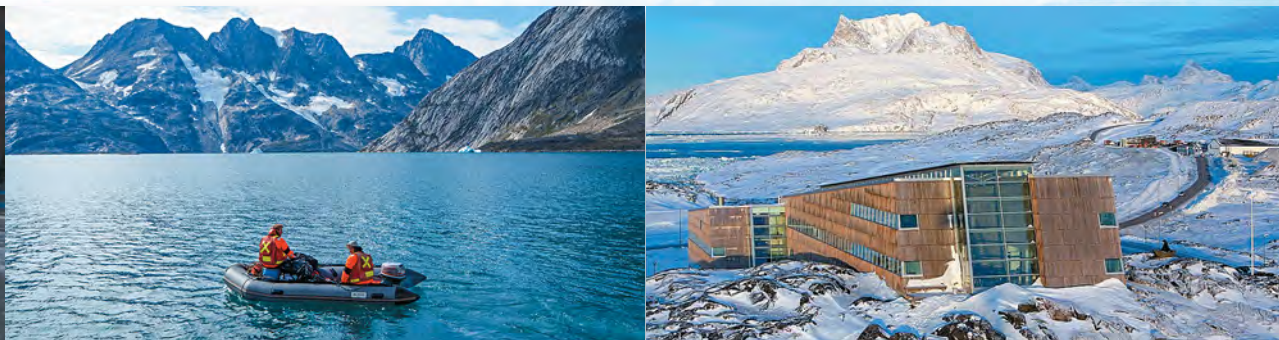
The information on the website is based on a comprehensive amount of data, which is being collected and processed by leading Danish research organisations every day. The website provides information about the degree of melting from the surface of the ice sheet, the volume of ice breaking off glaciers and the extent of sea ice. Polarportalen.dk is run by the Danish Meteorological Institute, GEUS and DTU Space in collaboration, and some of the data originate from the PROMICE monitoring programme on the Greenland ice sheet, which is being headed by GEUS.



## Climate change impact on hydrology and runoff

South-east Denmark will experience dramatic increases in the maximum surface watercourses runoff, while watercourses in north and east Jylland will experience more moderate increases up to 2050. This has been revealed by calculations from a nationwide hydrological model prepared by GEUS for the Danish Nature Agency. These calculations were performed using nine different climate projections. The greatest changes in maximum runoff in watercourses are more than 50%. These are predicted to occur in south-east Denmark in areas with clayey soils where much of the water will run off on the surface after a downpour. East, north and west Jylland will experience more moderate increases of between 10% and 25%. In the summer period from 1 May to 1 October, these increases will be even more dramatic. The implications of the extreme runoff in watercourses could lead to periodical accumulations of water that could impact drainage, rain-water and sewage systems and thus increase the risk of flooding. The study therefore indicates that preparing for changes in sea levels and threats of cloudbursts e.g. in urban areas, cannot stand alone, changes in maximum runoff in watercourses also have to be taken into account. The results of the calculations are available on the climate change adaptation portal [www.klimatilpasning.dk](http://www.klimatilpasning.dk), along with similar assessments of groundwater level, to give municipalities a quick idea of the magnitude of problems and where these may occur in future.





## Gas hydrates offshore West Greenland

Indications suggest that gas hydrates exist in the seabed in the Disko Bugt area in West Greenland. This is the outcome of the PERMAGAS project concluded by GEUS in 2013. Gas hydrates are ice-like structures with gas which form in the sediments below the seabed in the right pressure and temperature conditions. Gas hydrates contain large amounts of the greenhouse gas methane, which can be released in step with an increase in sea-temperature. Therefore, gas hydrates can potentially exacerbate the on-going global warming.

Information from seismic data and shallow boreholes drilled in the seabed, along with model calculations, brought the researchers on the track of the gas hydrates in Greenlandic waters. However, more surveys and drilling are needed to confirm and document the existence and amount of gas hydrates in the area. Gas hydrates are also a potential energy resource. The first long-term trial productions are planned to start in Japan and Alaska within the next two years. The PERMAGAS project, which is headed by GEUS, also examined the effect of climate change on onshore permafrost. The work took place under the auspices of a Geocenter Denmark project and received funding from the Danish Centre for Marine Research.

## Development of a 3D geological model commenced

In 2013, GEUS commenced development of a concept for building a nationwide digital 3D geological model. The aim is for the model to integrate well data, geophysics, geochemistry, etc. with the Quaternary geological surface mapping and the marine seabed mapping GEUS is continuously performing and compiling. At the same time, the idea is to incorporate interpretations from detailed local geological models into the 3D model, e.g. data from the national groundwater mapping and knowledge about the deep subsurface. For Greenland, GEUS is not aiming for a nationwide model, but for detailed models of selected delimited areas with special geological issues and interesting minerals.

The digital 3D model will be dynamic and, as a product, the model will be updated with new data on an on-going basis. The model will be an easily accessible common foundation for analyses and calculations. Furthermore, it will serve as a foundation and common reference for establishing local or regional models for various purposes. The establishment and development of the nationwide model will be a protracted assignment. However, the availability of such a tool will ensure that the administration, protection and use of groundwater and other geological resources such as raw materials, geothermal heating and cooling, etc. take place on the most optimal foundation.



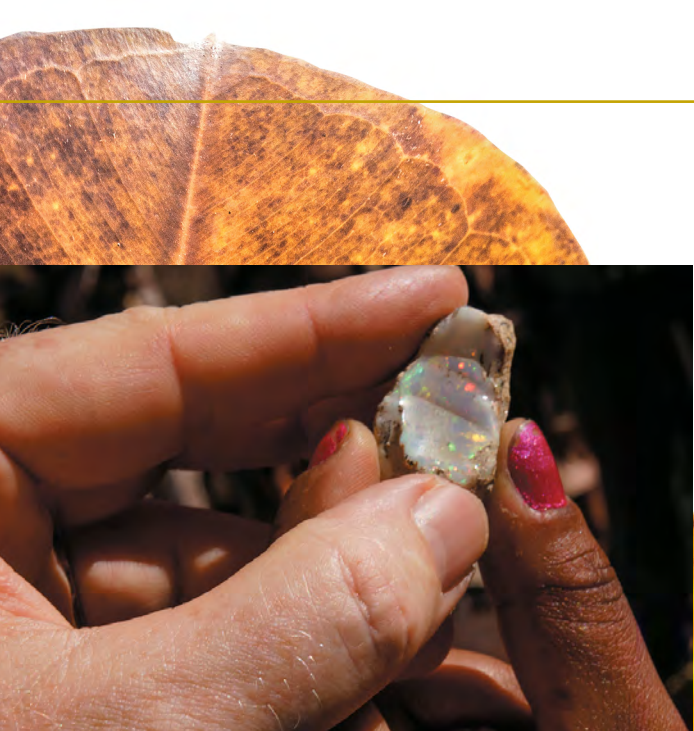


## Sustainable management of mineral resources in Malawi

Interest in exploiting mineral resources in Malawi is great. Exploitation of mineral resources can be a driver of growth and welfare, however, if not managed properly, mineral resources could lead to poverty and environmental disaster. This is the background for a new World Bank project to ensure that Malawi's mineral resources are managed sustainably. GEUS, two UK companies, Land Use Consultant Ltd. and Planning Green Future, as well as two Malawian consultants are behind the project. The new project is a part of the World Bank Malawi Mining Governance and Growth Support Programme; a programme aimed at promoting sustainable management of Malawi's mineral resources. The project will carry out a thorough analysis of the mineral resources sector, a Strategic Environmental and Social Assessment (SESA), the primary objective of which is to help raise the environmental and socio-economic standards in the mineral resources sector. GEUS will appraise the geology, minerals potential, the structure of public administration in the mineral resources sector, as well as national plans for this sector. Finally, GEUS is also participating in the environmental assessment.

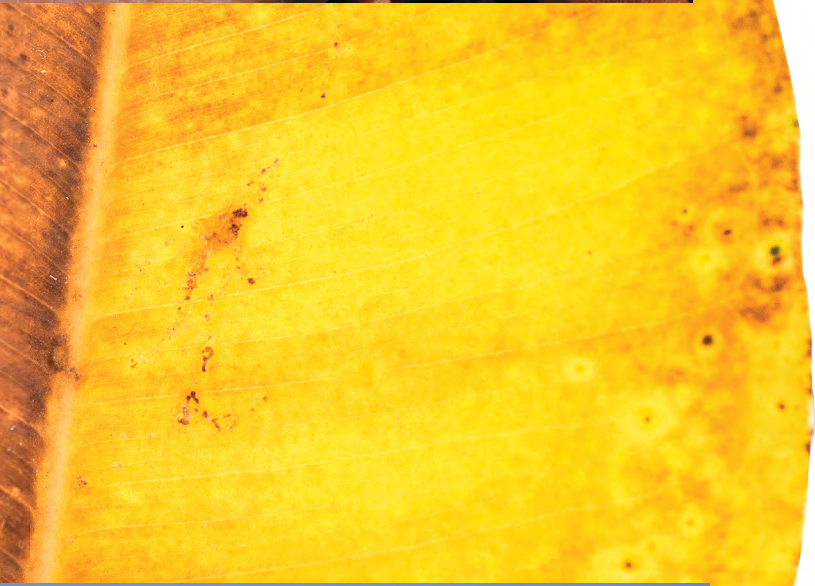






## Agreement on collaboration with Indonesia

On 25 June 2013, the framework for future collaboration between the Geological Agency of Indonesia (GAI) and GEUS was laid down when Managing Director Dr. Sukhyar from GAI and Managing Director Johnny Fredericia from GEUS signed a Memorandum of Understanding (MoU). Colleagues from the two organisations have met to discuss their future collaboration, first at GEUS and later at GAI in Bandung. It was agreed that the two organisations are to collaborate initially in the water area and later also in the energy area. In the water area, GEUS and GAI will together strengthen the mapping and management of Indonesia's groundwater resources, at central and regional levels, by transferring knowledge about effective geophysical surveying methods and by training Indonesian employees in interpretation of data. With regard to data, GEUS can help establish and run geological and geophysical databases. Finally, GEUS will help the Indonesians to prepare administrative guidelines to ensure sustainable extraction of groundwater for drinking water purposes. In the energy area, GAI has stated an interest in collaborating on surveying for geothermal energy and building databases for use in the management of oil and gas resources.



## Improved small-scale mining in Ethiopia

For some years, GEUS has been working with the Geological Survey of Ethiopia (GSE) and the Ethiopian Ministry of Mines (MoM) to market Ethiopia's mineral resources to the international mining industry. This work is now being followed up by a project to train employees at MoM and the individual Ethiopian provinces in all aspects of small-scale mining. The project is being financed by Danida funds, and is being managed by the Embassy of Denmark in Ethiopia. MoM assesses that one million people are working with this type of mining in Ethiopia, and the Ministry has established a system to channel gold purchases through a bank and onwards to the National Bank of Ethiopia. This resulted in a purchase of almost 10 000 kg of gold for the Ethiopian government. The extraction of gold often takes place under very poor safety conditions and using technology that could be improved considerably, thereby increasing the yields. This could help reduce poverty in rural areas as well as the negative impact on the environment locally. The project is carried out in collaboration with another project financed by the World Bank and the Japanese government, focussing primarily on how to improve the role of women in small-scale mining.





## New geological office in Nuuk

In September, GEUS opened a new office in Nuuk, Greenland. The office is to strengthen collaboration with the central administration, industry and academic collaboration partners in Greenland, and ensure a continued build-up of geological knowledge in Greenland. This will be achieved through teaching at schools and educational establishments, through lectures and excursions, as well as through establishing new collaboration projects with both public and private stakeholders. The office is currently manned by an office manager and a geologist domiciled in Greenland, while one or more researchers from GEUS in Denmark will be out-stationed to the office on an ongoing basis. The office is at the Greenland Institute of Natural Resources, with which GEUS collaborates. "Changing scientific staff and frequent visits from researchers from GEUS in Denmark will help ensure fast and relevant knowledge and consultancy services from throughout the GEUS organisation. It's our ambition that the office will serve as an access to the entire organisation and that it is not experienced as an isolated satellite," said Managing director Johnny Fredericia in his speech at the inauguration.

## Four recipients of awards in 2013

Four GEUS employees received awards in 2013. In March, Adam Garde, senior researcher, received the Danish Geology Prize 2012 for his extensive scientific work that led to the description of the gigantic meteorite crater at Maniitsoq in West Greenland. In September, Peter Friis Møller, senior consultant, received the Bodil Pedersen Foundation's Nature and the Environment Award 2013 for his numerous studies of natural forests in Denmark and for his extensive dissemination of knowledge about forests and nature. Towards the end of the year, Anker Weidick, senior geologist emeritus, was awarded the International Glaciological Society's Richardson Medal for his many years of research and mapping of changes to glaciers in Greenland. Finally, research professor Kim Esbensen received the Pierre Gy Sampling Gold Medal for many new applications of the Theory of Sampling (TOS) and for a decade of dissemination and teaching this theory.

Glimpses of the year





## GEUS employee followed the Olympic flame to the North Pole

The Olympic flame was on a long journey before the Olympic Winter Games in Sochi in February 2014. The North Pole was one of the most challenging destinations of this journey. The large Russian nuclear-powered icebreaker 50 let Pobedy set off from Murmansk in October 2013, heading for the North Pole a little more than 1300 nautical miles into the Arctic Ocean. The icebreaker carried the Olympic flame and representatives from the eight Arctic Council Member States to the North Pole, where the representatives participated in the Olympic Torch Relay. Christian Marcussen from GEUS represented Denmark. Christian Marcussen has been project manager for the Greenland part of the Continental Shelf Project since 2002. The aim of the project is to identify and document areas where the Danish Realm can submit claims for new seabed areas. In recent years, he has headed four icebreaker expeditions with the Swedish Oden icebreaker in the Polar Sea and off North-East Greenland; and in 2007 the expedition was accompanied by the powerful Russian 50 let Pobedy icebreaker.



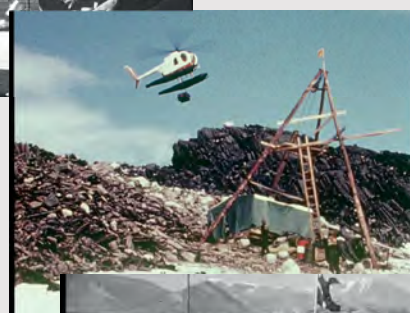
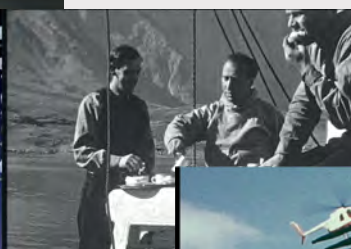
Photo: Sergey Dolya

## Expedition footage from Greenland

'First drillings into the Isua iron ore' is one of the many film clips that GEUS has now made available at its website, [www.geus.dk](http://www.geus.dk): Expedition footage from Greenland. Here, you can find film clips from geological expeditions and films published by mining companies that have explored for mineral resources in Greenland. The website is targeted at people with an interest in expeditions in Greenland, geological research of Greenland, and the hunt for mineral resources in Greenland. The film clips originate from old 16 mm films from GEUS' archives, which have been digitised and thus made available to a larger audience.

## Demand for knowledge at exhibitions

During the year, GEUS provided scientific assistance and material for two large exhibitions. February saw the opening of the temporary exhibition entitled 'Jagten på råstoffer' (the hunt for mineral resources) at the Ecolarium in the Danish city of Vejle. At the exhibition, visitors could learn about the many mineral resources that we rely on, and learn how geologists find these resources. The very topical Greenland minerals were given a prominent place in the exhibition. The exhibition was a huge success and the Ecolarium has decided to continue a reduced version of the exhibition in 2014. In September, the art museum Louisiana opened its exhibition entitled ARKTIS: a powerful and many-faceted mosaic of impressions that guided its visitors through a world of wonder and fear, strength and frailty. Some of the artefacts in the exhibition were on loan from GEUS. These included a piece of the Lomonosov Ridge, an approx. 1800-kilometre long underwater ridge on the seabed of the Arctic Ocean, as well as a jarred sample of the seabed at the North Pole.





# Key figures 2013

More detailed key figures for the activities of GEUS are available in *Årsrapport – Regnskabsåret 2013 (Report and Accounts 2013)*, and in *Faglige resultater 2013 (the latter in Danish only)*.

Both of these are available at [www.geus.dk-publikationer-institutionsrapporter](http://www.geus.dk-publikationer-institutionsrapporter).

Number of employees: **338**

Number of scientific projects: **687**

## ACCOUNTS 2013

Amounts in million DKK

<b>Revenue</b>	<b>305,1</b>
Net figure (Appropriation)	134,1
Operating income	171,0
<b>Expenditure</b>	<b>314,9</b>
Salaries	179,5
Other operating expenditure	135,4

## INFORMATION ACTIVITIES

### Long-term knowledge building

Articles in international scientific journals/publications	188
Other scientific publications	4
Conference contributions with abstracts/posters	171

### Ongoing scientific tasks, consultancy and presentation

Publicly available reports	61
Confidential reports	60
Memoranda, opinions, expositions, etc.	61

### General information

Institution reports (annual report etc.)	8
General and popular-science presentations - including popular-science lectures	138
	75

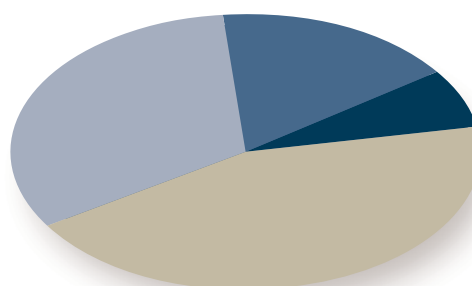
### Use of GEUS web

Visits to <a href="http://www.geus.dk">www.geus.dk</a>	510.000
Use of GEUS' web map services	2,4 mio.

## RESEARCHER TRAINING WITH GEUS TUTORS

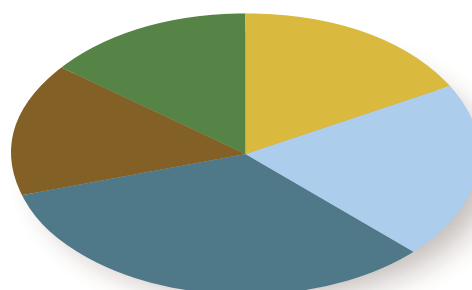
Current PhD students	71
Completed PhD degrees	10

## Revenue broken down by sources of revenue in million DKK



National budget and supplementary government appropriations:	134,1
Programme and external resources:	99,3
Other co-financed contract research:	51,1
Commercial contracts and sales of data:	20,6

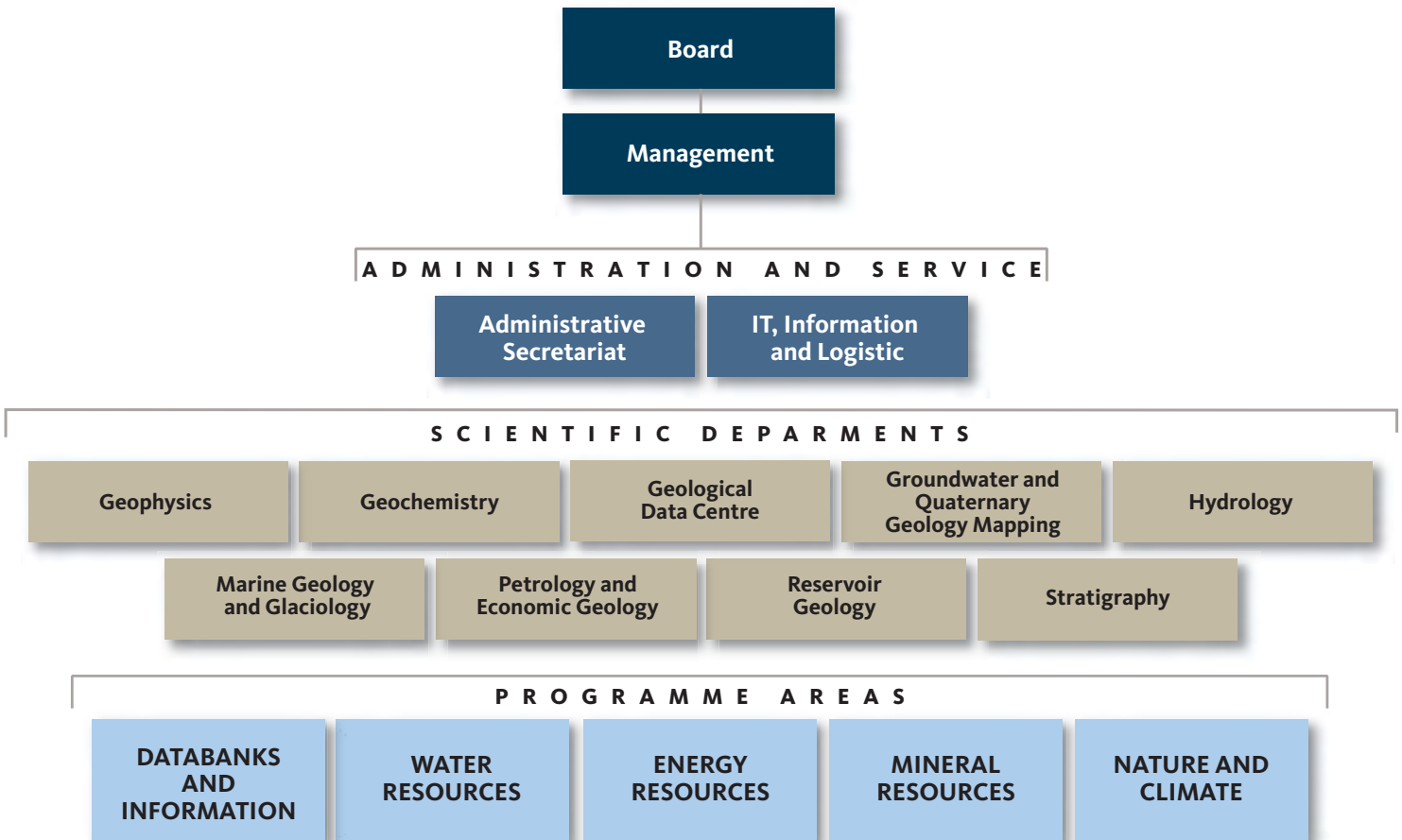
## Expenditure broken down by programme area in million DKK



Databanks and information:	53,9
Water resources:	63,4
Energy resources:	104,4
Mineral resources:	48,5
Nature and climate:	44,7



# Organisation



*In 2013 there were nine research departments at GEUS and two administrative/service departments. Scientific work is being done in five programme areas, where tasks are carried out in project groups in a matrix structure.*

## **Programme area: Databanks and information**

Storage, quality assurance and presentation of geological knowledge and data. The aim is to establish a level of quality of data and sample collections which helps work on monitoring, emergency management, advisory service and research. In addition, the programme area comprises IT projects, which ensure efficient and modern IT tools at GEUS, as well as presentation of data to the scientific community and the public.

## **Programme area: Water resources**

Knowledge to optimise the management of Danish water resources. Activities are directed at the water cycle, the amount and quality of water resources, and transport and decomposition of xenobiotic substances in the aquatic environment, focusing mainly on the groundwater. The activities also

form the basis for advisory services to authorities, regions and municipalities in Denmark and abroad.

## **Programme area: Energy resources**

Knowledge for exploration and exploitation of energy resources in Denmark and Greenland. This work comprises own research projects and international cooperation within oil/gas and renewable energy. The collected knowledge forms the basis for GEUS' advisory services to authorities in Denmark and Greenland, and also for projects carried out for the industry.

## **Programme area: Mineral resources**

Scientific basis for targeted and environmentally sound exploitation of mineral deposits in Greenland and Denmark. This work includes geological mapping and mineral exploration in Greenland, as well as

official processing and advisory services for the Government of Greenland. In addition, surveys are carried out in connection with raw materials and construction work in Denmark and internationally.

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

Identifying processes leading to today's climate and environment in Denmark and the North Atlantic. The objective is to improve the prospects of distinguishing between natural and human-induced environment and climate changes. The programme area also includes a mapping of onshore and offshore geological conditions, as well as earthquake research and monitoring.



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

Øster Voldgade 10  
DK1350 Copenhagen K  
Denmark

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



ISBN: 978-87-7871-384-1