

The Geological Survey of Denmark and Greenland



SURVEY PROFILE

The Geological Survey of Denmark was established in 1888 while the Geological Survey of Greenland was established in 1946. Merged into a single organisation in 1995, GEUS – acronym for Geologisk Undersøgelse – is responsible for all geological matters within the Kingdom of Denmark, which also includes Greenland and the Faeroe Islands. Few national geological surveys are charged with covering a similarly large and scientifically challenging area.

The total staff number is approximately 300 of which some 160 hold academic degrees at masters or Ph.D. level.

The annual turnover is about US\$ 30 million, 40% of which originates from external activities such as domestic and international research programmes, contract research with industry, and international aid organisations.

The cornerstone of the Survey's activities is to carry out geologically related basic and advanced research of relevance to society (i.e. state agencies, the public and private stakeholders). It is upon this solid knowledge base advisory and consulting activities are executed.

As a member of the Ministry's advisory board on the Danish environmental aid programme, active in Southern Africa, Southeast Asia, Eastern Europe, and the Arctic regions, GEUS provides technical and strategic input to the agencies in charge of these areas.

CAPABILITIES AND FACILITIES

GEUS acts as advisors to the Danish Ministry of Environment and the Government of Greenland on a range of issues including:

- Petroleum exploration and development
- Mineral resources mapping and assessment
- Geothermal energy
- Marine geology and raw materials mapping
- Coastal zone processes, mapping and management
- Ground and surface water resources, and glaciological processes
- Global climate change
- National data archives

Research and development activities are carried out within all of these topics. Many research and advisory projects are carried out by multi-disciplinary teams and a large proportion of key projects are conducted in international consortia in co-operation with private and public partners. Over the past decade, GEUS has become increasingly engaged in activities in developing countries and in transition economies in Eastern Europe.

GEUS' headquarters in Copenhagen comprise fully equipped modern laboratories, Geographical Information Systems (GIS) and mathematical models applied on workstations and PC's for nearly all types of mapping activities. Field activities are supported by advanced equipment for geological mapping, geological drilling and marine shallow seismic. Furthermore, the geophysical, stratigraphical, reservoir, mineral and hydrological & glaciological departments are fully equipped with state-of-the-art workstations and interpretation tools.

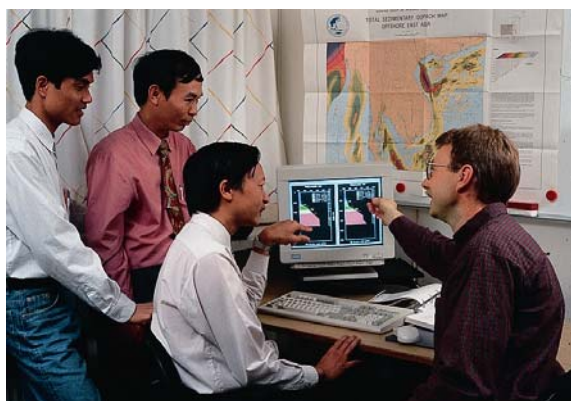


Fig. 1 The ongoing research provides the knowledge base for the advisory capability of the Survey.

An integral part of the Survey activities comprise hosting graduate students and supervision of Ph.D. projects. The GEUS headquarters thus also function as an education and training centre for staff from collaborating organisations and institutions in developing countries from Eastern Europe, the Far East and the former Soviet Republics.

GEOTHERMAL EXPLORATION AND RESEARCH CAPACITY

GEUS has for many years provided advisory, research and consultancy services within the field of geothermal activities. GEUS has since the 80'ties played an important and an increasing role within exploration of geothermal potential and storing of CO₂ in the Danish subsurface and has since 1998 worked together with DONG A/S to assess the possibility of using geothermal energy in Denmark.

GEUS has particularly been involved in areas as structural development, compilation and formulation of geological models in an attempt to predict where to find sandstone layers suitable for geothermal exploration. This ongoing work has further contributed to the geological knowledge of production characteristics and the stability of the hot water recovery, i.e. risking. Most of the work has been carried out as research and advisory projects in a small multidisciplinary team at GEUS, but in close cooperation with private and public partners.

GEUS has applied a multidisciplinary approach for data integration and compiling of geological models for the Danish area. The studies comprise e.g. the following disciplines:

- Seismic interpretation, mapping and structural analysis
- QC of acquired seismic data
- Mapping of structural development
- Mapping and assessment of continuity and barriers, i.e. facies variation and fault zones
- Interpretation of potential sandstone deposition and environment history
- Compilation and formulation of geological models
- Assessment of geochemical composition, salinity, aggressive fluids and effects on diagenesis
- Assessment of reservoir properties
- Assessment of geothermal resources
- GIS-based applications and integration of database and results
- Thematic mapping
- Recommendations for further work and future drilling sites

GEUS has contributed to two volumes of Atlas of Geothermal Resources in the European Community (1988 and 2002) where the aim was to put

together data and information for delineating areas of interest for further geothermal exploration. The latest Atlas (2002) describes the present day general knowledge on geothermal related issues within the Danish area.

Geothermal Energy in Denmark

The first national study on geothermal resources was initialised in 1981. Geothermal resources is mainly related to the Mesozoic succession of the Danish Basin and Fennoscandian Border Zone. This succession has been the target for exploration activities since 1935 and is known from approx. 60 deep wells drilled for hydrocarbons, geothermal energy or gas storage.

Denmark has one geothermal plant, located in Thisted in the north-western part of Denmark. It produces heat from 44°C, 15% saline geothermal water pumped from the Upper Triassic Gassum sandstone aquifer at 1,2 km depth. Experience from the Thisted plant have shown that heat and power plants integrated with geothermal plants with heat pumps (primary absorption heat pumps) can be used to produce heat and power with a high efficiency. Thus, although Denmark has moderate temperature gradients (0.03°C per meter), many areas and stratigraphic levels hold warm sandstone aquifers, which can be used for district heating.

Geothermal Related Services and Capacities

For geothermal exploration and assessment studies, there is a need to integrate the basic disciplines of biostratigraphy and sequence stratigraphy, seismic- and log- interpretation, core description/facies analysis and core analysis in an interactive process of building geological models.

Good biostratigraphic control is of great importance when dealing with geothermal reservoirs and the correlation of sand prone reservoir units. GEUS is equipped for micropalaeontological and palynological investigations and can offer a range of biostratigraphic services. A number of microfossil groups are used: foraminifers, diatoms, nannoplankton, and palynomorphs.

Seismic interpretation and mapping is based on the principles of seismic stratigraphy and seismic facies analysis and can be carried out either on field or regional scale, on both 3D and conventional 2D seismic. In addition to structural mapping and analysis, seismic data are utilised directly for

reservoir characterisation via inversion and attribute analysis.

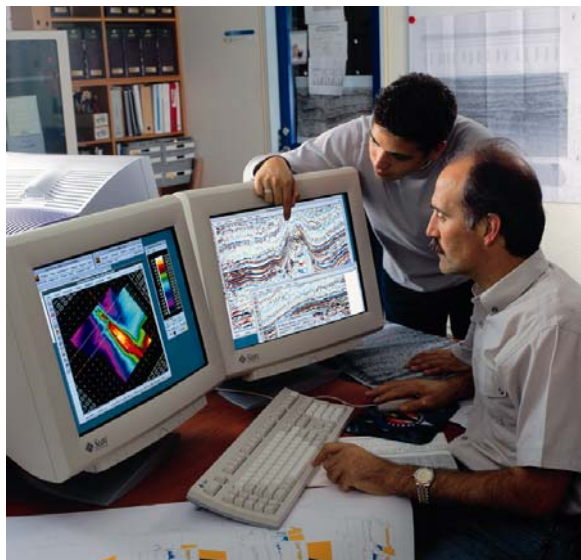


Fig. 2. GEUS are has long standing experienced in interpreting and mapping structural and stratigraphic features as e.g. continuity of sandstone layers.

Log interpretation and correlation of markers from various wells are correlated within the framework provided by the biostratigraphy and the seismic interpretation. The interpretation is carried out on a variety of logs. The logs are used for the evaluation of lithological and petrophysical properties. Analysis of density data sonic velocities of reservoir units could further support the existence of porous sandstone with low degree of cementation.

Core analysis, core description and material provides basic lithological and petrophysical information. Geological core descriptions complement the core analysis studies. The laboratories at GEUS are experienced within core analyses, and offer a range of customised petrophysical services, mainly in special core analysis, advanced core scanning and core imaging.

Recent Geothermal Projects

In 2000, a confidential study of the geothermal potential in the Copenhagen-Malmö region was initiated on behalf of DONG A/S. The interdisciplinary project involving participation by researchers from DONG A/S, The Geological Survey of Sweden (SGU), and GEUS, has since been working on improving our knowledge about the geothermal potential from sandstone reservoirs.

The geothermal study was successfully completed when 70 degrees hot water was found in a sandstone layer more than 2600 metre under Copen-

hagen. Prior to the successful drilling, GEUS had carried out assessments of six possible geothermal drilling sites and prepared the geological foundation for the drilling, using DONG A/S as the operator.



Fig. 3. The increasing involvement in geothermal related activities has so far resulted in two successful exploration wells near Copenhagen, Margretheholm -1 and -2.

Two wells have been drilled with an option for expansion. A multidisciplinary research team of geologists and geophysics from GEUS participated in the work both during and after the drilling.

As a direct result of these efforts, geothermal exploration has now been resumed in the rest of the onshore Danish area, and a number of prospective areas will in the near future be identified and further assessed by the GEUS team in cooperation with DONG A/S.

The ongoing research provides the knowledge base for the advisory capability, and GEUS is frequently called upon to supply geological, geophysical and engineering opinions on licence bids, drilling plans and field development plans put forward by companies operating on Danish territory.

For further information contact:
Anders Mathiesen, Lars Henrik Nielsen
E-mail: anm@geus.dk, lh@geus.dk

MINERAL RESOURCES

Very few organisations are charged with mapping of an entire continent. Greenland is similar in size to all of Western Europe, whilst the ice-free acreage is about the size of France. In addition to this come the territorial waters. In the aftermath of WW2 and during the cold war years the Survey was responsible for the huge task of compiling the basic geological maps of Greenland as well as conducts the search for economic deposits of minerals, some of which were of strategic importance (e.g. Uranium). Besides the logistic task of covering a country with extreme climatic conditions and a poorly developed infrastructure (not unlike the challenges faced by many of the developing countries elsewhere) the task of mapping and exploring Greenland called for an unusually high amount of international co-operation with other national survey, universities, mining and oil companies.

With much of the world's exploitation of mineral resources taking place in the developing countries, GEUS has increasingly sought to make its expertise available to these countries. Recent and current activities include small-scale gold mining and associated environmental/health hazards (Tanzania), mineral exploration and extraction activities (SADC/Zambia) as well as integrated mineral exploitation, environmental impact assessment and development of an educational facility (Tanzania). In Romania GEUS is engaged in the development of concepts for assistance to the mining sector as well as providing an analysis on the country's mining and licensing registry. In Bolivia activities are aimed at the pollution of rural water supply resulting from mine waste (tailings).

NATIONAL DATA ARCHIVE

As the national geological survey, GEUS is responsible for building and maintaining the records of past activities. These Data Bank activities as they are often called comprise very extensive printed and electronic files covering nearly all aspects of the subsoil. A separate warehouse facility houses hundreds of kilometres of cored samples and many thousand representative sediment and rock samples.

GEUS has developed a unique Data Bank database system which is more comprehensive than commonly available commercially systems. GIS technologies are extensively applied.

PETROLEUM EXPLORATION AND DEVELOPMENT

Denmark is the 3rd largest oil producing country in Western Europe and a sizeable gas producer. The country is a net exporter of oil and gas. With 16 producing petroleum fields in the North Sea and considerable - yet untapped - petroleum potential in both Greenland and the Faeroe Islands, petroleum related research and advisory services comprise an area of special competence at the Survey.

The range of advanced petroleum research at the Survey is wide covering exploration geology, geophysics, and maturation and migration studies through reservoir properties, fluid flow simulation and production field models. The majority of the work is carried out by multi-disciplinary research teams, with a view also to the training of younger researchers.

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GEUS has a long standing tradition for providing advisory, research and consultancy services to the international petroleum industry. Such work includes projects in Norway, United Kingdom, Italy, Greece, Canada and the Persian Gulf. Major petroleum related and training activities have also been carried out as international development co-operation with Vietnam (and the CCOP partners), Latvia and Lithuania. Other development activities have involved Poland, Estonia and Former Soviet republics. Particularly in Vietnam and in the Baltic countries, the activities have comprised a wide range of topics, supporting the institutional capacity building in these countries.

Web-Sites: www.geus.dk (GEUS homepage)

REFERENCES

- Atlas of Geothermal Resources in the European Community, Austria and Switzerland. 1988. Haenel, R. & Staroste, E. (eds.). Commission of the European Communities. Publication No. EUR 11026.
- Atlas of Geothermal Resources in Europe. 2002. Hurter, S. & Haenel, R. (eds.). European Commission. Publication No. EUR 17811.