BGR

Biennial Report

of the Federal Institute for Geosciences and Natural Resources




2003

2004

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BGR

Biennial Report 2003/2004

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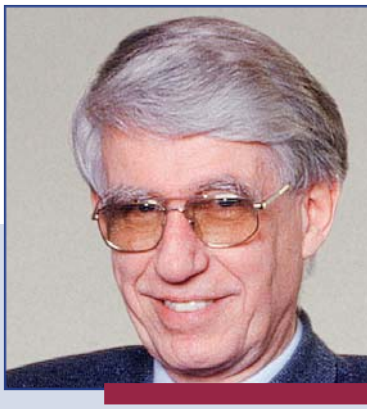
Foreword



Dear Reader,

A review of 2003 and 2004 immediately brings to mind the Tsunami disaster on 26.12.2004 and its horrendous consequences for the countries bordering the Indian Ocean. Two partner countries, Indonesia and Thailand, with whom the Federal Institute for Geosciences and Natural Resources (BGR) has co-operated for many years within the framework of technical co-operation activities, were particularly badly affected.

Two BGR experts made their way quickly to Thailand at the beginning of 2005 to provide advice to the Environmental Division of the Department of Mineral Resources within the framework of our ongoing project. The focus of this advice was reconstruction of the badly damaged coast of Phuket Island and the coastlines to the north.

In the project in Indonesia with the Directorates for Geological and Mining Area Environment, general recommendations for action and guidelines were elaborated for five model locations with the aim of reducing/preventing geo-risks. These recommendations and guidelines are aimed at improving the regional policy and regional planning management of natural disasters – aspects intended for incorporation in the reconstruction projects with our partner countries in the Tsunami disaster region.

Another important issue during the reporting period was the boom in commodities which saw rapid rises in the prices of important resources such as non-ferrous metals, iron ore, steel, oil and coke, not to mention freight rates. After many years in which commodities were always available on the world market in adequate quantities at favourable prices, resource supplies have now again moved into the political limelight. BGR always behaved anticyclically during this long stable period and maintained its high level of consulting and research competence within the commodities sector. Many inquiries regarding natural resources, and requests from the political sphere, industry and society for lectures on this topic, highlight the high demand for this expertise and the value of BGR's natural resource competence.

Specific activities involving this sector include the publication of the 2003 energy study "Reserves, Resources and Availability of Energy Resources"; fundamental work on German and global energy supplies; and the successful preliminary geothermal test phase in the Horstberg Z1 borehole near Uelzen – part of our GeneSys project to heat the office buildings at the Geozentrum Hannover with geothermal energy.

Other important milestones in the broad spectrum of BGR activities during the reporting period include:

- Certification of the IS 27 German infrasound station in the Antarctic, which is located close to the Neumayer research station run by the Alfred-Wegener Institute for Polar and Marine Research (our co-operation partner). Certification was undertaken by the Comprehensive Test Ban Treaty Organisation (CTBTO) of the UN in Vienna. As the national German data centre, BGR operates two certified infrasound stations and two certified seismic stations co-located at the GERESS location in the Bavarian Forest and in the Antarctic.
- Intensified co-operation with foreign partners in underground laboratories to investigate alternative host rocks for the permanent disposal of radioactive waste: such as the co-operation with ANDRA, the French organisation for the permanent disposal of radioactive waste which is investigating the suitability of a clay formation in the Meuse/Haute Marne (Bure) underground laboratory.
- Running the office of the Commission of Geoinformation Business (GIW Commission) on behalf of the Federal Ministry of Economics and Labour. The aim of the GIW Commission is to act as a contact to simplify access to geoinformation (i.e. location-specific information) mainly held by local authorities and the German states, and to make productive use of this information which has an estimated value of Euro 8 billion according to a consultation report. This process bundles all the sectors which can benefit from this information including tourism, utilities, real estate development and insurance.
- BGR's commitment to the German government's training campaign, aimed at increasing the number of training opportunities for young people, is highlighted by the expansion of its trainee positions from 27 to 35, and the broader range of its training opportunities:
  chemical laboratory assistants,
  electricians (since 2004),
  office communications assistants,
  media and information services staff (since 2005),
  precision mechanics,
  informatics experts, system integration (since 2005),
  cartographers,
  vehicle mechatronic technicians.

The foundation committee of the Hans-Joachim-Martini Foundation run by the BGR board of trustees awarded three Hans-Joachim-Martini prizes and/or Junior Science Prizes during the reporting period.

In 2003, Dr. Kurt Bram of the Leibniz Institute for Applied Geosciences (GGA Institute) received the Hans-Joachim-Martini prize for his overall operative and superb scientific work in the applied geoscience field, carried out in part during his earlier employment at the BGR.

The Hans-Joachim-Martini Junior Science Prize 2003 was awarded to Dr. Christian Müller of the BGR for his scientific work on the seismic analysis of underground gas hydrate resources.

In 2004, the Hans-Joachim-Martini Junior Science Prize was awarded to Silke Hillebrand and Katrin Hagemann of the Lower Saxony Geological Survey (our partner organisation at the Geozentrum Hannover) for their scientific contributions to implementing an internet information service for farmers aimed at optimising sampling to determine the residual nitrogen content in soils.

I warmly thank the members of the BGR Board of Trustees for their advice and support. I also wish to thank the German ministries and our domestic and international co-operation partners. And first and foremost, I would like to thank all of the BGR staff for their enthusiasm and commitment in the fulfillment of our duties.

Prof. Dr.-Ing., Dr. h. c. mult. F.-W. Wellmer
President

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of the Federal Institute for Geosciences and Natural Resources

The German Minister for Economics and Labour formed a Board of Trustees to provide the Minister and the BGR President with advice on all of the important aspects affecting the work of the BGR.

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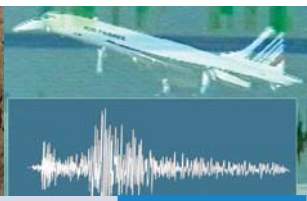

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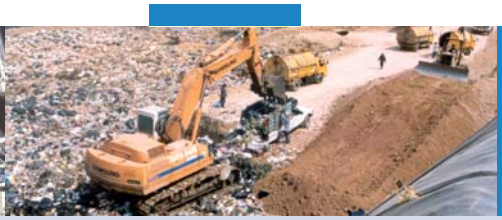


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Technical Co-operation
with Developing Countries

The Geological Side of Co-operation with Developing Countries

One for All!

There is only one planet earth on which we live and which we have to learn to respect. The global population is growing faster and faster. But there is no growth in the life support systems, even worse, the natural resources are shrinking as a result of global overexploitation and negligence. The global reserves of oil and groundwater are not only decreasing, they are also not distributed equally around the world. The consequences are the headline-grabbing social tensions and poverty in numerous countries reported daily in the media. The gap between poor and rich is increasing instead of decreasing. The future of mankind can only be guaranteed by forward-looking planning and development which conserves resources.

Global Crisis
What is the Answer?

The German government pursues the declared aim of de-escalating conflicts and reducing poverty. The Federal Republic of Germany is one of the biggest players on the international development co-operation stage. The aim of German development policy in its co-operation partner countries is to improve the quality of people's lives, especially of the poor. By using the leverage of technical co-operation, the German government supports development processes in its partner countries and empowers people and organisations to improve the quality of their lives. This is achieved by transferring technical, economic and organisational skills and knowledge, and creating the political frameworks for sustainable development.

The German government follows the millennium development objectives of the international community, and focuses its work on three main areas:

- combating poverty
- environmental and resource protection
- education and training

What Role does BGR play in Technical Co-operation Activities?

With its in-depth technical expertise and many decades of experience in projects in many countries around the world, the Federal Institute for Geosciences and Natural Resources (BGR) realises the geo-relevant aspects of development co-operation on behalf of the Federal Ministry for Economic Co-operation and Development (BMZ).

Main areas of BGR activity:

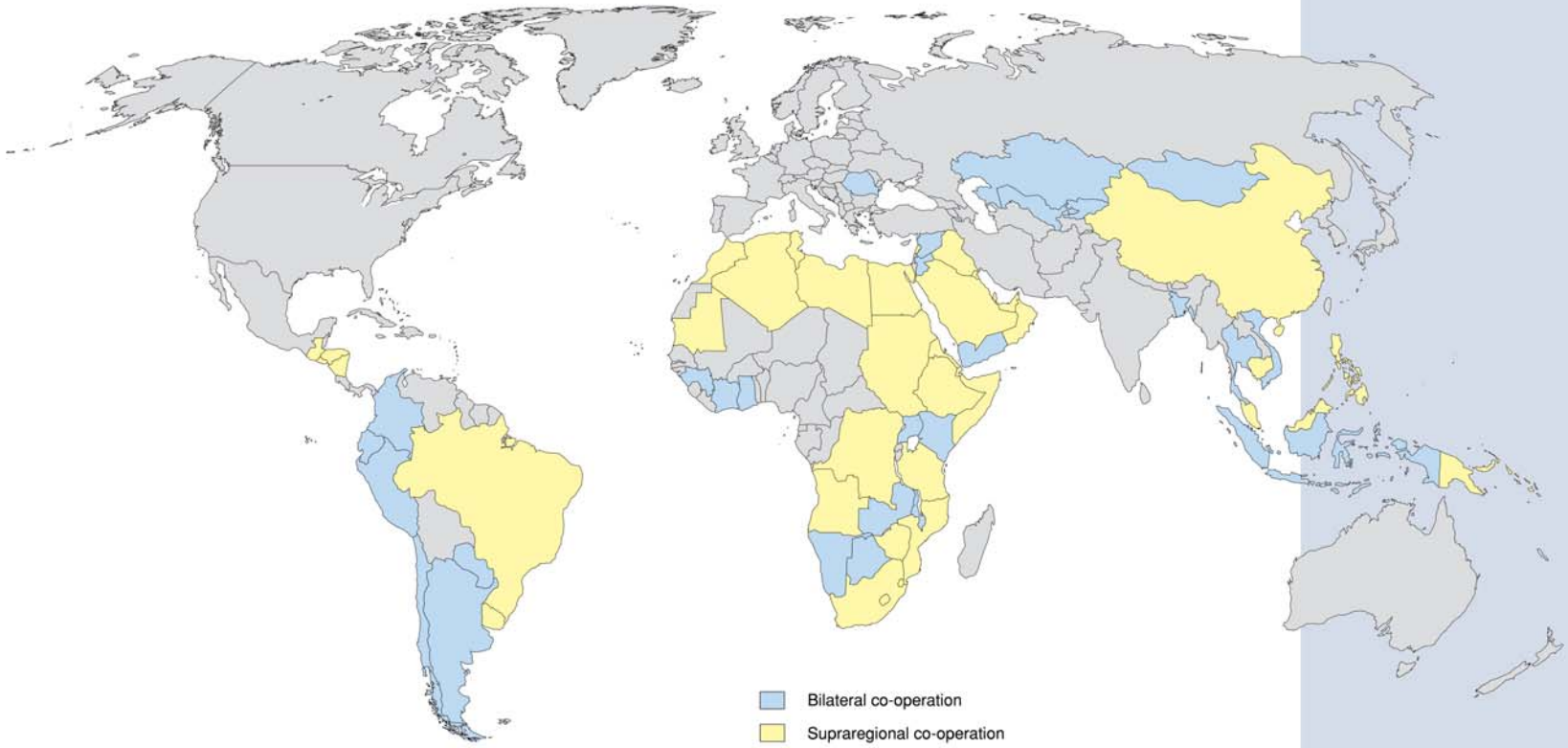
- **Groundwater management,**
  e.g. "Where are there adequate quantities of clean drinking water, and how can it be sustainably exploited?"
- **Geo-environment protection and resources protection,**
  e.g. "What is the best way of harmonising regional planning with the protection of the environment and natural resources?"
- **Geo-risk management,**
  e.g. "What preventative measures can be implemented to protect against geohazards?"
- **Advice on mining and mining environmental protection,**
  e.g. "How can the supply of resources be harmonised with the needs of environmental protection?"
- **Resources: energy resources, industrial minerals, metallic resources,**
  e.g. "Where can we find construction materials?"

What does BGR do Specifically?

BGR is currently involved in over 30 technical co-operation projects in these five main fields of activity, co-operating with more than 20 partner countries and organisations in Central and South America, Africa, Central and Southeast Asia, and Southeast Europe. The project partners are mainly government institutions, but also include technical associations and companies involved in the geoscientific, mining, water, regional planning and environmental sectors. Assistance is mainly provided in terms of technical advice, training, and consultancy work supporting the establishment of efficient organisation structures and their institutional frameworks (institution building, sponsoring agency promotion).

In addition to the German technical advisors from BGR, these projects also include consultants from industries in the partner countries. BGR also assists supra-regional organisations such as ACSAD ("Arab Center for the Studies of Arid Zones and Dry Lands" run by the Arab League) which pursue a cross-border approach to achieving their development objectives. The sectoral focus of technical co-operation activities involves major interdisciplinary programmes, in which BGR participates with its whole geoscientific competence and works closely together with other actively involved organisations in a pan-sectoral approach.

The Biennial Report of the BGR covering 2003/2004 presents three technical co-operation projects which involve different continents and reflect in an exemplary way the broad range of BGR technical co-operation project work in the geo-sector.



Partner countries of Technical Cooperation involving BGR in 2003 and 2004.

Mining Consultation and Contaminated Mining Sites **in Chile**

Historical Background

Mining plays a dominant role in Chile's history and economy. The country's metallic and non-metallic resources are located in the Cordillera, its strike valleys and salt lakes – particularly in the north of the country.

With a production of approx. 5 million t copper in 2003, Chile's mining output today makes it easily the biggest producer in the world, accounting for around 36 % of global production. The copper industry is of major significance for the Chilean mining industry and the whole Chilean economy. Chile is also the world leader in the production of lithium and iodine. It is also the third largest producer of molybdenum and silver.

Mine output in Chile has increased 500 % in the last 20 years largely thanks to the country's exceptionally open economic policy and the attractive investment conditions. In 2002, mining accounted for 8.2 % of gross domestic product and 41.6 % of its export revenues.

Chile can look back on over 150 years of industrial mining, primarily involving copper, but also saltpetre, gold and silver.

Small scale gold mining using a pan grinder.

In the pan grinder, mercury is usually spread onto the amalgamation sheets with bare hands.

In the traditional mining area of the city of Andacollo, 380 km north of Santiago, the mine waste extends right into the middle of the urban area in some parts.

Huge volumes of mining waste have accumulated during this period, particularly in the north of the country. Most of the contaminated sites concern residues from gold and silver processing, which in some cases contain high concentrations of arsenic, mercury and other heavy metals. There are also tailings ponds with copper processing residues, and tailings which are potentially unstable and at risk of releasing acid water.

The risks to the inhabitants and the environment associated with these contaminated mine sites come from the toxicity of the substances they contain as well as air-borne dust, hazards associated with the collapse of large tailings ponds, the acid mine drainage (AMD) potential, and to a lesser degree, unsealed and unsecured shafts and other mining facilities.

The environmentally-compatible handling of natural resources is becoming an increasingly important competitive factor on the global market for the mostly international mining companies involved in the Chilean mining industry. It is now becoming more important for companies to gain certification of their own operations and to be able to demonstrate the implementation of a sustainable development policy.

Chile's contaminated mine sites are therefore almost exclusively derived from the period before the coming into force of the country's environmental law (1994) and its implementation stipulations (1997). These now require environmental impact assessments to be carried out prior to the authorisation of all new industrial projects. In addition, since January 2004, operating mines have also been forced to submit abandonment plans which adequately take into consideration mine safety as well as environmental protection.

However, the law as it currently stands still completely ignores considerable risks to the environment and to the mining industry itself associated with some of the old contaminated mine sites. Although the environmental contamination is indisputable, and the number of old and abandoned mines and processing plants is far higher than the number of new mining operations complying with the mining laws, Chile has so far no regulations in place covering the inventorisation, classification and remediation of these hazardous contaminated mine sites.

Against this background, the State Geological Survey and Mining Service in Chile, "Servicio Nacional de Geología y Minería" (SERNAGEOMIN), decided in 2002 to make preparations for the establishment of legislation and to find technical solutions to the problems of these contaminated mine sites. To this end, it submitted an application to the Federal Ministry for Economic Co-operation and Development (BMZ) in Germany for a technical co-operation project with the Federal Republic of Germany.

The BGR-SERNAGEOMIN Project

The "Basic principles for the remediation of contaminated mine sites" project jointly implemented by the BGR and SERNAGEOMIN on behalf of BMZ aims to establish the basic principles for the environmental monitoring of contaminated mine sites and to initiate the remediation process to clean up hazardous mine sites of this kind.

Work began in August 2003 for an initial period of five years divided up into three main aspects:

- **Legal framework for contaminated mine sites in Chile**

  Creating an effective legal framework dealing with contaminated mine sites in Chile first requires stipulation of a specific objective and a number of basic conceptual principles which define the terms, and clearly assign responsibilities and accountabilities.

  The second step will look at the existing legal framework and assess its effectiveness in regulating the appropriate handling of contaminated mine sites in the sense of the target definitions and the conceptual principles. This then forms the basis for drafting proposals for new legislation or amendments to the existing laws.

  According to the current assessment, the main challenge for contaminated mine site legislation in Chile is to appropriately handle the property rights and mining laws concerning the affected areas, so that clean-up can actually take place in cases brought before the authority.

The Chuquicamata opencast mine belonging to the state Chilean mining company "Corporacion Nacional del Cobre de Chile" (CODELCO) which began operations in 1910. This mine lies at a height of 2870 metres in Northern Chile and is the largest opencast mine in the world with an area of 11 square kilometres and a depth of over 700 metres.

It is also the world's second largest copper producer with an opencast mine production of 467,000 tonnes of copper in 2003. This is in addition to another 140,000 tonnes of copper from SX-EW leach processing in 2003. The mine also produced 16,430 tonnes of molybdenum, 160 tonnes of silver, and 1.2 tonnes of gold in 2003 (photo: CODELCO).

The historical exploration and analysis of mine contamination often involves painstakingly detailed investigation to collect onsite information.

The project training programme included the preparation and implementation of pilot clean-up activities right at the start of the first phase, as shown here with the containment of a landfill which contains toxic residues from the processing of gold ore.

In addition, regulations are also required covering institutional accountabilities and responsibilities. The contaminated sites mainly involve historical pollution where it is no longer possible to establish the legal successors to those originally responsible for the contamination, or where accountabilities are barred by the statute of limitations when 20 years have elapsed. As a consequence, the responsibility for cleaning up the old contaminated mine sites will mostly be borne by the state. However, exceptions are possible and need to be properly taken into consideration in contaminated mine site legislation.

The work on the legal framework for contaminated mine sites will be carried out by the project team and a specially assembled committee, advised by a team of legal experts. The committee comprises all of the main authorities responsible for the mining and environmental sectors (National Environmental Agency "Comisión Nacional del Medio Ambiente" (CONAMA), Ministry of Mining "Ministerio de Minería", SERNAGEOMIN in its function as the central mining agency) as well as BGR and the UN Economic Commission for Latin America and the Caribbean "Comisión Económica para América Latina y el Caribe" (CEPAL) as advisory bodies.

Financing the remediation of contaminated mine sites

The second challenge is to finance a clean-up programme for contaminated mine sites. According to current analysis, it is thought unlikely that the state alone will be able to provide the necessary funding. The project therefore includes elaboration of proposals for alternative means of financing. These proposals are discussed with the responsible departments and will be presented to the legislative body at the end of the first project phase together with the recommendations for the new legal framework.

It can already be assumed that financing in most cases will involve the direct or indirect participation of the mining sector. Possible instruments may include funds, or sponsoring with appropriate tax incentives, as well as the use of non-tax government revenues such as income from the sale of mining rights and fines.

Establishing the technical skills required for cleaning up contaminated mine sites

The third aspect covered by the project is building up the technical qualifications of the project agency to enable it to raise awareness of the need to clean up contaminated sites, and to comprehensively monitor future remediation measures. SERNAGEOMIN's founding decree makes it responsible for monitoring the implementation of mining sector standards. In addition to mining law administration, this also includes monitoring compliance with mining safety regulations and environmental issues.

The legislation governing contaminated mine sites in Chile will assign SERNAGEOMIN responsibility for identifying and specifying the risks of contaminated mine sites, and in notified cases, responsibility for technically monitoring clean-up programmes to ensure that they comply with the stipulations.

To be able to fulfil these tasks, working groups have been created and provided with appropriate technical guidance to enable them to collect information on specific contaminated sites and prepare and supervise pilot-scale clean-up programmes. The pilot projects are mainly carried out to enable the groups to acquire practical experience in the identification, classification, and preparation measures needed for cleaning up contaminated mine sites.

Outlook

The project is currently in the first phase scheduled to last two years. Project duration is initially scheduled for five years.

The second phase which is due to run from 2005 to 2008 will concentrate on further increasing the technical qualifications of the partner institutions who supervise and manage the remediation of contaminated mine sites in Chile. Another important aspect is implementing the proposals presented during the first project phase for the legal framework and the financial instruments required.

The remediation measures elaborated during the first part of the project were primarily realised under the technical supervision of the project staff and external consultants with the involvement of technical staff from the partner institutions. During the second phase however, the leading role in the planning and supervision of clean-up measures will be in the hands of local experts. The intention is for the remediation measures to be implemented as soon as the legislation comes into force and the financing instruments become available.

The funding promised so far for the clean-up of old mine sites comes exclusively from the private mining sector. This highlights the serious interest of the industry in solving the problem of contaminated mine sites, and their future willingness to continue to participate in the financing of a national clean-up programme for contaminated mine sites.

Flotation tailings of the Salvador copper mine belonging to the Chilean state mining company "Corporacion Nacional del Cobre de Chile" (CODELCO), located 1100 kilometres north of Santiago. Mine tailings which have been dumped into the sea for many decades have extended the shore line over a large area with partially contaminated material (satellite image: Landsat 7, BGR).

Environmental Geology
in Town and Regional Planning in **Malawi**

Introduction

Malawi in southeast Africa is one of the poorest countries in the world. With its lack of natural resources, this predominantly agricultural country faces many problems during its development. Combating poverty in the country is made difficult by the large number of people infected by HIV/AIDS. This comes on top of the only marginal slow-down in population growth creating more and more pressure on its limited natural resources. Every household has on average less than 0.5 hectares of agriculturally usable land at their disposal – inadequate to feed a family. Unforeseeable natural disasters regularly destroy their harvests. Frequent flooding and landslides with associated repairs to the damaged infrastructure place an additional burden on public finances.

BGR-GSD Co-operation

The BGR has supported the Geological Survey Department (GSD) of Malawi since 1990 with the aim of improving its skills and making a contribution to Malawi's development. The technical co-operation has the goal of mapping the country's deposits of industrial minerals, assessing the mineral potential, and investigating potential "agro-minerals" which can be used as fertilisers. Following a natural disaster in Phalombe in 1991 where landslides killed over 500 people, technical co-operation since 1996 increasingly focused on geo-risk assessment with the aim of implementing preventative measures.

Environmental Geology Project

The co-operation since 2001 focusses exclusively on environmental geology issues to enable the Geological Survey Department to provide town and regional planners with the necessary level of support.

That there is an urgent need for this advice is clearly demonstrated by the city of Blantyre, the main industrial centre in the country. With a population of less than 600,000 as recently as 1999, the city has now grown to over one million people. The few town planners at present are unable to effectively and systematically plan the rapid growth of this city. However, there is an urgent need for careful planning so that the inhabitants of this city in the Shire Highlands with a relief extending from 750 to 1600 m are protected from rock falls, landslides and debris flows, and to establish the environmental conditions required to ensure that future generations also have an adequate quality of life.

Blantyre: recording a soil profile.

Studies demonstrate the close connection between geology and town and regional planning. The environmental geological investigations carried out during two years of field work in Blantyre covered many aspects including the evaluation of geological risks within the urban area, searching for suitable domestic waste landfill sites, assessing the potential of mineral construction materials, evaluating the sensitivity to erosion, and detailed environmental geology investigations for new town planning zones.

Geohazards

The urban area of Blantyre includes mountains with steep slopes and a long history of debris flows and rock falls. Rapid growth in the city's population has forced people to live on these steep mountain slopes. Anthropogenic activity increases the risks of mass flows being initiated during periods of heavy rainfall.

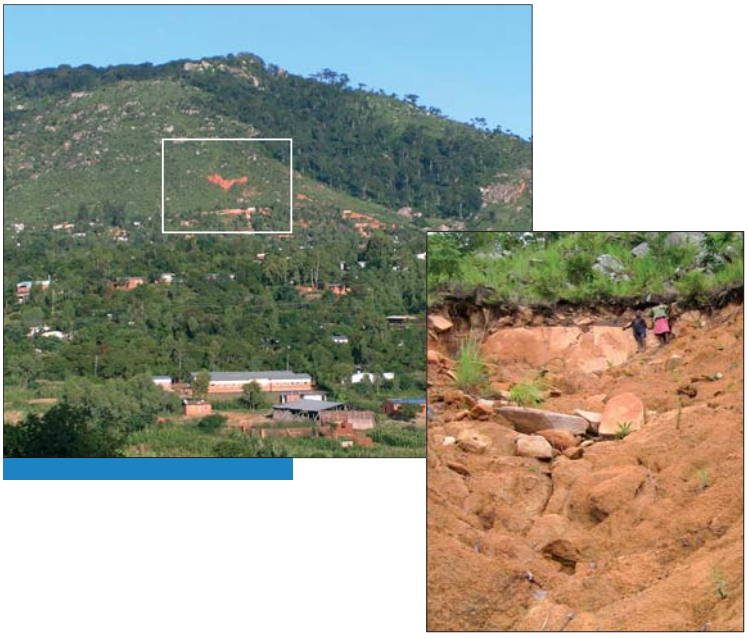
Erosion Sensitivity

Agricultural yields have declined by double figures in percentage terms in recent years as a result of fertile soil being washed away by heavy rain. This is exacerbated in the city of Blantyre by the inappropriate use of steep slopes for the cultivation of maize. The small businesses extracting construction sand and gravel from the rivers naturally welcome the continuous replenishment of their resources by the high loads of sediment carried by the streams.

But when river beds become filled with sediment, they represent a high level of environmental risk. This is because the reduction in drainage capacity of the rivers can cause unexpectedly strong flooding during periods of heavy rain. Moreover, the increasing amount of sediment in the river water increases the costs of drinking water treatment in Blantyre as well as reducing the amount of usable water.

Extracting brick clay from a former debris flow on the west flank of Mt. Soche.

Mt. Soche, Blantyre:
The extraction of brick clay can destabilise the slope and generate debris flows which endanger the settlements further down the slope.



Dwambadzi River bridge:
Remains of the bridge swept away by floods in 1999.

Dwambadzi River:
Destroyed auxiliary bridge in 2001.

This soil erosion also diminishes the amount of power generated by the country's three hydroelectric power stations on the Shire river. The water depth in the reservoir behind the three-year-old Kapichira hydropower plant dropped from 8 m to 2 m. And fine sand has abraded the turbine blades to such a degree that turbine capacity has fallen to 30 %.

Search for Landfill Sites

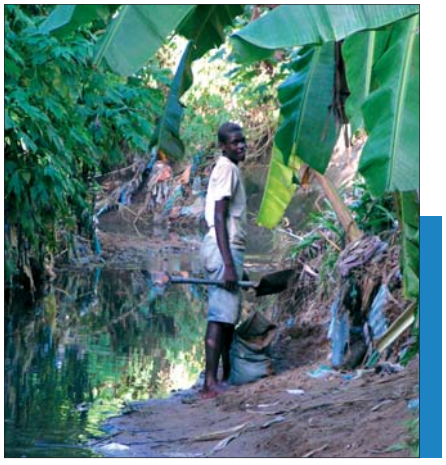
The current Mzedi Hill landfill used to dump the industrial and domestic waste generated in Blantyre, is located in a spring area, and has already caused irreparable pollution of a stream system. The city now has to supply the people living along this stream with drinking water pipes connected to a pipeline system specially built for this purpose. These costs could have been saved by advance planning of a safe landfill with a geological contaminant barrier against pollutants, and consequent protection of the surface water and groundwater.

Now it is a matter of urgency to establish an environmentally-compatible landfill because of the increasing contamination of the water on Mzedi Hill and the increasing quantities of waste generated by the city.

The following criteria are used in the search for suitable sites for landfills in the urban area:

- thick clay-rich soil cover over a sufficient area
- gentle slope
- adequate distance to housing areas
- adequate distance to water courses
- adequate depth of the water table
- favourable transport location

Because the urban area in the Shire Highlands was subject to strong peneplanation over geological time, there are only a few level surfaces available with an adequate level of soil cover. The only safe location at an acceptable distance to the city centre is in Chigumula.



Musa, Blantyre:
Extraction of building sand from the Likhubula River.

A landfill with a capacity adequate for the coming decades can be constructed here thanks to an area of over 20 hectares with an average soil thickness of 7 m, an average clay content of 55 %, a depth to water table of 6.5 m and a gradient of below 2 %. The morphology also allows an artificial wetland to be constructed for the cheap treatment of the landfill leachate.

Environmental-Geological Assessment of the Malabada Town Development Area

Blantyre intends to build schools, churches, a cemetery and housing in the Malabada town development area. However, because this area lies below one of the steep faces of Ndirande Mountain, an overall environmental-geological evaluation of the area has been carried out as part of a training measure for staff of the Geological Survey Department of Malawi.

This evaluation revealed the following risks and restrictions for the future use of the area:

- a school that has already been constructed lies partially within a zone threatened by debris flows;
- the building ground is not load-bearing because of the upwelling of slope water in some areas;
- low quality roofing tiles are being produced from fertile top soil which not only destroys soil forever, but also hinders the gardening which traditionally takes place in housing areas;
- because of the absence of a sewer network, it was originally planned to build drainage pits for the percolation of waste water. However, the presence of clay-rich soil derived from in-situ weathered rock makes the ground virtually impermeable to water and therefore unsuitable for waste water percolation. Drainage pits which have already been built spill over and increase the risk of epidemics during the rainy season and increase the number of cases of cholera. It is recommended that this area should be connected to the main sewer network.

Mzedi Hill, Blantyre:
Polluted well at the Blantyre landfill.

As a result of these findings, there is a need to modify the planning to reflect these local conditions and avoid potential damage in future. The school that has already been built needs to be protected by carrying out suitable stabilisation measures in the nearby stream bed, and it is also recommended as a precautionary measure that it is closed during periods of extreme rainfall.

The spring areas are unsuitable for the construction of housing and could be used as an urban green space instead.

Because the firing of clay tiles is not permitted in housing areas in Malawi, and the tiles are of low quality anyway, the planning authority should offer alternative areas to the small businesses involved.

The treatment of waste water in drainage pits is not a viable alternative in the planning area due to the impermeability of the soil. The town planning should therefore include connection of this area to the main sewer network, especially because a considerable proportion of faecal sewage can be expected from the school.

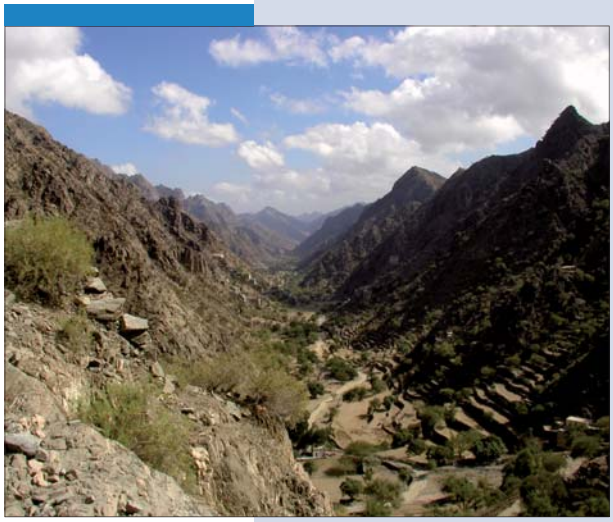
Geological Mapping
– a Vital Contribution to the Protection of Environmental Resources and Improving Living Conditions – an Example from **Yemen**

The "Yemeni-German Geological Mapping Project (YGGMP)" was arranged at the end of the nineties between the Yemeni and German governments. The project was financed by the Federal Ministry for Economic Co-operation and Development (BMZ).

BGR assisted the Geological Survey and Mineral Resources Board (GSMRB) in the geological mapping required for an official geological map at a scale of 1 : 100,000. In addition to establishing a modern digital mapping department, BGR implemented computer-supported image processing at GSMRB to enable the Yemeni partner to evaluate satellite images in a cost-effective and time-saving way for the production of geological and other technical interpretations and to transfer the results to appropriate maps. These measures were supplemented by a digital geo-database.

Training measures were a vital contribution to this project. These involved on-the-job training in the Yemen as part of the daily project work, as well as courses organised and implemented in Germany and Jordan. In addition to the training of geologists, the further education also included cartographers, who were taught digital cartography and the application of geographic information systems.

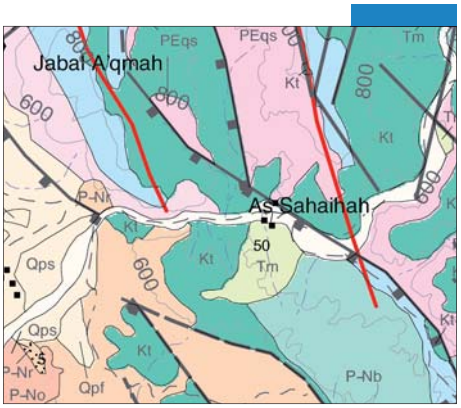
The geological work was rounded off by microscopic and geochemical analysis of rock samples, and the classification and interpretation of the geotectonic setting.



Wadi Adim – window into the Precambrian.

Field orientation.

Fourteen geological maps were produced at a scale of 1 : 100,000. The figure below shows a section of the Yafrus Geological Map in original size.



The work focused on the evaluation and display of data from existing reports. These were presented in the form of easily understandable maps. This was followed by a data collecting exercise, looking in particular at potential sources of air, soil, surface water and groundwater contamination.

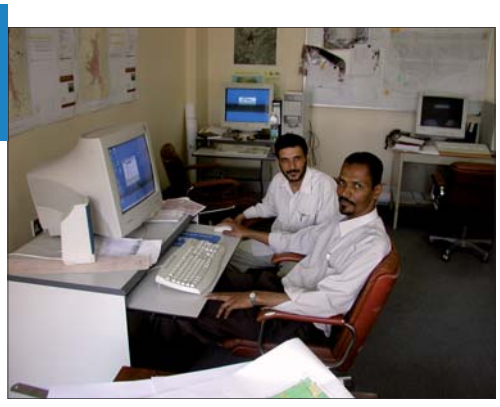
The basic geological information collected in this way forms an important source of information and the basis for discussions with decision makers in the Ministry for Water and the Environment, as well as the Sana'a local authority.

Because of its great success, the area covered by the project was extended at the wish of the Yemeni partner in 2004 to include the whole Sana'a basin.

The focus of the project has shifted since 2002 towards environmental geology and groundwater. The project therefore now makes a direct contribution to the Yemeni water sector, which is the main area of German-Yemeni development co-operation.

Accordingly, the work concentrated on the elaboration and compilation of environmental-geological maps of various kinds for the Sana'a region. These maps cover the following themes:

- historical development of Sana'a
- geology and shallow pit and quarry resources
- hydrogeological map with potential recharge dams
- geomorphology
- land use
- groundwater quality, e.g. nitrate content, electrical conductivity
- potential sources of air, soil, surface and groundwater contamination



Digital cartography in Sana'a.

Sampling downstream of the urban sewage works in Sana'a.

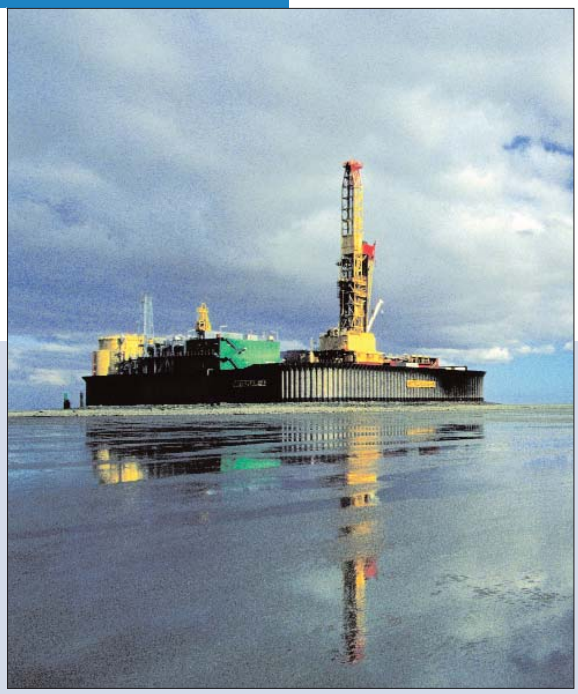
Analysis of the surface and groundwater downstream of the sewage treatment works for the city of Sana'a revealed considerable contamination attributable to the inadequate capacity of the sewage works. Thorough and detailed discussions with the politicians in charge formed the basis for the urgent provision of funding for an immediate expansion of the Sana'a sewage works.

The study of the dams installed in the Sana'a basin, which are mainly intended for groundwater recharge, produced another useful result. The geological field work and the additional geophysical survey which was carried out revealed that only some of these dams were actually promoting groundwater recharge effectively. The project partner is currently elaborating appropriate recommendations to improve the situation.

The work carried out so far clearly highlights special measures that are urgently required to monitor the surface and groundwater quality. Moreover, appropriate preventative measures must be put into place to avoid further contamination of the neighbouring water resources.

One of the major success stories of the project is that the political decision makers and the co-operating ministries, and sections of the parliament have recognised the enormous significance of environmental-geological information for town and regional planning. A vital element of this success was the early and continuous dialogue between geologists, regional planners and politicians.

Sampling contaminated surface water in a recharge dam.



Energy Resources

Energy Resources – the Backbone of an Economy

Where would our daily lives be without energy?

Showering in a pre-heated bathroom, hot coffee and toast for breakfast, the news on the radio – none of these pleasant aspects of getting up in the morning would be possible without energy. These small examples of individual consumption apply all the more to the economy as a whole: huge quantities of electrical power and fuel are required at all times for industrial processes, transport and services.

What are the Ingredients Required in the Energy Mix?

The primary energy consumption mix in Germany in 2003 depended on oil, gas, coal and nuclear power to provide 96 % of the country's needs. All of the other sources of energy such as hydroelectric power, biomass, wind, photovoltaics and geothermal energy only account for a very small proportion to date. The political intention of the German government is to increase the share of renewable energies producing electricity from the current level of around 8 % to 20 % by 2020. Or looked at from a different angle: conventional sources of energy will still account for 80 % of power production in 2020 – in addition to providing balance power to compensate for any reduction in output from wind turbines on calm days. This dependence will only diminish further in small steps in subsequent years.

On top of all this, Germany is dependent to a high degree on energy imports: 100 % in the case of uranium, 96 % for crude oil, 79 % for natural gas, and already 63 % for hard coal. The only energy source for power production exclusively derived from domestic reserves is lignite.

What is BGR's Role in this Context?

As a subsidiary institute of the Federal Ministry of Economics and Labour (BMWA), one of our important tasks is to provide the German government and industry with forward-looking advice on the availability of energy resources. We do this by continually monitoring global developments in the energy market. In addition to our core competence in the geological availability of energy sources, this work also includes observing the availability of production and processing capacities as well as developments in the transport sector.

As an example, let us have a look at the developments in the "nominal prices" for the four most important energy sources. For many months, the media have reported in particular on the rapid changes in the oil price. An "all time" high of 42 US Dollars per barrel was reached at the beginning of July 2004, only to see oil prices breach the 50 US Dollar mark in London by mid-October. This development is the consequence of many factors including economic development, the growing demand of the third world for energy and other natural resources, political instabilities in the production regions, speculation, production capacity shortages, natural disasters, and the availability of reserves. Astonishingly – and barely communicated to date – this trend is also being matched by the prices of the other energy sources.

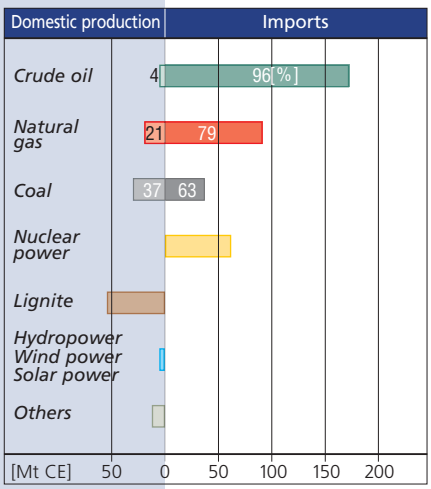
Unlike the situation in the 1970s when the parallel development in fuel prices could be easily explained by the two oil crises and a shift into other energy sources, this mono-causal relationship is definitely not the explanation for the situation we see today. The reasons are varied and include in the case of hard coal: the closure of mines in Europe, rapid growth in Chinese steel production, and shortages in marine transport capacities; in the case of uranium: the closure of mining capacities and market concentration on a few suppliers; and in the case of gas: the coupling of the gas price to the price of oil typical of many countries.

To competently fulfil its advisory role, BGR uses around 40 % of its capacities for research. In the thematic sector "energy resources", this research looks at areas which are not yet the focus of commercial exploration. These activities cover a broad spectrum from the evaluation of regions in which industry has not yet become involved so far (e.g. very deep water, circum-arctic areas) as well as subjects currently ignored by industry (such as gas hydrates), the development of equipment and methods, and pushing ahead with geothermal resource development (heat and power) to establish it in the market.

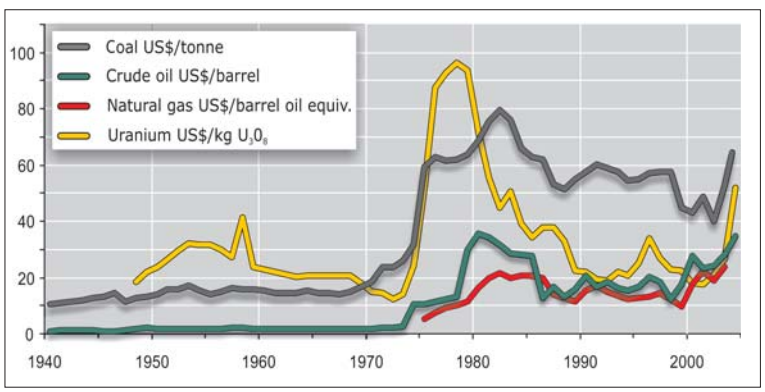
Because the use of fossil energy sources is always associated with the emission of CO_2, the "storage of CO_2 in geological structures" plays an increasingly important role in BGR's activities. Currently this work focuses on: establishing a national planning basis for government and industry; research regarding storage of CO_2 in mature gas fields; and the development of gas-geochemical monitoring instruments.

Primary energy consumption 2003: 14,334 PJ	
Source of energy	Share [%]
Crude oil	36.4
Natural gas	22.5
Coal	13.7
Nuclear power	12.6
Lignite	11.4
Hydropower/Wind power	1.0
Others	2.5

Structure of German primary energy consumption in 2003 (source: Energy balance sheet joint venture).



German domestic production and imports of primary energy resources in 2003. All figures converted to megatonne coal equivalents. The percentages refer to dependency on imports.



Development of nominal prices for energy resources (average annual figures) since 1940. The figures for 2004 are preliminary.

Magnetotelluric Surveys
in the North German Basin – a New Tool for Deep Gas Exploration

The search for hydrocarbons moves from shallower to deeper lying horizons in sedimentary basins. This makes it necessary to continuously expand the general understanding of the geological and tectonic structure of those basin parts and to gain a more accurate insight into the conditions governing basin building processes and the associated spatial and temporal distribution and generation of hydrocarbons. The magnetotelluric method was used in the North German Basin for this purpose.

Magnetotellurics (MT) is a geophysical method based on the principle of electromagnetic induction and is used to measure differences in conductivity in the earth's crust. Unlike other electromagnetic methods which use an artificially generated source field, MT measures the natural variations in the electromagnetic field of the earth. These are caused by variations in electric current systems in the ionosphere, and the magnetic fields induced in underground bodies by these variations.

Magnetotelluric (MT) surveys conducted by various institutes in the 1970s and 1980s surprisingly confirmed the presence of a layer with good conductivity in the pre-evaporitic, pre-Permian underground sequence. The in some places extremely high conductivity was initially attributed to fluid-filled pores and fractures. However, such an explanation implies the presence of unrealistically large pore spaces for the given depth of the horizon. Analysis of the conductivity of Lower Carboniferous black shales in the Münsterland 1 borehole revealed that the high conductivity could be explained by the presence of highly matured and therefore quasi-metallic conducting organic matter (electronic conduction mechanism).

Petrophysical analysis of black shales in other boreholes also revealed that the high conductivities were not only caused by the organic matter, but also by the cross-linkage of sulphides. This explains why highly conductive layers also occur in areas with a relatively low degree of carbonisation. Because black shales are known to be a potential gas source rock there is great economic interest in being able to confirm their presence.

Against this background, BGR began a new magnetotelluric surveying programme in 1993 which has now measured 226 points. The field surveys are carried out by METRONIX GmbH (Braunschweig) and the Institute for Geophysics at the University of Münster. The institute is also closely involved in the interpretation of this data.

The magnetotelluric surveys show that there are no pre-Permian beds with good conductivity in the NW-SE striking depocentre of the North German Rotliegend basin (south-eastern North Sea, western Mecklenburg-Vorpommern). This is interpreted to indicate the absence of pre-Westphalian gas source rocks in this area. This area is therefore not favourable for further exploration for deep gas.

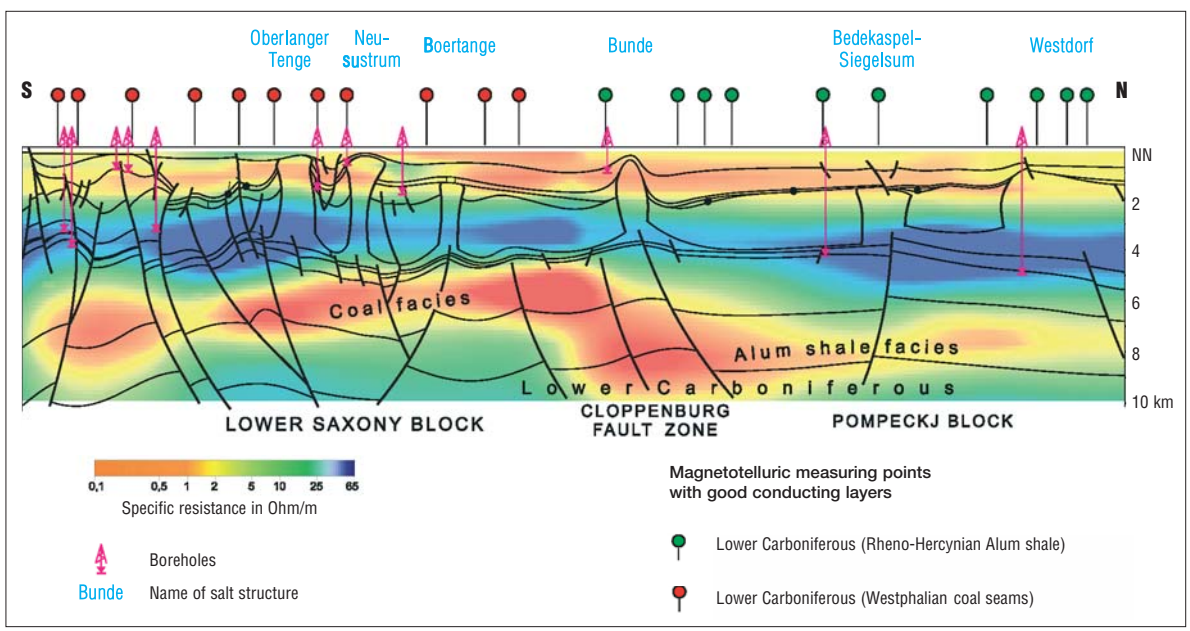
Whilst the good conductive horizons lying to the north of the Central Rotliegend Basin can be correlated with the Cambro-Ordovician black shales (Scandinavian Alum Shale) penetrated by the G14 Baltic Sea borehole, the good conductive beds south of the depocentre can be correlated with the Lower Carboniferous black shales. These organic rich shales explored by the Pröttlin 1, Münsterland 1 and Versmold 1 boreholes are potential gas source rocks depending on the degree of maturity of the organic matter.

The latest MT data of the Glückstadt-Graben area (Schleswig-Holstein) reveal the presence of a good conductive horizon within the graben at a depth of approx. 8.5 – 11.0 km. This possibly indicates the presence of Lower Carboniferous black shales. If this is correct, the graben must already have been tectonically active during the Lower Carboniferous and would therefore be much older than previously thought.

The sources of gases in the Rotliegend gas fields of the Ems estuary were identified by integrating magnetotelluric, paleogeographic, tectonic and isotope-geochemical data. This confirmed for the first time that these are mixed gases comprising highly mature dry gases from marine (sapropelic) organic matter (Rheno-Herzynian Alum Shale facies of Lower Carboniferous age – possibly closely related to the Lower Carboniferous Bowland Shale facies of central England or their equivalents in the southern North Sea) and less mature gases sourced from humic (terrestrial) organic matter (Westphalian coal).

These results support the interpretation of the magnetotelluric data of this area with respect to source rock distribution. The investigations show, that the integration of magnetotelluric data opens up new opportunities for deep gas exploration.

Stratigraphic interpretation of pre-Permian horizons with good electrical conductivity in the Emsland-Ostfriesland area shown in a geological cross-section.



Gas Hydrates and **Free Gas**
– an Example from the Continental Margin of **Northwest Borneo, Malaysia**

Gas hydrates refer to the hard, crystalline-like structures made up of water molecules and natural gases like nitrogen, hydrogen sulphide, carbon dioxide and various hydrocarbons, primarily methane.

In gas hydrates, the water molecules form a crystalline-like lattice with gas molecules trapped in the spaces. Gas hydrates are only formed under special pressure and temperature conditions and in the presence of adequate quantities of gas. These conditions are met in permafrost zones, on the shelves of active and passive continental margins, and in the sediments of deep lakes and seas.

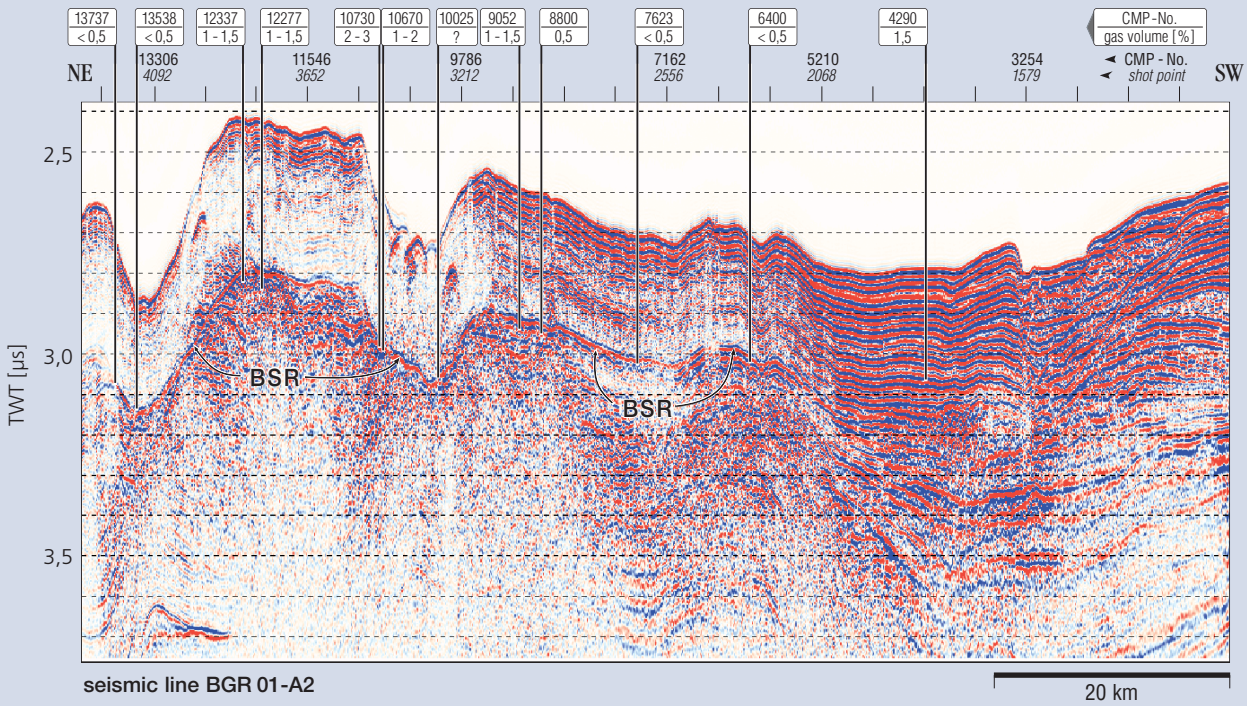
The base of gas hydrate accumulations is often shown in marine reflection seismic lines by the "bottom simulating reflector" (BSR). A BSR shows the base of the gas hydrate stability zone within sediments. This means that the sediments overlying the BSR contain gas hydrates, whilst free gas can be present beneath the BSR. It is called the BSR because it runs almost parallel to the ocean floor. Because the BSR is caused by pressure and temperature conditions, it can also cross sedimentary boundaries and is therefore particularly easily identifiable in reflection seismic lines.

Gas hydrates have gained a great deal of general attention recently because they are seen both as a potential future energy source as well as a geo-risk factor. Gas hydrates represent a geological risk because changes in pressure and temperature conditions could release huge quantities of the greenhouse gas methane and thus intensify the greenhouse effect. In addition, a reduction in cementation of the sediments associated with gas hydrate destabilisation could cause the sliding and slumping of underwater sediments and therefore generate catastrophic tsunamis.

It is therefore important that gas hydrates are investigated in more detail.

Burning ice: gases can combine with water to form gas hydrates under suitable pressure and temperature conditions.

Gas hydrates were recovered from the west coast of North America by the SONNE research ship. Before they decomposed, they formed white lumps in the deep sea mud which could be ignited.



BGR01-A2 seismic line along the continental margin of northwest Borneo: the BSR can be seen lying at around 250 to 300 ms (two-way travel time) beneath the sea floor. The lateral change in the amplitude of the BSR directly reflects the amount of free gas beneath the BSR. The amount of free gas varies between 0.5 to 3 %.

One of the main factors for estimating the value of gas hydrates as a potential future energy source and as a climate factor is an estimate of the amount of methane locked up in the gas hydrates and the underlying sediments.

A method already well known in oil and gas exploration (AVA – angle-of-incidence versus amplitude variations of the seismic signals) which was modified specially for the gas hydrate case, was used to estimate the volume of free gas and applied to the data from the continental margin of northwest Borneo. Of particular interest was whether this technique would reveal the presence of large volumes of methane in this promising hydrocarbon exploration area.

Analysis showed that the gas hydrate zone and the underlying volumes of gas only accounted for a minor percentage of the total sedimentary pore volume. Gas hydrates occupied around five per cent of the sediment volume whilst the amounts of free gas below the gas hydrates ranged between one and four per cent.

How Long will the **Oil Reserves Last**?

A Wrongly Formulated Question for an Obvious Problem

Oil currently accounts for approx. 37 % of global primary energy consumption, and is therefore the main energy source. This natural resource and its manufactured products are primarily used by the transport sector, and secondarily for heating and as a raw material for the chemicals industry. Stimulated by the rapid rise in prices in the crude oil market and their knock-on effect on petrol prices, we are all forced to consider the problem of the availability of oil in future.

When looking at the availability of oil, many experts are guided by the known reserves R and consumption C. These two parameters give rise to the static lifetime L = R/C, which as the name already implies, is a static approach. However, reserves and consumption are always changing and continuously adapting to new conditions.

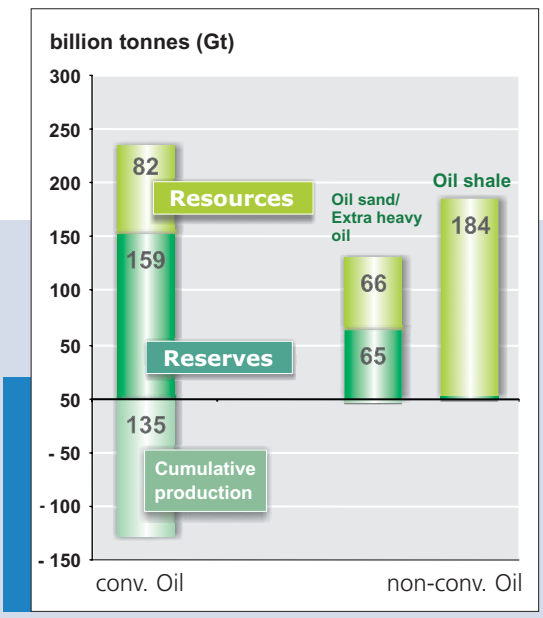
The dynamic processes behind the global demand for oil are easily explained. These include factors such as changes in economic development, trends in motorization and mobility, changes in the retail price of petrol, and indirectly also climatic changes.

But what about the Reserves?

The reserves are defined as the amount of oil economically exploitable using existing technologies – and should not be confused with the term "resources" which refers to the amounts of oil which are not currently economically exploitable or are thought to exist on the basis of geological findings but have not yet been proven. This definition highlights the dynamic character of reserves because technical innovation can take place at any time and make previously unexploitable resources economically producible. Rising oil prices also mean that more resources are reclassified as reserves because the higher price makes them economically exploitable.

How are Reserves Calculated?

It is more honest to talk about reserve estimates because even before the first well is drilled the oil industry experts involved have to use seismic surveys and their own experience to make assumptions on the size of a reservoir, its porosity and permeability, the oil saturation of the pore spaces, the degree of fill of the reservoir, not to mention the recovery factor. Right from the start, the determination of reserves is therefore clearly subject to a certain degree of uncertainty.



Cumulative production, reserves and resources of oil (per end 2003). The non-conventional oil – heavy oil, bitumen and tar sands and oil shale – are dealt with separately.

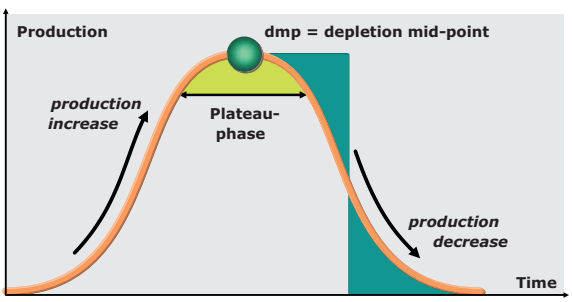
Given the fact that the static lifetime has hardly changed in the last 15 years – remaining stable at an estimated lifetime between 40 to 50 years – it looks as if the oil industry is able at any time to replace the oil consumed each year by additional reserves. Despite this, there is a consensus that more oil has been consumed around the world every year since the 1980s than has been found in new accumulations. The annual growth in reserves reported since then is largely attributable to improved recovery factors thanks to technological innovations or the re-evaluation of known fields.

So the key question is not so much: how long will oil last? But rather: how long will we have adequate quantities of oil at our disposal?

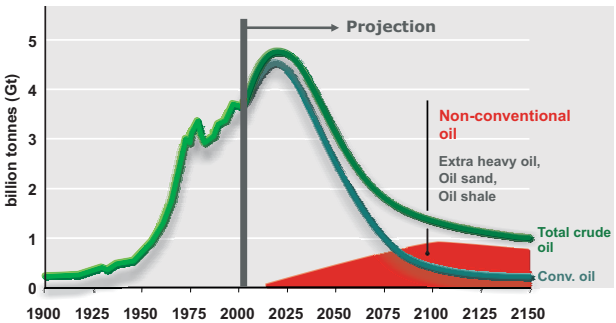
The answer to this question can in principle be shown in a lifecycle curve. This bell curve shows in an ideal way the production and consumption of oil – whether for a single field, all fields within a sedimentary basin, or on a global basis. The area beneath the curve represents the available amount, and the curve itself is the production or consumption profile over time. Ideally, peak production coincides with 50 % resource depletion (the depletion mid-point). Production then continues along an unstoppable declining trend.

Improvements in production methods – also including unconventional oil reserves – and the shifting of resources into reserves can only change the steepness of the curve on the declining side of the bell curve.

One can therefore plausibly assume that once the depletion mid-point has been crossed, it will no longer be possible to balance supply and demand. According to BGR's database, we expect this point to be reached sometime in the next two decades. It is unfortunately not possible to pin down this time more precisely, mainly because of the lack of transparency of the oil potential of the most important OPEC countries around the Arabian Gulf (Saudi Arabia, Iran, Iraq, United Arab Emirates, Kuwait, Qatar). We also question whether it will be possible to cover the projected oil demand of well over 5.5 Gt in 2025 estimated by EIA (2004).



The bell curve used by M. K. Hubbert for the first time in 1956 to depict US oil production.

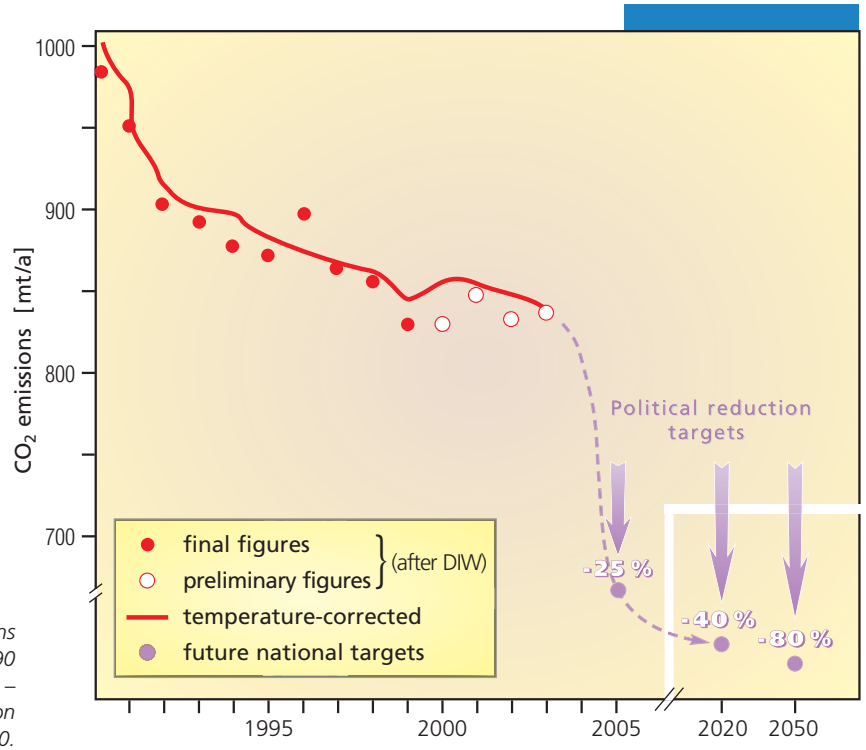


Global oil production between 1900 and 2150: History and an attempted forecast.

Back to the Underground – a Contribution to **Reducing CO_2 Emissions**

As a signatory to the Kyoto Protocol, Germany is obliged by 2008/12 to reduce its greenhouse gas emissions by 21 % with respect to output in 1990. We are confident that this objective will be reached – however, the reduction targets of 25 % for CO_2 (by 2005) and 40 % (2020) and 80 % of all greenhouse gases (2050) are much more ambitious in comparison. The underground storage of CO_2 could be a bridging technology to fill this gap.

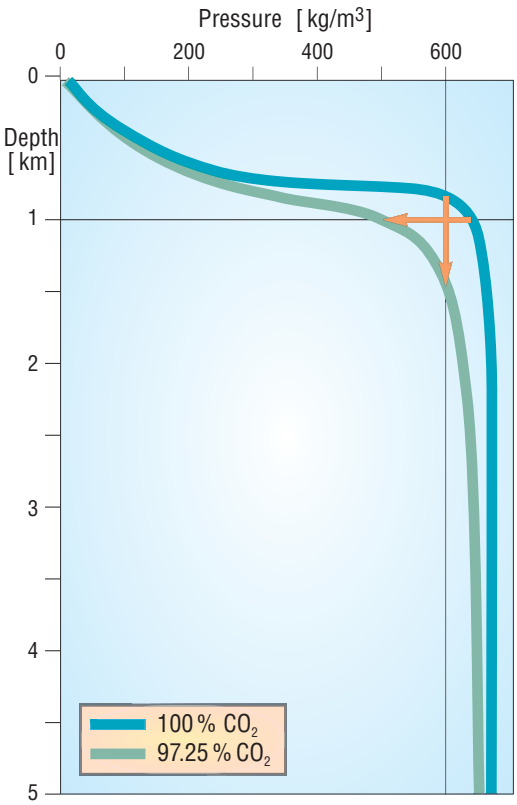
To make a significant contribution to the reduction of CO_2 emissions in this way, it will be necessary to separate the CO_2 from the flue gas at the major point sources (power stations, refineries, steel works) and to compress it for transportation. Only these sites have the potential to separate the large CO_2 volumes per time unit necessary for economic storage.



Reduction in CO_2 emissions achieved in Germany since 1990 (after ZIESING 2004) – and depiction of the reduction targets up to 2050.

The main potential sinks in Germany are depleted gas fields as well as deep, highly saline water-bearing aquifers. Storage in coal seams (with simultaneous coal seam gas production) will probably not be feasible at an economically interesting scale. German oil fields are also usually too small, fractured, or too shallow to be suitable for the storage of CO_2. Virtually the only oil field with the potential for CO_2 storage is the Mittelplatte oil field – but it will only reach the appropriate production stage in around 10 years time. The storage capacity of salt mines is low and should therefore preferentially be used for the disposal of other "wastes". Coal mines have numerous connections to the earth's surface – either natural or created by mining – and are therefore unsuitable for safe storage.

The quarry shown here highlights the typical appearance of the Bunter – a potential aquifer for the sequestration of CO_2.



Density/depth graph of pure CO_2, and CO_2 contaminated with 2.75 % oxygen and argon.

Underground Properties of CO_2

When buried underground, CO_2 can only be in either a liquid or gaseous form. The critical point of carbon dioxide lies at a pressure of 7.38 MPa and a temperature of 31 °C. The changes in density of CO_2 with depth can be calculated using as an example the hydrostatic pressure gradient (10 MPa/km) and a geothermal gradient of 30 °K/km. Under these conditions, CO_2 is gaseous and has a low density at depths shallower than around 600 m. Once the critical point is reached at around 700 to 800 m depth, even minor changes in temperature or pressure can result in strong variations in CO_2 density. Below around 1000 m, however CO_2 is only very slightly compressible – a supercritical fluid whose density only changes very slightly with increasing depth. The changes described, however, are only valid for pure CO_2. As soon as contaminants – e.g. oxygen and argon resulting from "oxyfuel-combustion" – are admixed, the densities tend to be lower.

CO_2 Storage in Gas Fields

Depleted or almost depleted gas fields are highly interesting locations for CO_2 storage because their seals have been proven at a geological time scale – i.e. millions of years. Due to their geological history it can be confirmed that most of the gas fields in North Germany were filled with gas around 80 – 90 million years ago and that this gas has remained in place over this enormous period of time. The production history of the gas fields also provides detailed information on how these reservoirs have emptied during production. This information could also be of enormous value in future if these fields are subsequently used for the storage of CO_2. Moreover, an infrastructure already exists in the form of drilling sites, boreholes and connections to a pipeline network which could be partially used or adapted for the new purpose.

There is also another aspect which boosts the economic efficiency of the subsequent use of gas fields in particular: during conventional gas production, around 75 to 80 % of the reserves in a field are recovered. If it were possible to begin the injection of CO_2 at the right time in an almost depleted gas field, and to thereby increase the recovery factor by displacing the hydrocarbon gas with CO_2, this extra production could cover some of the costs of CO_2 storage.

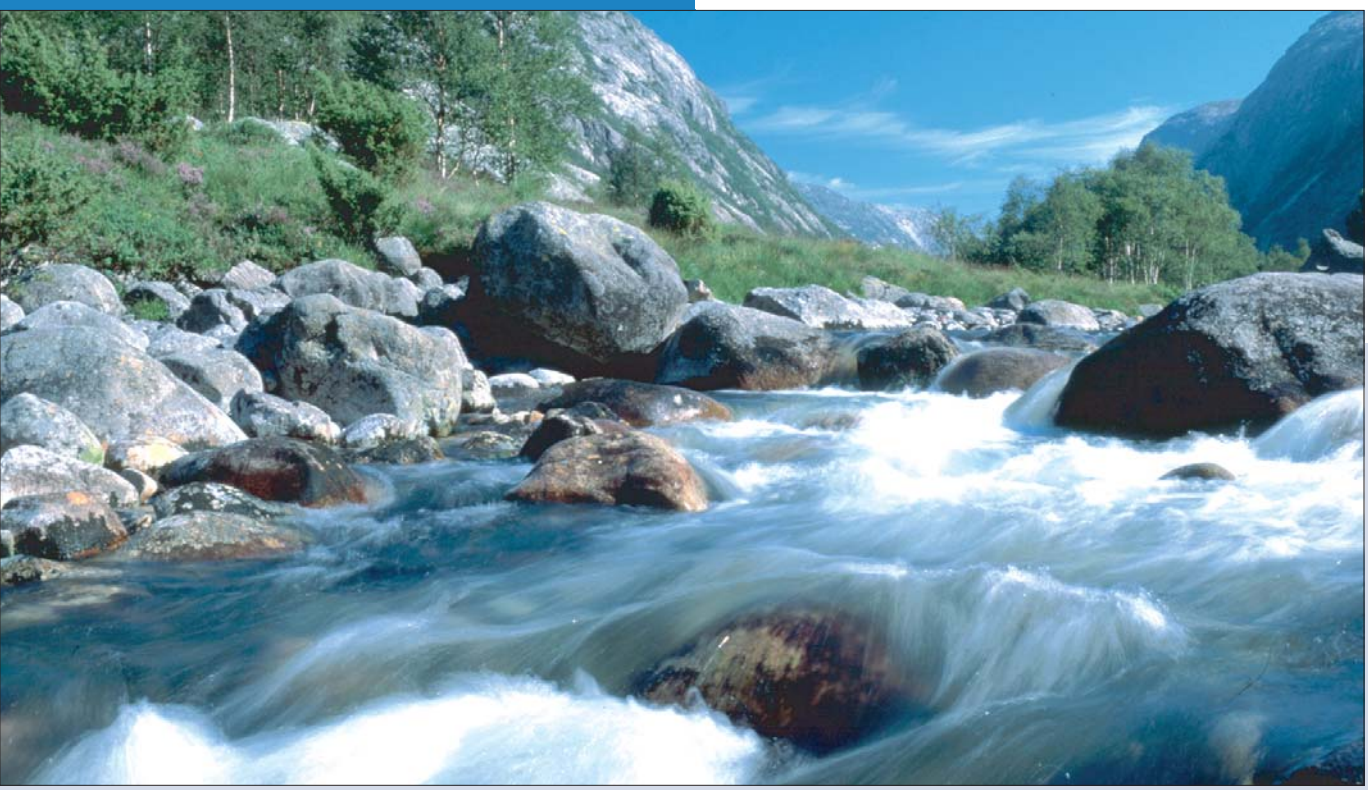
North Germany is the only area in the country where there are gas fields with the economically required storage potential of at least 10 Mt CO_2. The five largest German gas fields – Salzwedel-Peckensen, Hengstlage, Siedenburg-Staffhorst, Goldenstedt-Visbeck, Rotenburg-Taaken – have estimated storage potentials of 572 to 110 Mt. The way injected CO_2 spreads out in a gas field (Salzwedel-Peckensen) was simulated by BGR in co-operation with the Lawrence Berkeley National Laboratory in California using special computer software. Depending on the assumed permeabilities of the reservoirs, simulation revealed that it would take between 3 to 10 years before CO_2 could "break through" into one of the boreholes still used for gas production. This means that the injection of CO_2 in an almost depleted gas field can increase the lifetime of a field at the same time as increasing the recovery factor.

CO_2 Storage in Deep Highly Saline Aquifers

Beneath the required minimum depth of 800 to 1000 m a large number of aquifers filled with highly saline water are present in many geological formations within sedimentary basins. These rock sequences are not considered to have any potential for future drinking water extraction because of the water quality and their great depth. The potential CO_2 storage capacity of these deep highly saline aquifers is considered to be ten times higher than the gas fields.

There are, however, restrictions: information on the lateral extent, thickness, porosity and permeability of the aquifers is based on relatively few boreholes. Not only can rock properties change over short distances, there is also often not enough information available on the geometry of the structural traps and their spill points. Moreover, differences in viscosity between the CO_2 and the formation water, and the heterogeneity of the aquifers can give rise to preferential migration of the injected CO_2 along specific horizons. This fingering of the injection front reduces storage capacity as well as increasing the solubility of CO_2 in the formation water. The spread of CO_2 in the storage horizon can be optimised (flooding efficiency) by appropriate reservoir management – using several injection wells for instance.

Notwithstanding the many unanswered details, CO_2 storage in an aquifer instead of the better explored gas fields has the advantage that it is not necessary to wait until gas production has been completed.



Water

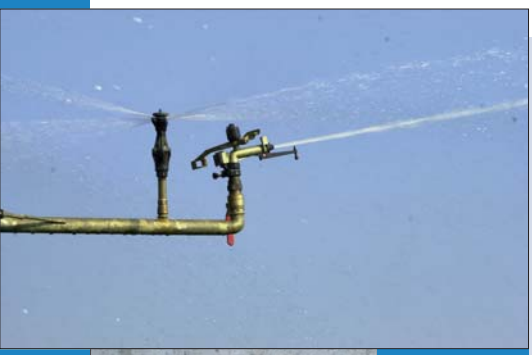
Water – the Most Widespread Natural Resource and Essential for Life

Groundwater is the most widespread and most highly used natural resource. It is also unique, completely irreplaceable and absolutely essential for biological life. People, animals and plants can only survive for a short period without water. It is priceless, particularly in the world's arid zones. The importance of groundwater resources as a safe, high-quality source of water supplies will grow considerably in future. Groundwater can help us solve the global water crisis if it is used sensibly and sustainably.

Groundwater is a basis for sustainable development and is increasingly becoming an important economic commodity. Several international conferences (Dublin 1992, Rio de Janeiro 1992, Bonn 2001, Johannesburg 2002, Kyoto 2003) looked at the need to handle water resources more carefully, and agreed on the principles of sustainable water management.

The United Nations designated 2003 the International Year of Fresh Water because of its concerns about water as a natural resource.

In its liquid form, water is the most important nutrient for humans as well as a fundamental requirement for hygiene and health, not to mention being a source of energy and a production factor in agriculture, industry and mining. Its value as the most important component in the environment requiring protection is particularly highlighted when it is not available in adequate quantities or quality. Groundwater forms the hidden underground part of the natural water cycle which mainly comprises precipitation, evaporation, percolation and drainage at or below the ground surface. Groundwater forms continuous water bodies above impermeable layers and follows the pull of gravity. It is formed by precipitation entering the ground (underground drainage, percolation water) and flows into surface waters or forms springs at the earth's surface.



The height of the groundwater surface (the water table) is subject to natural fluctuations depending on the level of precipitation and the river conditions (e.g. high water). Groundwater is perfect for drinking water. It is normally completely hygienic, tasteless, fresh, clear and cool. Undisturbed natural groundwater contains no pathogenic germs or toxins, and is therefore preferentially used for the supply of drinking water.

Water was considered to be an inexhaustible natural resource until only a few years ago.

The earth contains an excess amount of water because over 70 per cent of the earth's surface is covered with water. However, most of this is salty and only 2.5 % of global water resources consist of fresh water – corresponding to around 35 million cubic kilometres or 700 thousand times the volume of Lake Constance in southern Germany. The amount of available fresh water shrinks considerably because around 69 per cent consists of ice and snow lying mainly in the Antarctic and Greenland. The reserves of fresh water are mainly stored as ice and snow and in groundwater. Only around three thousandths are in surface water in rivers and lakes. This is the fraction which is largely regenerated and strongly exploited during the course of a year.

Although there are adequate quantities of water on the planet overall, it is spread irregularly amongst the various climatic zones.

Plants and animals in natural communities are adapted to the local living conditions so that problems only occur during unusually wet or dry periods. Water shortages only arise because of the needs of humans. The wide-ranging anthropogenic exploitation of the environment inevitably leads to the contamination of valuable water resources which can only be reduced, prevented or cured by technical means. Population and economic growth increase the demand for water, e.g. as drinking water or water for irrigation. At the same time, globally available water resources are shrinking as a result of overexploitation or contamination. Moreover, population growth in those parts of the world already suffering from water shortages also gives rise to distribution conflicts.

However, such problems and conflicts can be identified and ameliorated by concepts aimed at achieving the sustainable use of the available water. The gap between supply and demand is growing continually. Real shortages arise in countries which depend on renewable resources within their own small national boundaries, e.g. Singapore or Malta. The degree of water exploitation in these countries is very high because of the minor amount of water available and the high demand. This corresponds to major spending on water management measures for storage, purification and recycling. Some of these countries can use alternative resources: cross-border river water such as in Egypt (Nile) or stored groundwater in the case of Libya. The countries around the Arabian Gulf with very limited fresh water resources but cheap sources of energy can generate large volumes of good quality water in seawater desalination plants. In general, the levels of drinking water supplies do not so much affect the amount of locally available water but rather the degree of economic development and the financial strength of the countries. The discussions on future water shortages – and especially the supply of drinking water – are therefore distorted by the

mistaken view that there is a strong dependency between the population of a country and its water resources. The truth is that inadequate supplies of healthy drinking water are frequently not so much caused by a shortage of water resources, but by a lack of financial resources, i.e. poverty.

Distribution of global fresh water resources after UNESCO 2003.

Global Fresh Water Resources	
Water in form of	Proportion [%]
ice and snow	68.7
fresh groundwater	30.1
permafrost	0.86
lakes	0.26
wetlands	0.03
rivers	0.006

To protect and maintain valuable groundwater resources, they first need to be explored, evaluated, assessed and continuously monitored. The aim is to ensure that groundwater is not contaminated in the first place, and to protect the resources to preserve their natural state in the long term. Preventative groundwater protection is therefore an important responsibility for the water industry. The EU Water Framework Directive which came into force in 2000 extends water protection to all waters within Europe and defines clear targets to ensure that all European waters can be classified as being of "good water quality" by 2015. The overall aim is to guarantee sustainable water usage.

Anyone who has seen the large catchment areas of rivers such as the Danube and the Rhine knows that water does not stop at national borders. This is why water is best managed within the framework of international co-operation. Implementation of the Water Framework Directive is unique. It involves the participation of all affected parties. It offers the European Commission, member countries, EU applicant countries, and other interested parties the unprecedented opportunity of forming a new partnership to steer the process and guarantee effective and coherent implementation.

The global supply of renewable water is estimated to average around 43,000 cubic kilometres per year.

This corresponds to half of the fresh water contained in all natural lakes, or ten times the volume of all artificial reservoirs. This means that every person on earth has an average of over 7000 cubic metres of renewable water at their disposal. However, there are still water shortages in many regions around the world. Global water extraction by different sectors can be classified as follows: agriculture 70 per cent, industry 20 per cent, households 10 per cent. These proportions vary from region to region and according to the degree of economic development: industrial water consumption dominates in Europe and North America, while irrigation accounts for the main proportion of water resources used in Asia and Africa.

Agriculture is the largest consumer of water worldwide, followed by industry and households. Whilst considerable efforts have already been made to reduce the water consumption of the latter sectors, there is still a great deal that can be done to achieve the potential water savings possible by agricultural irrigation technologies. There is particular concern about the increasing use of barely renewable groundwater for the irrigation of marginal locations in arid zones. The proportion of groundwater used for irrigation in many semi-arid and arid regions has already risen to 30 per cent today, and the trend is upwards.

Many of these groundwater resources include (fossil) reserves of groundwater formed thousands of years ago. Deep groundwater basins within some of the world's arid regions locally contain huge reserves of groundwater with excellent drinking water quality. However, there is virtually no renewal today. Once it has been extracted, mankind loses it forever.

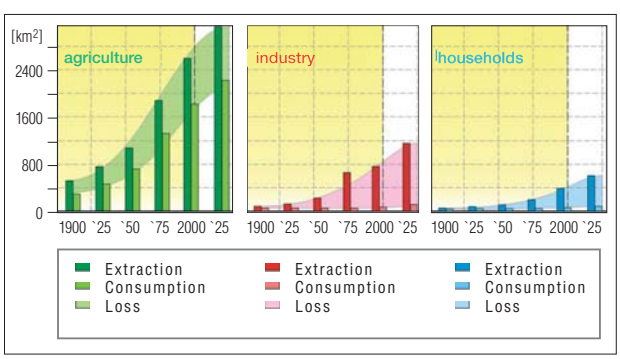
The current use of water exacerbates the water shortage situation in many of the world's arid regions.

Unlike Germany, where daily water consumption per capita has shrunk from 130 litres per day to less than 120 litres per day in the last ten years, water consumption in the USA and many countries around the Arabian Gulf has doubled or quadrupled. Numerous countries with poor water resources subsidise the supply of water. The exploitation of valuable fossil groundwater reserves for the uneconomic production of food in arid regions should be reduced as a matter of urgency. A partial solution to this problem is the recycling of treated waste water.

The demand for water in the Federal Republic of Germany is covered by the extraction of "real" and "enriched" groundwater from wells and springs, as well as water from rivers and man-made reservoirs. The water production and supply equipment and infrastructure are owned by public water works as well as industry and agriculture. In addition to extracting their own water, many industrial operations cover the whole or some of their needs by purchasing water from the public water supply. The reserves of groundwater are generally larger than the volumes of surface water stored in lakes and artificial reservoirs. This is why groundwater reserves are not seriously affected by short droughts. Given the numerous and increasing demands for water, it is essential that adequate and effective legislation is in place to safeguard water resources for future generations.

The importance of water for life as a whole and as an element in the global ecosystem is becoming increasingly apparent. It is a resource which not only satisfies humankind's basic needs, and forms the vital platform for its development – in particular to create and maintain prosperity through agriculture, commercial fishing, power generation, industry, transport and tourism – it is also much more significantly the most vital element in all the world's ecosystems.

Global classification of water consumption by agriculture, industry and households.



Nitrate in **Groundwater** in Southern **Africa** – a Problem for Drinking Water Supplies

The supply of drinking water is affected by the problem of raised nitrate concentrations in groundwater reserves in the Kalahari in Botswana, South Africa and Namibia.

Drinking water with high levels of nitrate increase the risk of "blue baby" syndrome (medically termed: "methemoglobinemia") which can be deadly, particularly for babies and small children who take in the nitrate in baby food. The international limit for nitrate in drinking water is therefore only 50 mg nitrate per litre.

This problem also affects cattle farming which is an important sector of the economy in this region: high nitrate concentrations have frequently led to the death of animals.

Potential sources of nitrate in the Kalahari:

- precipitation
- vegetation
- wild animals, ground dwelling animals
- cattle farming
- soil processes
- nitrate salts in rock
- groundwater rising up from deeper horizons

Unlike intensively farmed areas where raised nitrate concentrations in groundwater are fairly common, one would not tend to expect an area like the virtually uninhabited Kalahari to have a nitrate problem. The causes for the high nitrate concentrations in the groundwater of the Kalahari are so far largely unexplained. Scientists in South Africa, Namibia and Botswana are therefore working together with BGR in a research co-operation project to discover the cause of the nitrate contamination problem in the Kalahari.

BGR's contribution here involves research projects in Botswana carried out in co-operation with the Geological Survey of Botswana (DGS). The aim is to identify the nitrate sources in the Ntane Sandstone aquifer in Botswana with its deep water table and to investigate the processes giving rise to nitrate enrichment in the soil zone or underlying rocks and the transport of nitrate into the groundwater.

Much higher nitrate concentrations are found in soil water beneath natural vegetation and termite hills.

The investigation looks at aspects including the deposition of nitrate associated with precipitation, the nitrate concentrations in soils under natural conditions and in the vicinity of livestock ponds. These investigations revealed that concentrations of 50 – 500 mg nitrate per litre are possible in soil water beneath natural vegetation. Very high nitrate concentrations of over 1000 mg nitrate per litre were found beneath termite hills and particularly in the vicinity of livestock ponds. Unlike the nitrate deposited by termite hills,

which are of natural origin and typical for the Kalahari, the deposition of nitrate arising from cattle breeding is of anthropogenic origin and has only existed for about fifty years.

High nitrate concentrations in soils around livestock ponds are a groundwater hazard.

In addition to the soil zone, groundwater is also subject to intensive research within the Kalahari in Botswana. Alarmingly high nitrate concentrations within the groundwater in some cases were already revealed by initial analysis of water samples carried out on site and by the subsequent precise analysis in BGR laboratories in Hannover. Extreme variations in nitrate concentrations were not only shown from borehole to borehole, but also vertically within the boreholes themselves. Because the groundwater is stored within a highly cemented sandstone, it is only possible for significant water movement to take place along major fractures and faults within this rock. Detailed field studies revealed that the heterogeneous distribution of the nitrate is determined by the complexity of these fractures and faults, as well as the nitrate sources and hydrochemical processes within the aquifer.

Groundwater samples from the Ntane Sandstone below the Kalahari revealed very high nitrate concentrations in part.

Analysis of the noble gases and isotopes in the groundwater samples revealed that the nitrate could only have entered the groundwater from natural sources. Evaluation of the radioactive carbon isotope showed that the groundwater with high nitrate concentrations not only differs chemically from groundwater with low concentrations of nitrate, but also that they are only 1000 to 5000 years old and therefore "relatively young". Waters with generally low nitrate concentrations have a different chemical composition and are up to 15 000 years old. In addition, the noble gas analysis revealed that these waters were formed under completely different infiltration conditions and therefore also climatic conditions. A comparison of the age determined for the groundwater and the calculated age of the soil water clearly demonstrates that only nitrate from natural sources has so far entered the groundwater. The nitrate in the vicinity of livestock ponds is obviously still moving in the direction of the groundwater and will only cause considerable additional contamination of the groundwater at some time in the future.

Hydrogeological Base Map (HÜK 200)
– a Foundation for the Implementation of the European Water Framework Directive

Standard nationwide hydrogeological maps and land use data are required to implement the EU Water Framework Directive which came into force in December 2000.

The EU Water Framework Directive sets up water management for the first time based on the natural catchment areas of major river systems. Implementing the directive therefore completely transcends national boundaries – which therefore lose their significance in this context. This makes it clear that the previous practice in Germany of allowing each German state to separately collect hydrogeological data within their own borders, largely without any co-ordination between states, is now no longer adequate for the realisation of the new tasks. It therefore became essential to produce base maps of the hydrogeological conditions in the whole of Germany (and beyond) tailored to the needs of the European Water Framework Directive.

The state Geological Surveys reacted early on to this new situation and launched the production of the digital Hydrogeological Base Map of Germany. The hydrogeological base map (HÜK 200) was developed and implemented as a GIS-based information system according to the concept put forward by the state Geological Surveys.

The hydrogeological mapping instructions of the state Geological Surveys defined hydrogeological mapping as follows: "Hydrogeological base maps are synoptic presentations of hydrogeological information in generalised form. They compile information on an area and reveal large-scale relationships." This principle also applies in full to the "Upper Aquifer Map" of HÜK 200 which has been worked on since 2001. Three years after beginning work on the Hydrogeological Base Map of Germany 1 : 200,000 (HÜK 200), the last sheets of the Upper Aquifer Map for the whole of the Federal Republic of Germany were finished at the end of 2003. The 55 sheets of this map display the hydrogeological situation in Germany for the first time according to standard criteria. Although base maps at comparable scales (1 : 100,000 to 1 : 500,000) have already been published for some German states in recent years, the only recent cross-border maps currently available are the Berlin and Bern sheets of the International Hydrogeological Map of Europe 1 : 1,500,000 which describe the whole of the Federal Republic of Germany in a standardised methodical way.

The HÜK 200 maps are a joint project involving the Geological Surveys of the German states and the Federal Institute for Geosciences and Natural Resources (BGR).

The overall concept for the Hydrogeological Base Map (HÜK 200) reflects modular implementation in three thematic groups with subordinate specific themes and the following general classification:

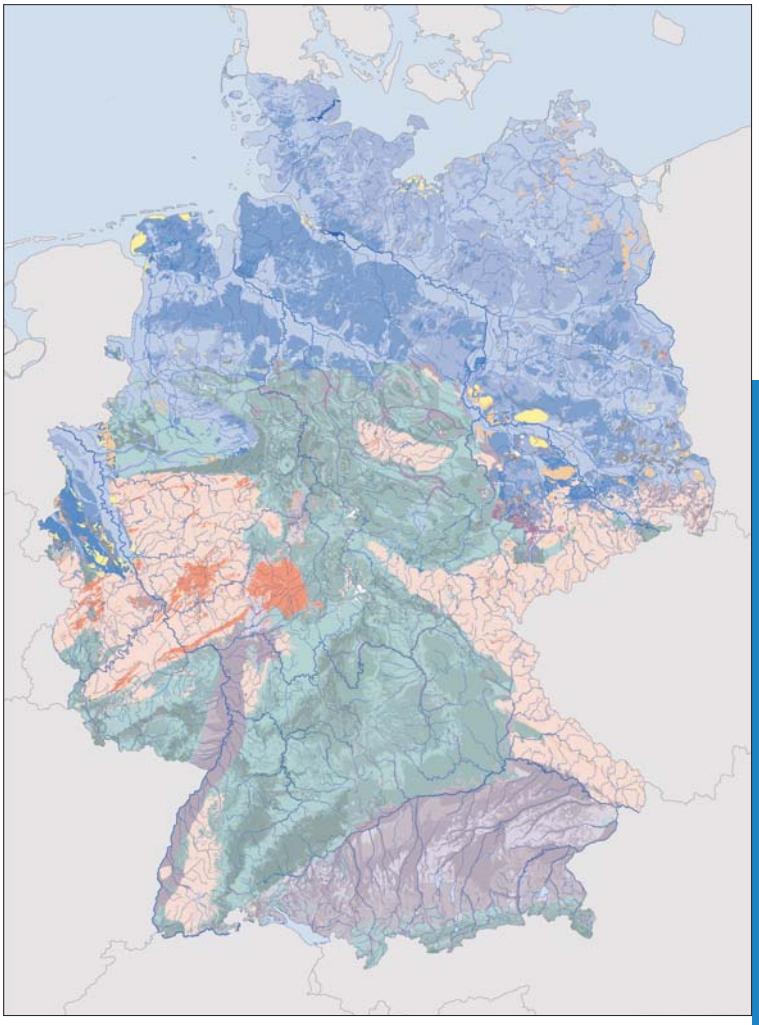
- Part 1 Hydrogeological structures:
  These maps show the areal extent and relationships between relevant hydrostratigraphic units. Interpreted rock properties are used to delimit hydrogeological structures and document their thickness, structure and distribution.

- Part 2 Groundwater dynamics:
  The "Groundwater dynamics" maps show the main hydraulic relationships and water regime conditions.

- Part 3 Groundwater attributes:
  These maps primarily show the various separate hydrochemical parameters.

The state Geological Surveys were responsible for preparing the hydrogeological maps, whilst BGR managed project co-ordination and financing.

Most of the map sheets span two or more German states. Intense co-operation was required between the state Geological Surveys involved in a particular sheet to ensure that there were no inconsistencies at the boundaries between the states and the sheets. All of the work carried out on HÜK 200 was carried out with the technical support of the "EU Water Framework Directive Sub-Working Group", the ad-hoc hydrogeological working group of the Federal/State Geological Committee.



The first thematic map "Upper Aquifers" from HÜK 200 Part 1 "Hydrogeological Structures" was based on data from the 1 : 200,000 Geological Base Map of Germany (GÜK 200) which was only partially available in digital form when work began on the Hydrogeological Base Map. This was integrated step-by-step into the 55 sheets of the 1 : 200,000 Topographic Base Map (TK 200).

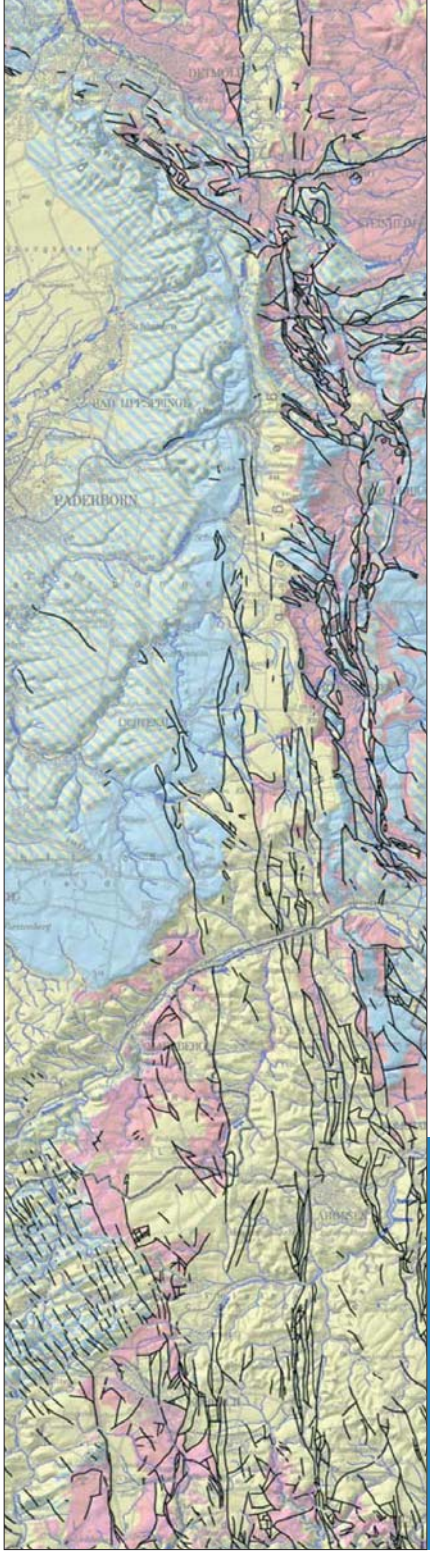
The Geological Base Map (GÜK 200) was however digitally finished before the work on HÜK 200 itself had been completed.

The hydrogeological information presented in the Upper Aquifers Map refers to the areally significant continuous aquifers of relevance to water resources management. The hydrogeological attributes were worked out on the basis of the petrographic, lithological, genetic and stratigraphic details of the Geological Base Map (GÜK 200). The classified attributes were: "consolidation", "rock type", "porosity type", "geochemical rock type" and "permeability" together with the associated class information. All of these attributes are shown in separate maps.

An aggregated map covering the "Upper Aquifers" compiles and displays the separate pieces of hydrogeological information extracted by reattribution. This map is primarily classified according to hydraulic permeability within the major hydrogeological structures in the unconsolidated sediment and consolidated sediment zones – here again divided up into cover rock and basement.

The figure shows a smaller scale base map (scale approx. 1 : 7 million) of the Upper Aquifers Map for Germany – compiled from 55 separate sheets. Similar small scale base maps are available for all of the aforementioned thematic maps.

The areal information displayed in this way in each of the thematic maps can also be used to prepare other hydrogeologically informative map combinations, e.g. geochemical rock type and porosity type, or porosity type and permeability.



Diminished section of the Thematic Map "Geochemical rock type".

All of the HÜK 200 data is integrated within the BGR's technical information system which makes it available to all of the staff from the state Geological Surveys involved in the project. This simplifies the exchange of data during elaboration and production of the maps. The data is also archived in a MAPSERVER for easy access to individual maps. Subsequent use of the project data as part of the Federal Institute for Geosciences and Natural Resources website is also planned.

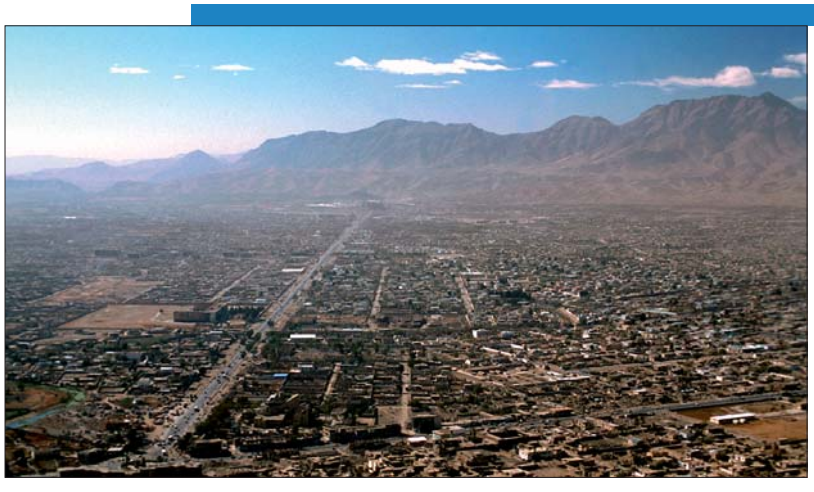
The comprehensive database can now be used to support the reporting obligations laid down within the European Water Framework Directive as part of the "Inventorisation". In addition, the data is also suitable for a broad spectrum of uses by the water industry, waste industry, for soil protection and nature protection, as well as for planning activities. They are also available in digital form to interested parties.

In addition to the existing maps, work is currently being carried out on the preparation of 40 hydrogeological cross-sections covering the whole of the Federal Republic of Germany in accordance with the cross-section map agreed by the state Geological Surveys. More detailed work is now also being planned covering "Groundwater dynamics" and "Groundwater attributes".

Improving **Groundwater Protection** in the **Kabul Basin**, Afghanistan

Almost three years after the end of over 20 years of aggression, Afghanistan is still in the reconstruction phase. In addition to the political and social reorganisation of Afghan society which has been initiated and is showing the first signs of success, further development is still being seriously hampered by the drought and its associated effects. As a result of the five-year-long drought, surface water, e.g. the Kabul river, only flows a few weeks during the year (see figure above). The shortage of water has already led to cuts in agricultural production because not enough surface water is available for traditional crop irrigation. In addition, many of the traditional irrigation systems have fallen into disrepair and are no longer usable.

A large number of refugees moved into the Kabul area during the war, and especially when the war ended. The population of Kabul has grown from only around 800,000 inhabitants 20 years ago to around three million today. Because of this huge increase in numbers, the built-up area now stretches in some places as far as the slopes of the mountains surrounding the city which are covered in snow in the winter (see figure below). These mountains are vital for the city's water supply. As the old Kabul saying goes: "... Kabul can do without gold, but not without snow on the mountains...". This applies just as much today as it did then because groundwater regeneration relies almost exclusively on the short season when the rivers are in flow, and this only comes about in spring if there are adequate quantities of melting snow.



Kabul has a long-term annual precipitation average of less than 300 mm. These extreme climatic conditions have meant that groundwater has been exploited for hundreds of years to supply the inhabitants with drinking water. Whilst this previously only involved extracting water from hand-dug wells, water today is pumped up from thousands of small hand-pumped wells located on every corner in the city. This overexploitation of the groundwater reserves has unfortunately lowered the water table to such a degree that one third of these shallow wells have already run dry. Although Kabul had a public water supply network before the war – which was almost completely destroyed during the fighting and is now being reconstructed at huge expense – the immense investment in the public drinking water network will not be able to supply more than 35 % of the city's inhabitants with clean drinking water in the foreseeable future (up from the current level of approx. 15 %).

In addition to the general water shortage, increasing groundwater contamination also threatens the supply of drinking water. Sanitation in the city is catastrophic – most of the sewage percolates into the ground untreated from countless ditches, not to mention thousands of utterly basic cess pits, and filthy ponds. It then enters the shallow groundwater. Because there is no systematic sewage disposal system in the city, over 50 % of the shallow hand-pumped wells are already contaminated with faecal bacteria. The catastrophic state of the sanitation is undoubtedly one of the reasons for the high level of child mortality in Afghanistan. According to the United Nations High Commission for Refugees (UNHCR) and the United Nations Children's Fund (UNICEF), 148 new born babies per thousand die before they are one year old. Diarrhoea infections caught from contaminated water account for approx. 70 % of these deaths.

Typical wells with hand pumps in the urban part of Kabul. Some of the groundwater in the urban area of Kabul is of very poor quality.

Our Afghan colleagues collecting data on the chemistry and hygiene of groundwater in the urban area of Kabul.

Groundwater levels are now very low because of the lengthy drought and overexploitation of the groundwater reserves. And if the water table rose again under more favourable climatic conditions, there is a risk of a hydraulic short-circuit between the groundwater and the percolating waste from the countless sewage pits and broken sewage pipes. The main water supply problem is therefore not only the limited availability of groundwater, but also the serious deterioration in water quality.

At the request of the Working Group for Humanitarian Aid of the Foreign Office in Berlin, BGR experts have therefore begun to make an initial assessment of the state of the groundwater reserves and to implement measures to protect these valuable groundwater resources for drinking water supplies within the Kabul Basin. There is an old maxim which still applies to all the work carried out by experts in the water sector: every type of preventative measure is much more beneficial and cheaper than any type of remedial measure. To put this into effect, investigations are being carried out jointly with our Afghan colleagues to determine the attributes of the shallow and deep groundwater. The results so far emphatically confirm that numerous wells have much higher concentrations of nitrate and sulphate compared to measurements carried out at the end of the 1960s. The electrical conductivity of the water has also risen strongly, indicating a marked increase in the concentration of dissolved chemicals and salt within the water. The values recorded in many wells exceed by several times the limits laid down in the German Drinking Water Directive.

Groundwater protection in practice can only be initiated if local staff are first trained in how to collect basic water management and drinking water hygiene data. Our Afghan partners are therefore being taught how to measure the most important water management and drinking water hygiene parameters of the Kabul Basin groundwater. Without these training measures it would not be possible for our Afghan partners to provide the hydrological and hydrogeological planning data required such as maps, databases and geoinformation systems (GIS). The sustainable management of groundwater resources is only possible with a proper information base.

The BGR experts are therefore teaching our Afghan partners the skills needed to tackle the challenging tasks of water framework planning themselves in the near future, and to monitor groundwater attributes and groundwater hygiene.

Well construction in Afghanistan – a training measure in applied hydrogeology at BGR Hannover.

Geotechnical Safety / Permanent Disposal

Geotechnical Safety
– Who is Responsible?

Reliable supplies of electric power have become an unquestioned part of our daily lives. Very few of us ever ask ourselves whether the food we put in the fridge has always been kept cold, whether the lift will stop in the shaft, or the underground train will come to a stand-still in the darkness, or what farmers would do if there was no power to run their milking machines. Our experience teaches us that we will always have enough power at our disposal to switch on equipment and processes that we take completely for granted at home, at work, in industry, in hospitals, and all sorts of means of transport. And experience has also shown us that societies which depend on technology can be faced with enormous costs if power supplies are suddenly cut: the damage caused by the power cut in North America in August 2003 totalled several billion US dollars.

Everyone knows that electricity does not come out of the socket by magic. Nevertheless, we rarely spend much time thinking about the amount of effort and expense involved in guaranteeing the extremely high reliability of electricity supplies we depend on so much. To ensure that we can make adequate volumes of power available at any time independent of the weather, we have to operate power stations running on fossil fuel or nuclear fuel. It is not possible using present day technology to supply all of the power we need from renewable energy sources. The generation of exhaust gas and waste is therefore unavoidable if we are to have a reliable system for the supply of electricity. The generation of 1000 kilowatt hours of electric power produces around 1000 kg CO_2 in a coal power station or 3 g spent nuclear fuel in a nuclear power station.

BGR actively tackles the geoscientific challenges faced by the state in the context of energy supplies by working on projects involving the use of geothermal energy (see special topic Geothermal energy), CO_2 reduction (see special topic Climate), and the permanent disposal of radioactive waste.

The figures show the Mont Terri underground laboratory in Switzerland.

Dealing with these gaseous effluents and waste in a responsible way goes without saying for an industrial country like Germany, which has a sustainable development strategy. Sustainability in terms of today's supply of electricity specifically means that we reduce as far as possible the emissions of climate-relevant gases, and that we safely dispose of the radioactive waste generated in nuclear power stations.

This means that the state faces very specific practical challenges: it has to proactively further develop the state-of-the-art on a scientific and technical level when the driving force is sustainability rather than the market. And when these activities involve geoscientific issues, the challenge is passed on to the German government's key institution for handling geoscientific matters: the Federal Institute for Geosciences and Natural Resources (BGR).

Disposal of **Radioactive Waste**

There is an obvious close connection between the permanent disposal of radioactive waste and the geosciences: various disposal options like burial in subduction zones or storage in Arctic ice are investigated scientifically in an objective way – and there is international agreement that the high levels of safety required can only be guaranteed by disposing of radioactive waste in deep underground repositories within geological formations. Even before carrying out in-depth geological analysis of a specific repository site, the geosciences play an important role here in the classification of the site-independent properties of different host rock types (types of rocks in which repositories can be built). This information helps the design of a repository to be specifically adapted in an optimal way to the individual interactions between host rock and waste. This improves the ability to forecast future developments and increase the security of the repository.

Potential host rocks in Germany include salt rocks and claystones. BGR has accumulated a great deal of expertise on both of these host rock types in recent years by carrying out research work in various international rock laboratories.

Host Rock: Salt

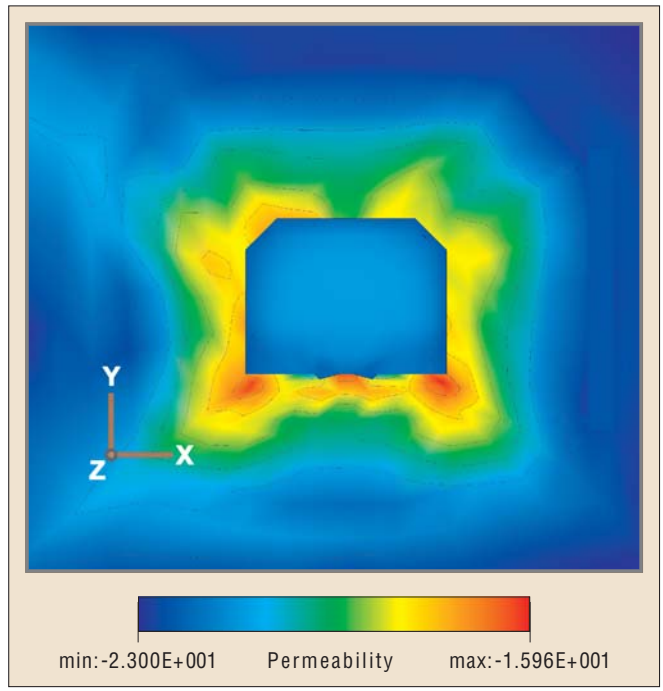
For example, the "Bambus" project (Backfill and Material Behaviour in Underground Salt Repositories). This project investigated the disposal of heat-generating waste within salt host rocks, and tested the effects of thermal stress. This involved the "permanent disposal" of several repository containers in underground workings specially excavated for this purpose in the Asse research mine in Germany. The experiment was carried out at a depth of 800 m to mirror the conditions in a repository. The only difference was in the type of waste: instead of highly radioactive waste, the repository containers contained electric heating elements.

Exhumation of a stress monitoring station cemented into the salt for more than ten years.

The processes taking place in a salt repository after waste emplacement were observed over a nine-year-long heating phase. Permeability measurements to determine the permeability of the backfill and the rock, as well as comprehensive geomechanical and geophysical surveys – in particular the long-term stress measurements carried out by BGR using borehole monitoring stations – enabled the development and spatial distribution of disturbed zones around the repository tunnels to be determined. At the end of a cooling phase, two of the repository containers were then "exhumed" to directly examine their condition. This was accompanied by the collection of numerous samples from the surrounding rock and the backfill – i.e. the now compacted crushed salt used to fill in the cavity between the containers and the rock. The aim of this investigation was to compare the physical properties of the samples with the parameters derived from predictive calculations.

Comparisons of this kind are invaluable for the analysis of long-term repository safety because when making forecasts for periods of 100,000 years and more, even the slightest change in rock properties can have enormous consequences on the result. It is therefore important to confirm that the material laws used to describe the material behaviour in the forecasting calculations also provide the right results over long periods of time far exceeding the short time periods involved when carrying out experiments at a laboratory scale.

Salt rocks behave plastically. Cavities in salt close over the course of time, because salt creeps into the cavities – in the same way as sealing wax. This creep process is dependent on the heat generated by the waste. On the other hand, the temperature distribution also depends on the compaction of the backfill and therefore on the deformation of the rock. The mechanical and thermal processes have to be calculated as a couple to properly predict the mutually interactive effect. BGR specially developed a material law for the salt rock and the backfill material. This material law also makes allowance for a special type of salt deformation – dilatance – which gives rise to migration paths in impermeable salt rocks. In a first step, BGR used two-dimensional models for the computer-aided simulation of the thermo-mechanical reaction of the rock and the backfilled test tunnels to the input of heat. The parameters calculated in this way show considerable deviations in some cases from the reactions of the rock observed in situ. A new program based on the finite element method was developed during the course of the research. This made it possible to conduct three-dimensional, completely coupled thermo-mechanical model calculations of the experiment. The results of these calculations (temperature, stress, rock deformation, tunnel convergence, dilatant rock zones, permeability of the backfill and the rock) correspond very closely to the results of the in situ investigations. A suitable instrument is thus available for forecasting the thermo-mechanical reaction and integrity of the rock barrier in a repository.



Calculated permeability distribution (logarithmic) of an emplacement drift in the "Bambus" project.

The "Bambus" project was successfully completed in the last two years with the aforementioned follow-up calculations.

Host Rock: Clay

In the past two years, BGR has also continued its research into the mutually interactive processes taking place in clay host rocks. The BGR took part in this context in a heating experiment in claystone (Opalinus Clay) carried out at the Mont Terri underground laboratory in Switzerland. In addition to thermal and mechanical processes, the barrier effect of clay is also influenced by hydraulic processes because clay swells up and becomes increasingly impermeable when it comes into contact with water. A heating element simulates highly radioactive waste in the heating experiment. The cavity between the waste and the Opalinus Clay host rock is filled in with bentonite bricks consisting of clay with specially strong swelling properties. The heating experiment lasted eighteen months and entered its final phase at the end of 2004. The thermal-hydraulic-mechanical coupled calculation results have so far corresponded well with the test observations.

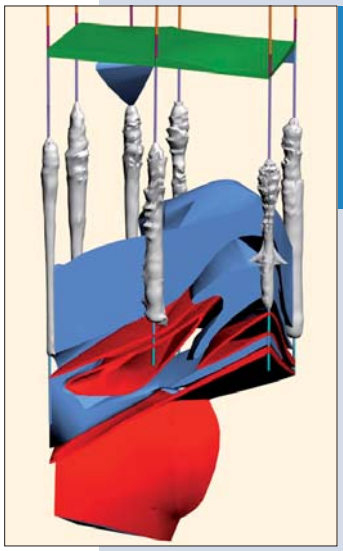
The cooperation with the French organisation responsible for the final disposal of radioactive waste "ANDRA" (**A**gence **N**ationale pour la Gestion des **D**échets **RA**dioactifs) has been continued successfully. ANDRA is investigating the suitability of a clay formation near the village of Bure in eastern France. For this purpose, two shafts are being sunk for the construction of an underground laboratory. The shafts are being sunk as quickly as possible. Therefore, the tests in this phase have to be carried out under extreme time pressure. BGR is the only partner from a foreign country conducting geotechnical measurements during the shaft sinking process. With these measurements, we are directly involved in the site investigation of a pilot clay repository.

Underground Caverns

Geotechnical safety is not only important for the permanent disposal of radioactive waste, it is also a significant aspect in all underground applications which could have a potential impact on the surface. This applies to the construction of caverns in salt domes for the storage of gas or for the extraction of salt by solution mining. The stability of these large underground caverns is crucially dependent on having a cavity with a favourable shape. Constructing caverns with a favourable shape can be controlled during the solution mining process – i.e. during the underground dissolution of the salt by pumping in fresh water and pumping out salty water.

The solution mining process can only be properly controlled in a specific way if information is available on the sequence of different salt types within the salt deposit, because salts have different degrees of solubility. The salt layers in northern Germany which were originally laid down in horizontal beds by the evaporation of the Zechstein Sea around 250 million years ago, were subsequently squeezed up to form salt domes – resulting in very intense folding. Computer programs are used to map the three-dimensional structure of such complexly folded features, and need to be customised for the special needs of salt geology.

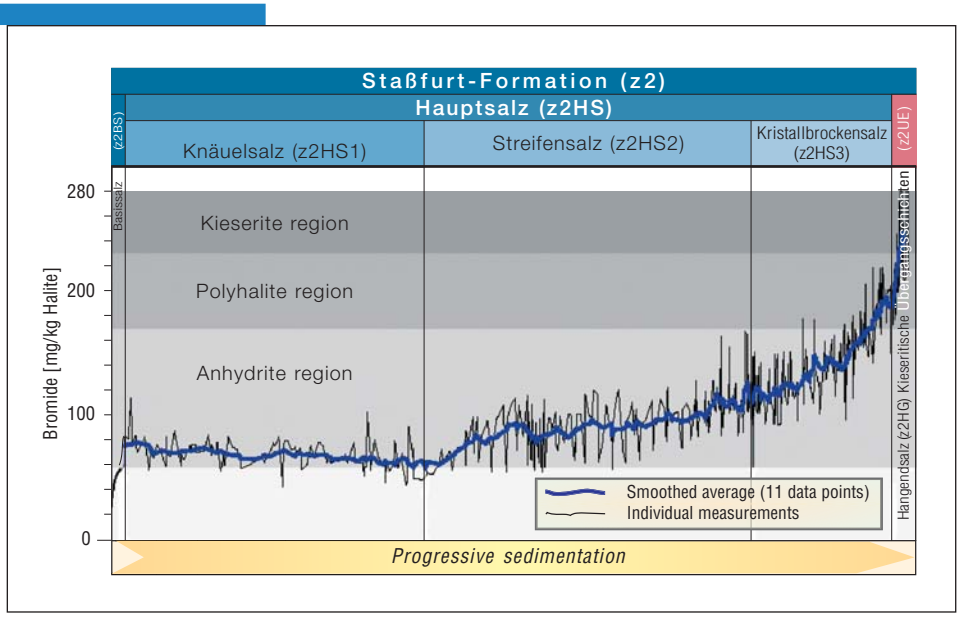
The BGR has recently acquired a unique amount of experience – in Germany and probably world-wide – in the operation of such software and its further development.



Section of a 3D geological model of a cavern field (grey bodies) in a salt dome (salt body shown in colour).

BGR uses the OpenGeo software system for the 3D geological modelling of salt structures. The special feature of this system compared to other software packages is that instead of defining the geological units by way of two-dimensional boundary surfaces in space, they are defined as real three-dimensional bodies. This method developed by the BGR allows the calculation of volumes and the production at any angle of the cross-sections required for solution mining planning. Another important advantage of using real three-dimensional models is the ability to compare them directly with the results of sonar surveys. During cavern solution mining, this enables the actual leaching progress to be compared online with the planning targets. Solution mining can then be controlled more effectively.

The BGR was therefore able to successfully conclude the modelling of the Benthe salt structure (Hannover) and the Rüdersdorf salt structure (Berlin) in 2003 and 2004. Ongoing projects are modelling the Gorleben, Etzel and Rüstringen salt structures (all in Lower Saxony).



Standard bromide profile above the Basissalz (z2BS), Hauptsalz (z2HS) and Hangendsalz/Kieseritische Übergangsschichten (z2HG/UE) of Zechstein 2 in the North German Zechstein Basin.

In addition to this work with its clear application relevance, the BGR also carries out basic salt geology research whose practical value only becomes clear at second glance. This applies for instance to the ongoing research on the distribution of bromide in halite within the Zechstein salt sequences. Work has been carried out on this project since 2003 to elaborate standard bromide profiles for different regions. The aim of the investigations is to use bromide analysis to generate viable geological data to assess repository and cavern sites within the salt of the Middle European Zechstein Basin. The main focus of the work is bromide analysis of the Hauptsalz within the Staßfurt Series.

During the exploration of the Gorleben salt dome, BGR already developed a bromide standard curve for this salt which is also suitable for the construction of salt caverns. The applicability of this standard bromide curve to other localities needs to be investigated so that stratigraphic classification can be carried out on the basis of the bromide content of the salt. This involves comparing samples from identical stratigraphic horizons at different locations.

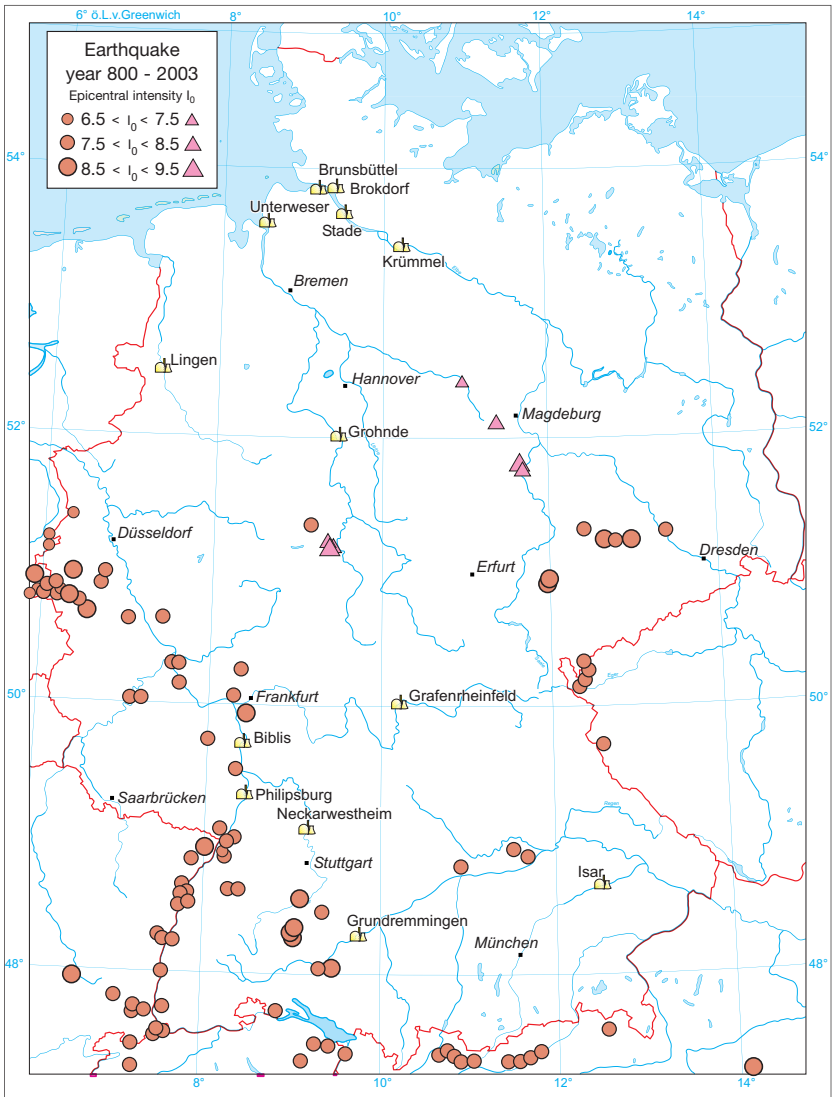
Geochemical analysis has been carried out on several thousand halite samples from the Zechstein since the project began. The samples come from drill cuttings and cores from various boreholes in northern Germany and adjacent areas to the west in Holland. The results confirm that the bromide concentrations of different stratigraphic units are characteristic and repeated at each location. For instance, the bromide content within the Hangendsalz (z2HG/UE) in north Germany is 180 to 300 mg/kg, but only 30 to 60 mg/kg in the Basissalz (z2BS). These clear differences are repeated wherever these sequences occur and are therefore a rapid means of stratigraphically dating salt rocks even as drilling continues. The potassium : magnesium ratio is also taken into consideration in borderline cases to improve the accuracy of the method.

This combined bromide concentration and K : Mg ratio method has already been used very successfully in two new cavern exploration wells where considerable costs were saved because the originally planned coring was no longer necessary.

Earthquake Protection
of Interim Storage Facilities at
Nuclear Power Stations

"Earthquake-proof" is a term which is often spontaneously and completely correctly linked with geotechnical safety. This is another field where BGR makes a valuable contribution.

When the German government and the German nuclear power station operators agreed on 14 June 2000 to phase out nuclear power stations, the power station operators were given the promise that interim storages could be constructed at the power station sites to store spent fuel elements.



Map of the epicentres of damaging earthquakes in Germany showing the marginal areas and the locations of (planned) interim storages at German nuclear power plants. The map shows all earthquakes which took place from 800 to 2003 with an intensity of 6 to 7 (minor building damage) measured on the 12-part macroseismic scale. The triangles mark non-tectonic tremors such as rock bursts (partial collapse of a mine) which caused damage to surface buildings.

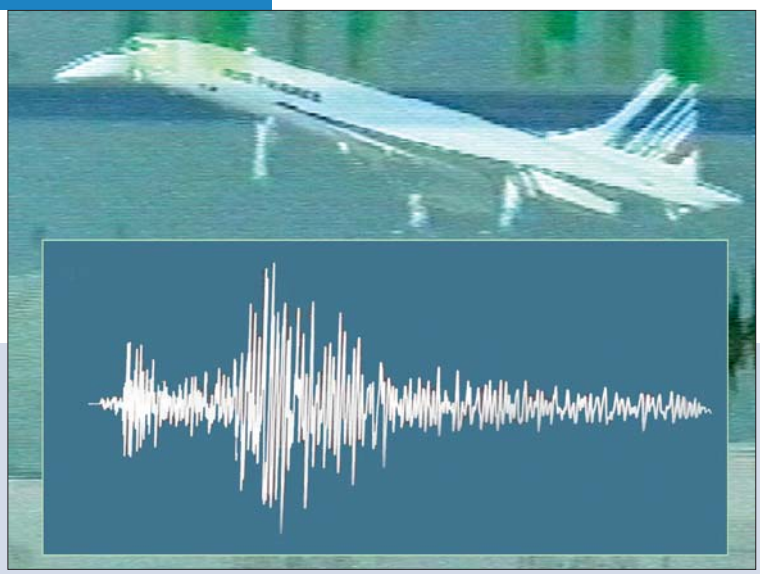
Part of the approval process for these construction plans involves submitting confirmation that these buildings are designed to be earthquake-proof. The applicants (the power station operators) are obliged here to submit relevant documentation which estimates the seismic risk. The licencing agency checks these documents and engages specialists to prepare expert reports whenever special expertise is required. BGR was engaged as the expert to review the documentation on seismic risk.

Selecting the BGR to carry out this work not only reflects its many years of nationally and internationally recognised experience in this field, but also fundamental aspects: when dealing with such a highly charged political topic as nuclear energy, it is essential that there are absolutely no doubts about the neutrality of the experts working for the licencing agency. Although this independence might also be guaranteed by a private-sector expert, the relevant credentials of BGR are obvious to all, particularly because of its public-sector status and the associated economic autonomy.

The seismological expert reports examined by BGR for each of the sites define the parameters required to calculate the potential stresses acting on the building during an earthquake. This allows the building to be designed in such a way that no safety-relevant damage would occur during an earthquake.

Examining the parameters submitted in the reports to assess whether they are appropriate first requires determination of the reference earthquake – in other words the severity of an earthquake taken into consideration in the design which might occur in the area of the site after considering the regional seismic activity. This assessment is based on the German Earthquake Catalogue administered by BGR and which is accessible to the public at the BGR website. This database is used to assess the seismic activity at each site and then define the reference earthquake in accordance with the technical safety regulations laid down by the German Nuclear Technology Committee. This involves determining the reference intensity as well as the probability of it being exceeded, and the frequency of its occurrence. When also making allowance for the site-specific subsurface conditions, this finally generates the parameters required for designing the building: the frequency-dependent maximum vertical and horizontal acceleration, their duration during an earthquake, and the length of time they need to be withstood by the structure.

Within the stipulated tight timetable, the BGR successfully completed the examination of the seismological expert reports for the thirteen interim storage sites and the definition of the load assumptions applying in each case.



National Seismological Data Centre / Comprehensive Nuclear Test Ban Treaty

National Seismological Data Centre / Comprehensive Nuclear Test Ban Treaty

Listening for Peace – What is the **CTBT?**

The efforts of the international community to ban nuclear tests led to the Comprehensive Nuclear Test Ban Treaty (CTBT) which was opened for signature on 24 September 1996. Up to the end of 2004 this treaty has been signed by 173 countries. However, the CTBT only enters into force when it has been ratified by all of the nuclear powers and countries with civil nuclear programmes.

Even though the achievement of this goal is currently not in sight for political reasons, the technical preparations for monitoring CTBT compliance are moving ahead rapidly. This involves setting up a network of 321 "listening posts" around the world, of which one third are already in place. All of the IMS stations (International Monitoring System) are scheduled to be operational by 2009.

Four different technologies are used in the monitoring system to detect, localise and identify nuclear explosions underground, in the water and in the atmosphere: seismology, infrasound, hydro-acoustics and radionuclides.

Completion of the primary seismic network is the most advanced of the four technologies: around 80 % of the 50 stations are already in place. These primary stations form the backbone of the CTBT verification system because underground nuclear explosions are still considered to be the most likely scenario for violating the treaty.

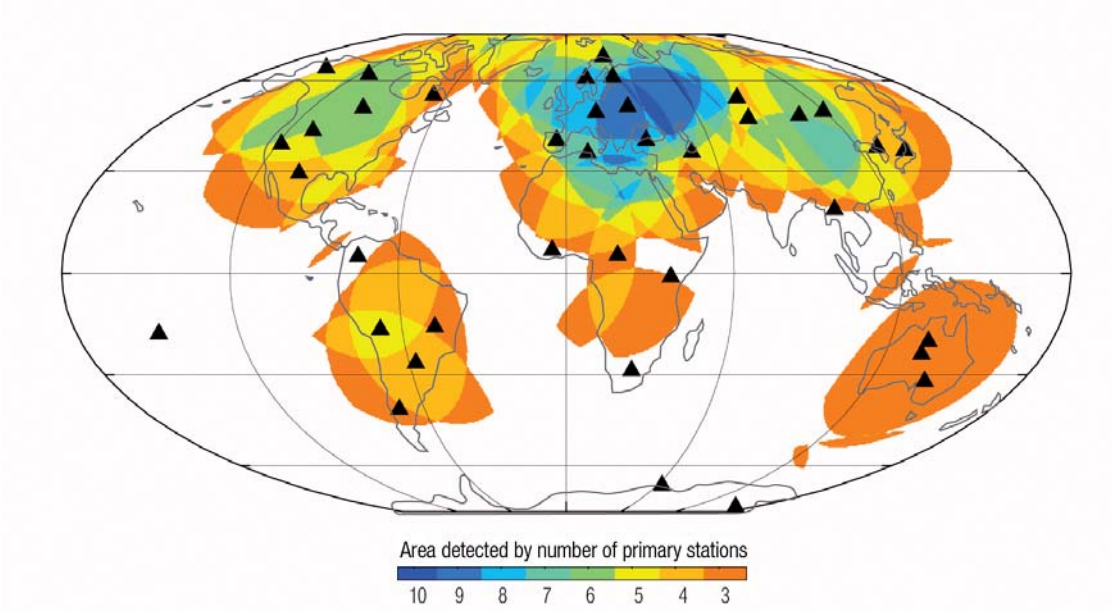
Germany has already fulfilled its obligations with respect to the participation of German stations in the monitoring system. BGR plays a major role in this respect because it is responsible for four of the five German IMS stations. These include the GERESS seismic array in the Bavarian Forest consisting of 25 individual seismometer stations.

An infrasound array with five elements, named IS26 in the Comprehensive Nuclear Test Ban Treaty is co-located at the GERESS site. It was the first infrasound array which fulfilled all technical specifications of an IMS station. It was certified in 2001 by CTBTO (Comprehensive Nuclear Test Ban Treaty Organisation).

The other two stations operated by BGR are in the Antarctic. Installation of the IS27 infrasound array close to the German Neumayer Antarctic research base run by the Alfred-Wegener Institute for Polar and Marine Research was a technical and logistical challenge. Consisting of 9 elements, IS27 was successfully certified in June 2004. The SNAA 3-component seismic station was certified a month earlier. This station is located at the South African SANAE IV Antarctic research base. SNAA was originally installed by the Alfred-Wegener Institute for Polar and Marine Research in collaboration with the South-African Geological Survey. It was upgraded by BGR to bring its technology in line with that required by an IMS station. Installation of the new high-sensitive broad-band seismometer confirmed that this location is currently the quietest place on earth – the level of seismic background noise is lower than everywhere else in the world.

The following figure shows the current detection capacity of the monitoring system. The coloured areas mark the number of primary stations which could detect an underground nuclear explosion with a strength of around 1 kt TNT conventional explosive at these locations.

The signals need to be detected by at least three stations to enable a seismic event to be defined as such and be subsequently localised. The white areas and the distribution of the coloured areas highlight the current gaps in the detection capacity of this network. Similar coverage is also provided by the other verification technologies.



Detection capacity status of the CTBTO seismic monitoring system in December 2004. All of the locations covered by at least three or more seismometer stations are colour-coded in the world map. This assumes that the IMS stations marked with triangles are able to detect a seismic event with an explosive force of around 1 kt conventional explosives at a distance of up to 30°.

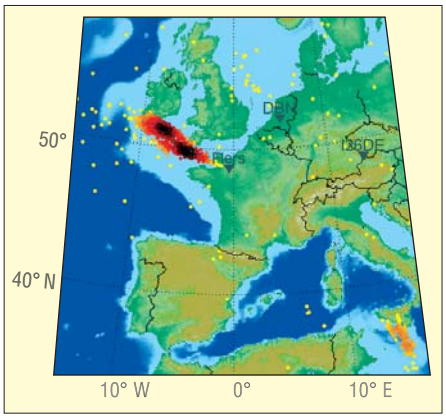
BGR – Control Institution
for Monitoring Compliance with the
Comprehensive Nuclear Test Ban Treaty

The International Data Centre (IDC) of CTBTO in Vienna records all of the data from the international monitoring system via a global satellite system, before processing the data. However, controlling compliance with the Comprehensive Nuclear Test Ban Treaty is in the hands of National Data Centres (NDCs). BGR is the German NDC and is therefore not only responsible for the German seismic and infrasound stations incorporated within the International Monitoring System (IMS), but also for detecting and verifying any treaty violations.

To fulfill this duty, the NDCs need the appropriate technical and scientific infrastructure to analyse and evaluate the data retrieved on request from the IDC. With respect to the hydro-acoustic and radionuclide verification techniques, BGR can call on the expertise of FWG (Federal Armed Forces Underwater Acoustic and Marine Geophysics Research Institute) and BfS (Federal Office for Radiation Protection) when required. In-house know-how is, however, indispensable for seismology and infrasound.

Although the necessary skills are already available in seismology on the basis of many years of experience in the analysis, interpretation and identification of seismic data from national and international seismometer stations, infrasound opens up a completely new area of activity.

When IS26 became operational (station code I26DE) in 2000, the problem was to detect, localise and identify acoustic signals in the recorded data. The first step was to utilise the well-known methods used in seismology. However, their application was only partially successful. The search therefore began for methods which were better adapted to the requirements of infrasound. Comprehensive testing revealed the qualities of the PMCC algorithm *(Progressive MultiChannel Correlation)* whose main strength was in the detection of coherent signal energy dependent on its direction and apparent speed – and where signal amplitude has lower relevance.

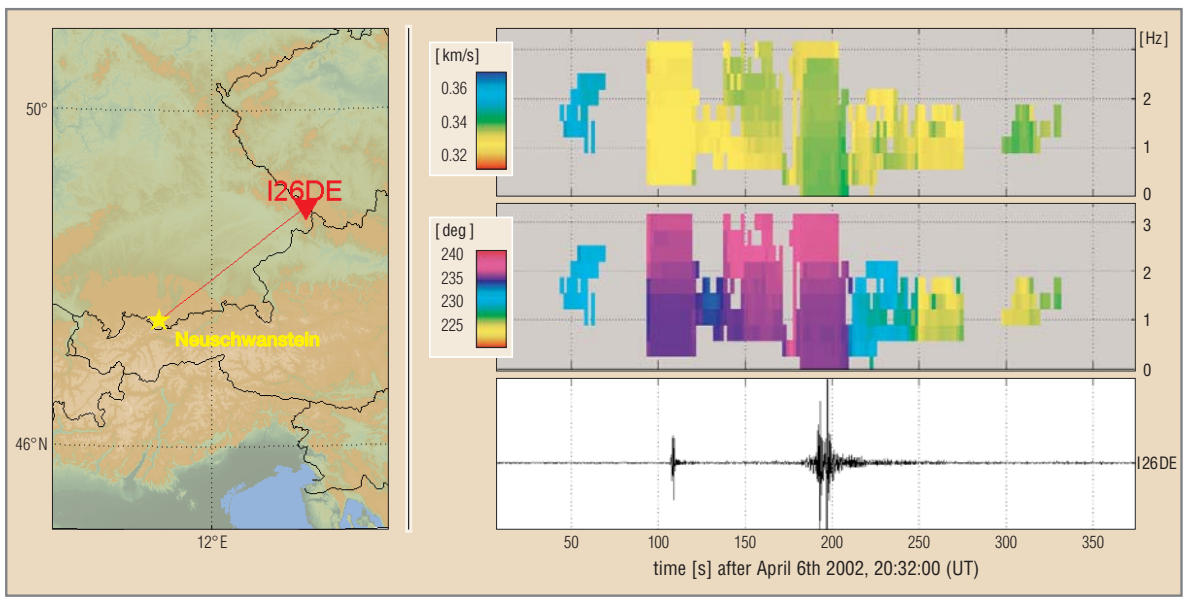


Localisation result according to relative frequency coloured yellow through red to black, of acoustic sources from September 2000 to August 2004 detected with the help of the infrasound monitoring stations at I26DE (Germany), Flers (France) and DBN (The Netherlands).

If the azimuth of incoming infrasonic waves is known from at least two infrasound arrays, the source of the acoustic energy can be located by cross-bearing. However, this option is only possible for IS26 in those cases when the infrasound stations in The Netherlands or France – which do not belong to IMS – have also recorded the signal. The most prominent examples are signals from Etna, or Concorde when it breaks the sound barrier on its flights to Paris or London. The source of most of the other peaks are accidents involving explosions (Toulouse 2001, Ath/Belgium, 2004), military aircraft, meteorites and natural gas flares on North Sea drilling rigs.

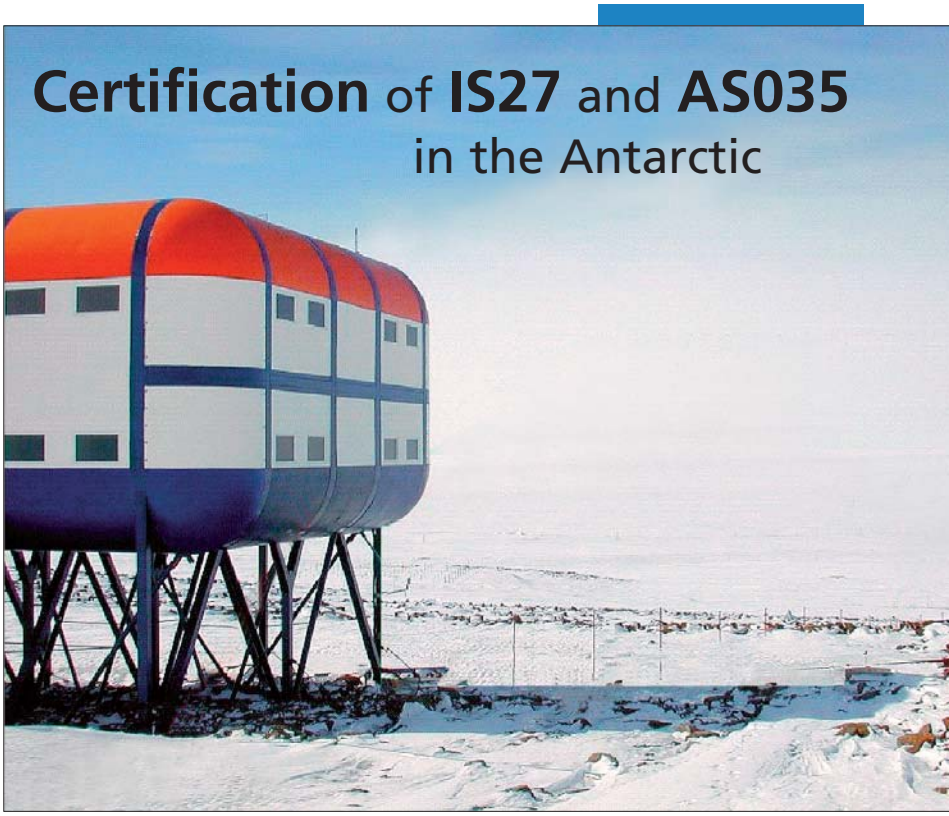
Locating the signal source is much more complicated if it has not been recorded by any other stations because determining the distance has to be carried out from travel time differences on the various paths in the atmosphere. This demands a highly sophisticated locating method and far exceeds the derivation of simple travel time curves as in seismology. This is because the atmosphere is subject to strong daily and seasonal fluctuations in phase and wind speed which give rise to significant changes in signal shape. Despite having a global four-dimensional atmosphere model there is still no guarantee that an infrasound source can be located by only one station.

With the analytical methods discussed above, the German NDC now has the infrastructure required to use infrasound in addition to seismology to verify compliance with the Comprehensive Nuclear Test Ban Treaty.



Use of the analytical method to locate coherent energy using the Neuschwanstein meteorite of 6 April 2004 as an example. The map shows the location of I26DE (red triangle) as well as the fragmentation epicentre of the meteorite (yellow star) located 260 km away. The right-hand picture shows the barogram (bottom), the coloured time-frequency analysis for directional determination (middle diagram) and the apparent velocity (top).

Commissioning and **Certification** of **IS27** and **AS035** in the Antarctic



The first step into unknown "infrasound" territory took place in 1997 with a survey in the Bavarian Forest for the infrasound station termed IS26 in the Comprehensive Nuclear Test Ban Treaty. This station, which was commissioned by BGR in 2000, was also the first station in the IMS infrasound network to be certified by CTBTO. Certification not only means successfully passing a detailed test programme, it also means that the station has been operated for several months with a reliability of 98 %, and that it is possible to demonstrate that this high level of operational reliability can be maintained in the future. IMS stations also have to send the data collected by the sensors within five minutes to IDC in Vienna via a satellite-based communications system.

Digging one of the nine infrasound elements out of the ice after one year of operation. Reinstallation on the surface.

Whilst infrasound stations in other parts of the world such as in the Bavarian Forest use dense vegetation to further reduce the effect of wind, this effect can be achieved in Antarctic areas by using snow cover. The wind noise can thus be reduced without significantly attenuating the infrasound signals. The filter system is therefore placed in a trench which is then covered with snow. The average natural increase in snow cover of 60 cm per year also promotes the formation of a homogenous and increasingly thick blanket of snow cover. However, this additional snow also makes it necessary to regularly dig out the monitoring stations and filter systems and re-install them just beneath the surface again.

Work being carried out at station AS035 during the certification test.

Apart from the technical aspects, certification is also economically relevant. According to the CTBTO regulations, the costs run up by an institute for the construction or technical expansion of a station are only reimbursed in the year after certification. This "no certification, no money" model is both a stimulus and a threat to get on with commissioning the station as fast as possible.

The installation and operation of an infrasound array in Germany, and the use of the existing infrastructure of the co-located GERESS seismic array, proved to be "child's play" compared to the effort involved in installing a similar station in the Antarctic next to the Neumayer research station. The site survey began in the 2000/2001 Antarctic summer. Installation was planned for 2002/2003.

To exclude as far as possible any problems when installing the station in the Antarctic, it was originally intended to completely assemble and test the stations at BGR before dismantling them again and packing them for shipment to the Antarctic. However, delays in delivery of most of the equipment meant that this plan had to be abandoned. Almost all of the electronics were only supplied at the last minute and so the equipment had to be forwarded unchecked to the Polarstern research vessel. The fears were justified when the equipment was finally tested. However, the enormous commitment and improvisation skills of the installation team enabled the station to become fully operational by the end of the Antarctic expedition in February 2003. The station passed all of its certification tests one year later.

Detailed testing of a similar nature was also conducted during the same Antarctic expedition at the upgraded AS035 seismic station with the code name SNAA. It is located at the South African SANAE IV research base around 200 km from Neumayer station. Technical conversion work had already been carried out during the 2002/2003 Antarctic summer. CTBTO officially certified SNAA as an IMS station in May 2004, followed by the official certification of IS27 in June. BGR thus fulfilled one of Germany's fundamental obligations arising from the Comprehensive Nuclear Test Ban Treaty.

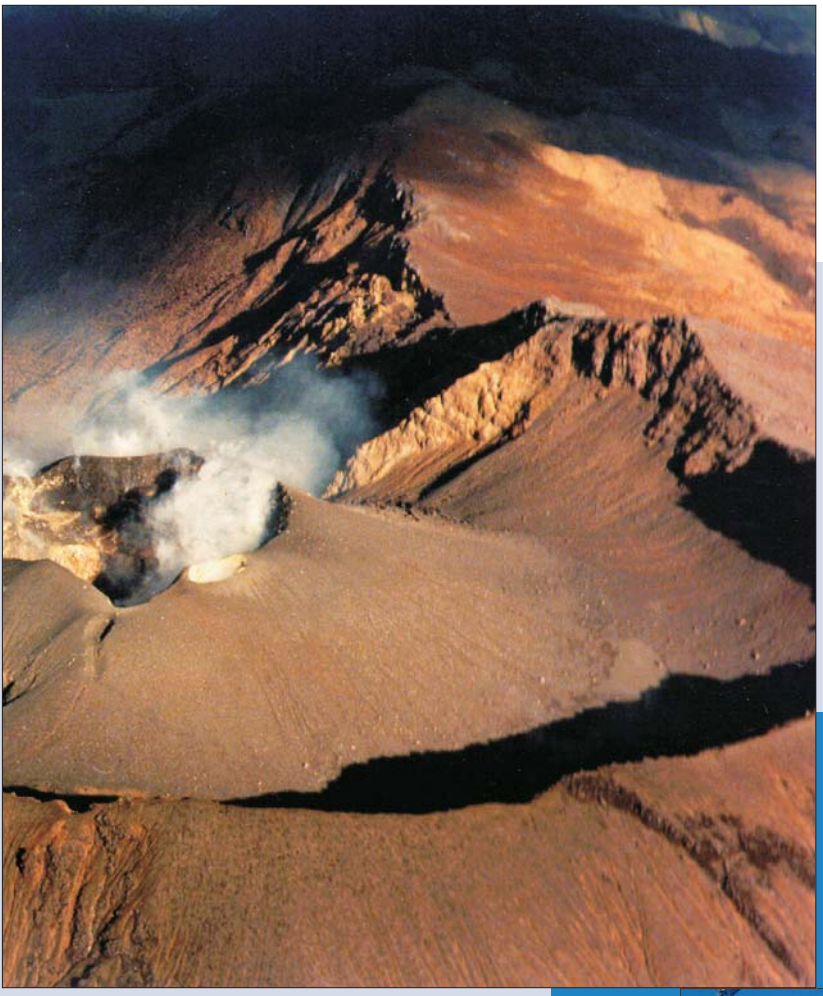
Location of the German-South African IMS seismic station AS035 at the SANAE IV research base.

Geological Hazards

Geological Hazards
– Unforeseeable **Fate**?

The global population continues to grow. More and more people live in regions threatened by natural disasters. These include most of the coastal regions around the world, steep slopes threatened by landslides, or areas in the vicinity of volcanoes. In addition to the loss of human life, there are also increasing risks to expensive and often vital high-tech infrastructures. It is not normally possible to do anything to stop a natural disaster. But preventative measures can reduce the extent and scale of the damage caused by such disasters.

BGR carries out research on the often highly complex relationships involved in areas where people and their environment are at risk from geological processes. BGR also works specifically on early warning methods for geogenic risks. BGR's work therefore brings together basic research and its effective practical application with the aim of protecting life and maintaining the conditions required to support acceptable living conditions.



Monitoring **Mud Volcanoes** in **Azerbaijan**

Mud volcanoes are volcanic mountains consisting of dried mud. They are formed by the episodic upwelling of mud flows which originate in deep ineffectively sealed underground oil and gas deposits. Mud volcanoes can erupt like conventional volcanoes, but instead of spewing ash and lava, they expel mud flows which are sometimes associated with burning gas. Such eruptions are extremely dangerous to any nearby habitation or infrastructure. Azerbaijan has the world's highest density of mud volcanoes, with over 400, of which a few erupt every year.

The mud volcanoes in Azerbaijan lie above an ultra-deep sedimentary basin which formed during the closure of the former Tethys ocean which lay between Africa and Eurasia in the geological past. The basin developed so rapidly that even at great depths some sedimentary horizons have still not become adequately consolidated. They are therefore episodically mobilised and then rise up along fault zones in the form of mud flows. When they reach the surface they flow out to form mud volcanoes. Large amounts of flammable gas (mostly methane) can also rise up inside the mud flow channel. This gas can self-ignite during an eruption to form flames tens of metres high as hundreds of thousands of cubic metres of mud spew out of the volcano.

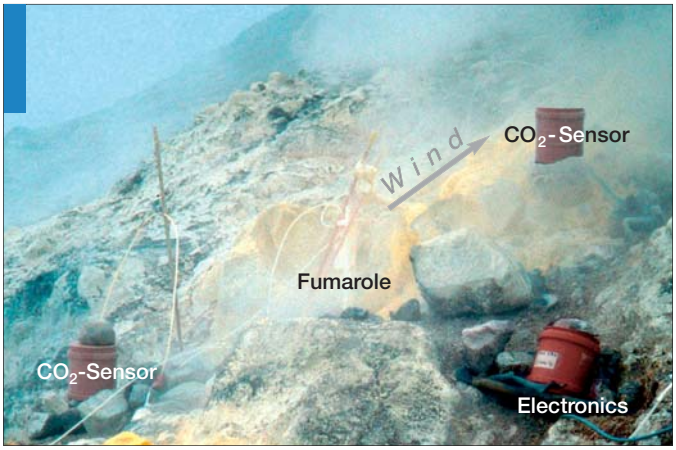
Burning gas.

These eruptions normally take place without any warning. To gain a better insight into the mechanisms involved in the ascent of this mud to the surface from deep underground, and identify any early warning signals which occur prior to an eruption – such as a change in gas chemistry or a change in gas flow rate – BGR established a mud volcano monitoring programme at the end of 2003 together with the Azerbaijan National Academy of Sciences in Baku. The flow of methane from two mud volcanoes on Dashgil and Perikushkul is now being continuously measured. The outflow of radon is also monitored on Dashgil in addition to the methane. The first results indicate that there are periodic changes in gas flow rates with daily as well as monthly cycles. As time goes by, we hope to collect data continuously until immediately prior to a future eruption. Our long-term aim is to develop a method which enables a warning system to be set up at risky locations to forecast violent mud volcano eruptions.

The BGR monitoring station on the Dashgil mud volcano collects gas rising up under a lake and records measurements including the change in the amount of gas upwelling over time.

Latest Results on the **Galeras Eruption** in August 2004

The approx. 4300 m high Galeras in south Colombia in South America is one of the most dangerous volcanoes in the Andes and has erupted repeatedly, with the latest activity taking place very recently. It is a potential hazard to the more than 300,000 inhabitants of the nearby city of Pasto. BGR's research into the processes going on in the interior of the volcano involves the joint operation with its partners from the Colombian Geological Survey (INGEOMINAS) of a multiparameter station in the Galeras caldera. The station records seismic and electromagnetic signals, the concentration of gases emitted by fumaroles, and their temperature and pressure. The temperature distribution on the surface of the caldera has been recorded several times by a helicopter-mounted thermocamera. The changes in this data over time are interpreted to determine the status of the Galeras volcano.



BGR measuring instruments installed around a fumarole on the Galeras volcano.

From July 2004 onwards, the multiparameter station instruments picked up an increased level of seismic disturbance which indicated an overall rise in the level of activity within the volcano. The composition of the fumarole gases changed several days before the beginning of the first eruptions. The temperature of the fumaroles also changed shortly before the first eruptive activity. The activity of the volcano increased strongly on 16 July 2004 accompanied by the first observations of gas and steam eruptions. The ash clouds spread as far as Quito, the capital of Ecuador, but were primarily a hazard to the people living close to the volcano. The eruptions were accompanied by the expulsion of rocks hurled up to several kilometres away from the centre of the eruption.

This project has therefore succeeded in learning more about the characteristic signals made by a volcano prior to an eruption – information which can provide the authorities with an early warning of an imminent geo-risk.

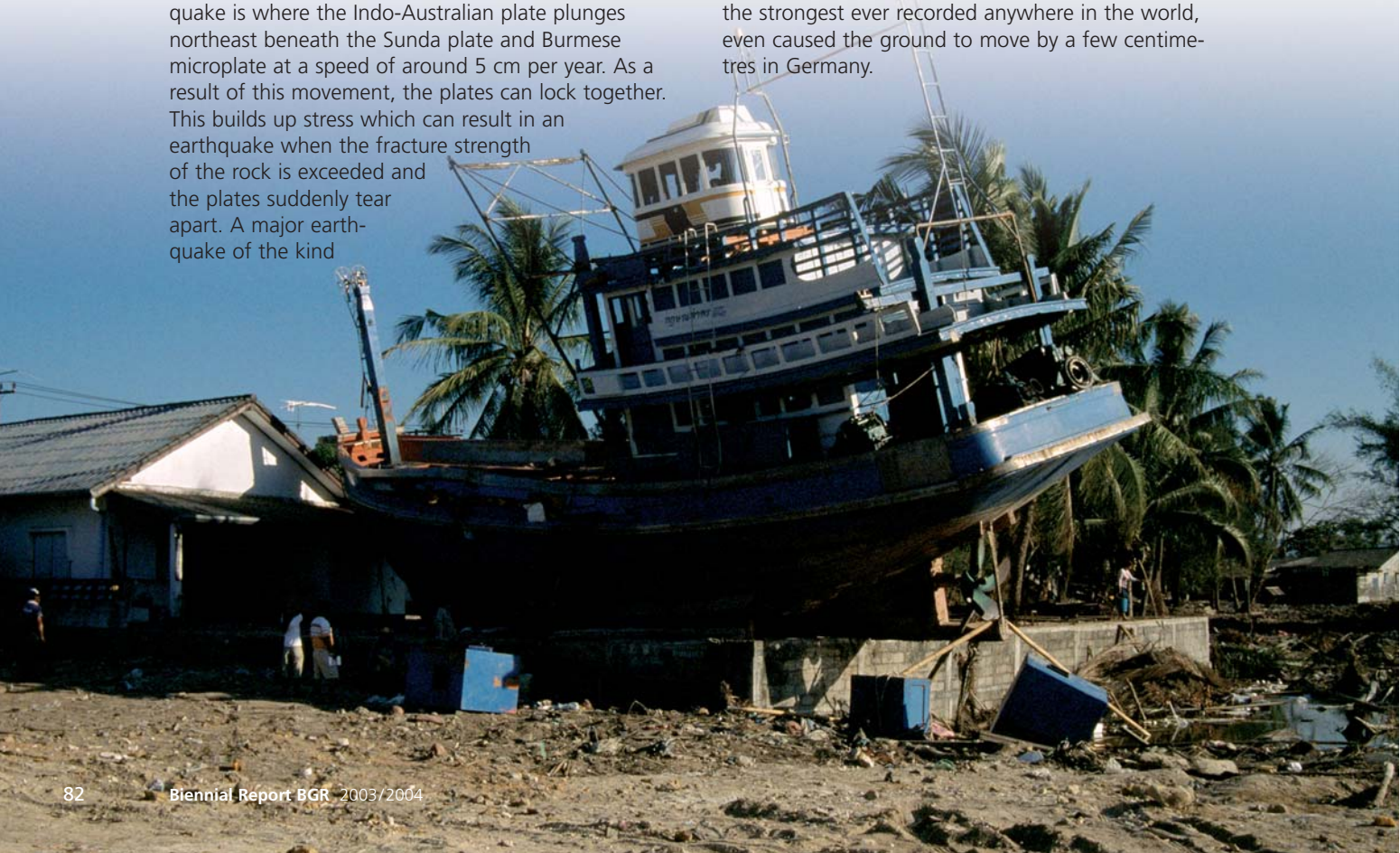
The solar cells used to power the multiparameter station were covered by ash during the eruptions, shutting down the power supply. The further changes in gas composition and fumarole temperatures were therefore only registered very approximately after this failure. The volcano continues to spew out steam, ash and rocks. It is therefore not safe to go near the crater at present. The examination, possible repair and restart of the measuring equipment will therefore continue to be delayed.

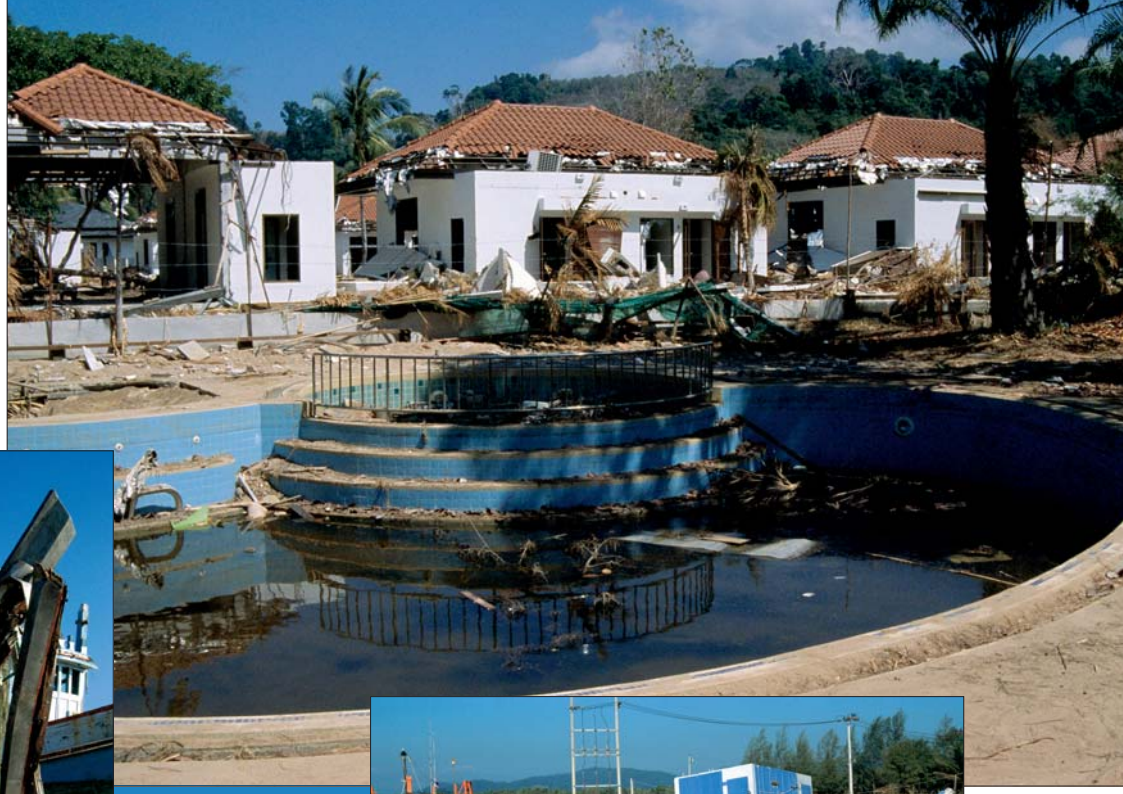
The **Southeast Asian Submarine Earthquake**

The whole world now knows what a tsunami is. On 26 December 2004, a major submarine earthquake with a magnitude of 9 shook the seafloor off the island of Sumatra and generated the huge wave, a tsunami, which claimed countless lives along the coasts of India, Thailand, Malaysia, Indonesia, Sri Lanka and the Maldives. Even the far away African coastlines of Somalia and Kenya were hit by the tsunami which also caused catastrophic damage to buildings and infrastructure wherever it hit. More than 300,000 people died and several million became homeless. The worst affected areas are on the east coast of Sri Lanka, the holiday region around Phuket on the west coast of Thailand, and the region of Aceh on the northern end of the Indonesian island of Sumatra.

The main earthquake (star in the map above) took place off the northern tip of Sumatra approx. 250 km south-southeast of Banda Aceh. The site of the earthquake is where the Indo-Australian plate plunges northeast beneath the Sunda plate and Burmese microplate at a speed of around 5 cm per year. As a result of this movement, the plates can lock together. This builds up stress which can result in an earthquake when the fracture strength of the rock is exceeded and the plates suddenly tear apart. A major earthquake of the kind that occurred on 26 December 2004 involves a fracture zone mostly consisting of several fracture surfaces which became activated in a cascading sequence. The map shows more than 100 aftershocks with a magnitude exceeding 5.0. They are all located along a 1000 km long south-north fracture surface.

The length of the fracture can be precisely defined from the shocks registered by the "first arrivals" at the German Regional Seismological Network (GRSN) located more than 9000 km from the epicentres. Energy released by this earthquake, which is one of the strongest ever recorded anywhere in the world, even caused the ground to move by a few centimetres in Germany.





Because these ground movements were very slow, they could not be detected without instruments and did not cause any damage. Long amplitudes of this kind are generated by surface waves which, unlike body waves, do not travel through the earth, but much more slowly along the surface of the earth (at around 3.7 km/s). With an earthquake of this magnitude, the surface waves travelled around the earth several times.

A tsunami (a Japanese word meaning large wave in the harbour) can be generated by a strong shallow submarine earthquake (magnitude exceeding 7; depth less than 10 km), or a volcanic eruption or submarine landslide. A tsunami spreads out almost concentrically over the surface of the water away from the epicentre. The whole of the water column from the surface of the water to the sea floor moves until it reaches the coast. Just like a breaker, when it hits the coast, the wave can rise up to an impressive height – the largest waves observed so far reached a height of 30 m. The speed at which the waves travel away from the epicentre depends on the water depth.

With an average depth of 5 km, the waves spread at a speed of approx. 220 m/s (800 km/h) and have a wave length of up to 200 km. These extremely long wave lengths and the low amplitude in the open ocean (of around 1 m) explain why tsunamis are not registered by ocean going ships.

In addition to Japan and the South Sea islands, the areas with the highest tsunami risk include Hawaii and parts of the Pacific coast of North and South America. This is clearly shown in the map on the following page by the global distribution of earthquakes which generated tsunamis. Because of the far higher number of tsunamis in the Pacific, the area benefits from an early warning system. The Indian Ocean has not so far had such a system because tsunamis occur much more rarely here. They are also rare in the Atlantic and the Mediterranean where there are also no warning systems in place.

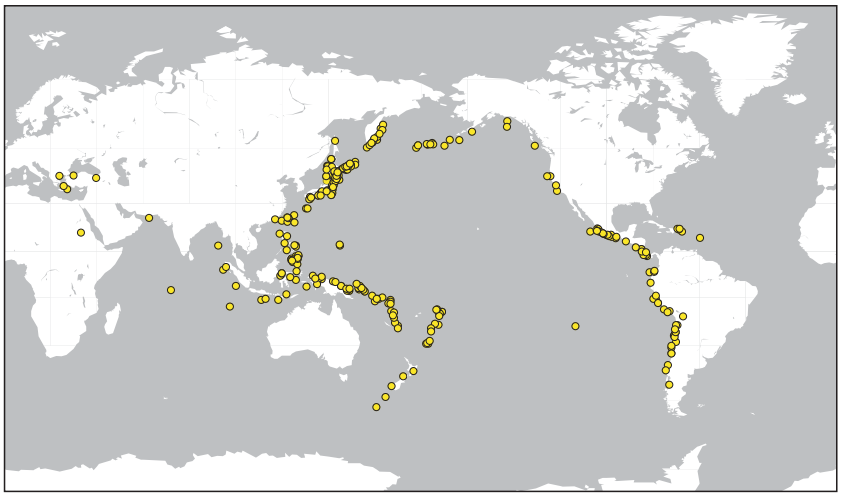
Geological Hazards Indonesia

Earthquakes, floods, volcanic eruptions, landslides and tsunamis are natural disasters which take place in Indonesia almost daily, and cause an enormous amount of personal injury and damage to property every year. They are a serious and constant threat to the inhabitants. They cause considerable economic losses every year and have a negative impact on social and economic development throughout the country. In 2003 alone, Indonesia was affected by around 500 natural disasters resulting in 800 dead, 4500 injured and leaving almost 500,000 homeless.

Most of these disasters have one thing in common: they usually take place suddenly and unexpectedly.

But do disasters really occur unexpectedly? And is it possible for the inhabitants of affected regions to actively implement preventative measures to avoid the risks or at least reduce the consequences?

As a result of a finding that a reduction in the impact of natural disasters is an urgent social and economic requirement, the Indonesian government turned to Germany with a request for technical co-operation. Indonesia has therefore been assisted since 2003 within the framework of the German-Indonesian co-operation project "Mitigation of Geo-risks" (GEORISK). The project is conducted in co-operation with the Directorate General of Geology and Mineral Resources (DGGMR), the Directorates for Geological and Mining Area Environment (DGMAE) and the Directorate for Volcanology and Geological Hazard Mitigation (DVGHM) in Bandung, West Java.



Map of the world with the 299 earthquakes which have caused tsunamis during the period 1900 to 2004 (source: NOA). Most of these earthquakes took place in the Pacific.

The project is the main component of the German-Indonesian technical co-operation project "Civil society and inter-communal co-operation for improved urban services and quality", conducted by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and the Indonesian Ministry of the Interior. As part of this project, the two governments promote co-operation between non-governmental organisations and the local administrations with the overall aim of improving the efficiency of urban and district government.

The efficiency of selected local authorities in East Java and the islands of Lombok and Flores is enhanced in the following areas as part of the two project segments "Qualified urban development" and "Mitigation of Geo-risks":

- Advising local urban and district governments as well as NGOs with the aim of implementing active disaster management.
- Strengthening the advisory competence of partner agencies in the analysis and evaluation of the causes and effects of natural disasters, and the ability of society to cope with known risks.
- The elaboration of natural disaster management guidelines as the basis for a nationwide legislative framework for local decision makers.

Consultation was carried out in the Sikka administrative district (project town: Maumere) and the Ende administrative district (town of Ende) on the island of Flores. A debris flow killed more than 30 people in the north of the town of Ende in April 2003.

An evaluation of the natural disaster risk was carried out in the district of Sikka. This formed the basis for recommendations enabling planners and political decision makers to make allowance for the local geo-risk potential in their urban planning. The town of Maumere in particular has a high risk of flooding by tsunamis and is subject to strong ground movement caused by earthquakes. Responsible urban planning therefore requires changes to be made to the planning concepts: the coastal area, which is currently occupied by large parts of the town, should not contain any strategic buildings. The town also requires a second safe access road to the airport because the existing road lies within the three-metre-high intertidal zone. If this road were destroyed by a tsunami, the town would be cut off from emergency help. The municipal authority was therefore handed a recommendation to build a second access road. As a result, the municipal authority included the construction of a road in its budget. In addition, a doctoral thesis carried out by the University of Göttingen as part of the "GEORISK" project, evaluated the tsunami risk of the area, which is also associated with earthquakes.

The Egon, Iya and Kelimutu volcanoes on Flores were mapped and their risk potential evaluated. The risk map for the Egon volcano had only just been completed when the volcano erupted and 5000 people had to be evacuated. Another finding was that a future eruption of the Iya volcano would take place in the direction of the sea and would produce around 70 million cubic metres of volcanic material. Because the town of Ende lies in the completely opposite direction, it is unlikely that the town would be directly threatened by lava, lahas and pyroclastic flows, even though a slight risk to the town from volcanic ash cannot be excluded. However, it is highly probable that a volcanic eruption of this kind would generate a tsunami. This could flood the eastern and western coastline of the town up to a height of 3 m and therefore damage the strategic infrastructure such as the airport (it has already been flooded once), the central fuel tanks, and one of the adjacent electricity works.

The city of Semarang has long been associated with considerable surface subsidence, which is problematic in particular for the centre of the port area, the neighbouring industrial areas and the railway station. DGMAE conducted geodetic surveys to produce precise subsidence rates. These subsidence rates were used to generate two subsidence scenarios: one for 2008 and one for 2013. There are currently 1500 houses with 8000 inhabitants which are permanently at or below sea level. This will rise in 2008 to 5000 houses and 25,000 people and to more than 20,000 houses and around 65,000 people in 2013.

The project activities in the city of Yogyakarta concentrate on raising the awareness of the inhabitants of the effects of natural disasters. The city is dominated by the infamous Merapi volcano and its associated secondary and tertiary risks. Because a large number of risk evaluations have already been carried out, the Georisk project concentrated on local authority disaster management. On the basis of a customised series of risk indicators, a risk evaluation was carried out for the local communities together with representatives of local authorities and NGOs. Over the course of time, these indicators will provide information on whether the disaster risks are increasing or decreasing. They will then be suitable as a monitoring tool for the effective reduction of geo-risks and the way the local inhabitants manage these risks.

A database concept was implemented as part of the Georisk project with the aim of strengthening the advisory competence of the Indonesian directorates by bringing together all of the information available in the country on current and past risks within a standardised data gathering and evaluation system. The database currently contains the results of the natural disasters during the last ten years, and already reflects in a useful way the regional variations of all the natural disasters occurring in the country. The database provides reliable information with which to improve the prediction of natural disasters and their consequences. The project co-operates closely with the National Secretariat for Natural Disaster Management (BAKORNAS PBP), the Ministry of Health and the Meteorological and Geophysical Agency (BMG) with the aim of integrating their separate databases within one national database.

As part of this project, a method was also formulated for evaluating the economic risks to the city of Semarang. There is international agreement that the different types of natural disasters can only be compared with one another on the basis of their economic impact. Political decision makers can only assess the value of measures to mitigate geo-risks by considering the economic losses in monetary terms. The loss assessment incorporates information on housing and population density. It also integrates data on income from industrial and agricultural production as well as the value of the public and private infrastructure.

Protection of the Geoenvironment and Georesources

Working for the **Environment** – Protection of the Geoenvironment and Georesources

We all want to play a role in protecting the environment, but we also expect resources to be exploited – sensibly of course!

What is the Contribution of the BGR?

Environmental geochemistry is an area of interdisciplinary research looking at the behaviour of substances in the environment. It involves the investigation of the processes which change organic or inorganic, biotic or abiotic, anthropogenic or natural substances, and those processes initiated by these substances themselves.

Identifying and understanding such processes are important aspects in geoenvironment and georesource protection to ensure that any impact on the environment is identified early on, and to recommend pro-environment methods for the sustainable use of natural resources. With such an understanding it is also possible to support environmental policy and legislation.

We tackle the issues looked at here in close co-operation with our partners at universities, research institutes, state Geological Surveys and industry. This allows us to quickly access and utilise a very broad spectrum of up-to-date and specialized know-how.

Our current focus is on

- the detection of oil contamination
- the long-term in situ monitoring of contaminated sites
- describing the geochemically and microbiologically influenced chemical reactions taking place in contaminated mine sites

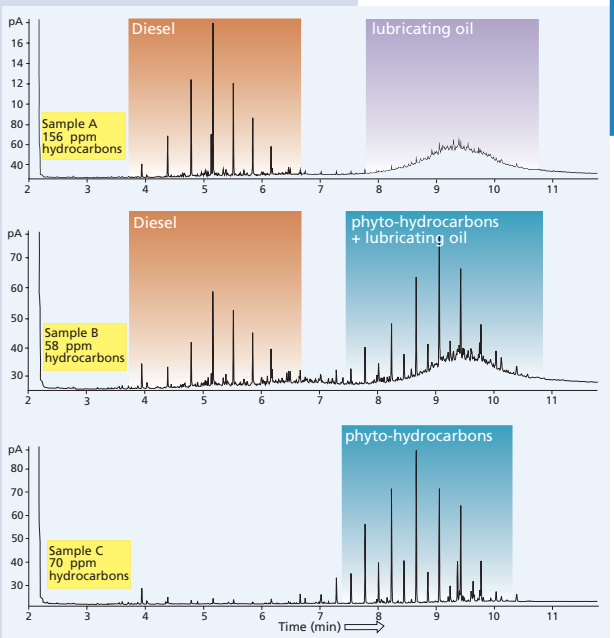
Confirmation of **Hydrocarbon Contamination** in Soil – **Hyperspectral Remote Sensing**

Unlike the detection of oil pollution on the surface of the ocean which is now possible with the help of radar surveys from aircraft or satellites, there is still no reliable airborne method for the much more difficult problem of detecting oil contamination in soils.

Part of our investigations involves simulating oil-contaminated soil produced from an artificial mixture of soil and oil. These test plots are then surveyed from the air using a HyMap-hyperspectral scanner. Subsequent data analysis indicates that the absorption of electromagnetic radiation at 1.73 µm is suitable for the direct detection of oil contamination in soil.

The hydrocarbon index formula (= HI) was developed and successfully tested for the aircraft-borne direct detection of oil contamination in soil. The applicability of this approach was confirmed by additional tests carried out on behalf of the oil industry.

A ground check is required to precisely identify the type of hydrocarbon involved (diesel oil or similar liquids). Petroleum contamination, whether from diesel oil or lubricants, can be differentiated from natural plant-derived hydrocarbons by the special analysis of soil extracts using gas chromatography. This reveals the distribution pattern of the normal alkanes, the unbranched "paraffin" molecules. Gas chromatograms of refined petroleum products show a smooth n-alkane distribution curve and an undifferentiated background ("hump"). N-alkanes from the wax layer of higher plants which are frequently preserved in soils and sediments differ because they are preferentially made up of molecules with uneven numbers. Gas chromatography with a flame ionisation detector (GC-FID) generates much more accurate information compared to the previously used infrared spectral analysis method based on analysis of molecular vibrations in the infrared spectrum.



Distribution pattern (gas chromatogram) of normal alkanes.

Investigation of **Landfills** and **Contaminated Sites** – Environmental Protection in **Thailand**

"Mae Hia" landfill near the city of Chiang Mai which was closed for fear of groundwater contamination.

BGR managed the technical co-operation project "Environmental geology for regional planning" from 1996 to end 2004 together with the Department of Mineral Resources in Thailand (DMR). The aim of the project was to support the sustainable use of geological resources in rapidly developing regions of Thailand by making environmentally-relevant geoinformation available to regional planners. This involved areas in the vicinity of conurbations where there is a high level of exploitation of geological resources and competing demands for the use of the available land.

The German contribution was to train DMR experts via practice-oriented and problem-focused courses and provide them with the qualifications required in the various disciplines, including groundwater protection, waste disposal, non-metallic resources/shallow construction materials, engineering geology, soil protection, remote sensing, geographic information systems (GIS) and database management.

This involved producing environmentally-relevant geoinformation in the form of thematic maps (1 : 100,000) on the above mentioned topics for the two pilot areas in Chiang Mai (phase I: 1996 – 1999) and Surat Thani (phase II: 2000 – 2001). The project ended in December 2004 with the completion of the training review phase (Nakhon Ratchasima project area focusing on groundwater and soil salination).

As a result of the project activities and the knowledge and experience acquired by the DMR experts via the training courses, the department now independently produces geo-risk and environmental geology maps for regional planning. The Environmental Geology section of DMR has also benefited from a considerable increase in staff numbers and funding in recognition of the importance of their work.

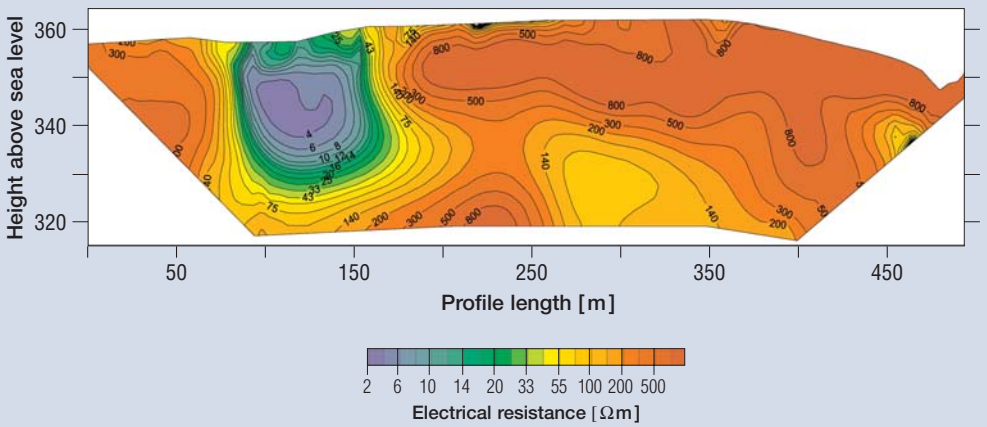
In a second agreement between BGR and DMR which is independent of the technical co-operation project,

activities focus on the problems surrounding the geological barriers of urban landfills, including detailed analysis following systematic site investigations. This WADIS research project (Investigation of Waste Disposal Sites) funded by BMBF (project agency: Water and Disposal, Karlsruhe) has the medium-term aim of also establishing the statutory multi-barrier system in Thailand which became obligatory in Germany in 1994. Other objectives include the elaboration of specific recommendations for suitable investigation measures for the evaluation of geological barriers. Managed by BGR, the project involves the co-operation of the Brandenburg University of Technology Cottbus, Geophysikalische Dienste GGD/Leipzig, Boden-Grundwasser/Dresden and Hansa Luftbild/Münster working in association with Thai partners.

In the Chiang Mai area, a broad range of geophysical and hydrogeological methods was used as demonstration examples on two open landfill sites to evaluate the protection properties of geological barriers and their risk potential. In another example on the Khorat Plateau, several potential sites for a planned landfill were evaluated to select the site with the best geoscientific parameters.

The evaluation of the field work was completed in 2004 and the results will be presented in 2005 in the form of publications and a working seminar involving the relevant groups from authorities, universities and engineering committees. Co-operation between German and Thai authorities and companies promotes the cross-border adoption of German environmental standards and improves the opportunities for German industry of becoming involved in future tenders for landfill planning contracts.

Vertical cross-section showing the electrical resistance of a landfill body located in a former quarry for construction materials. The sharp contrast between the electrically conductive contents of the landfill and the poorly conducting surrounding rock (very dry, clay-rich colluvial sediments) highlights the efficiency of the geological barrier at this position preventing the spread of contamination into the approx. 15 m deeper groundwater horizon.



Environmental Risks of Mine Dumps in **Botswana**

Dumping processing residues on a mine tip. The ore treatment plant is shown in the background.

Mine dumps consist of waste rock from mining or residues from mineral processing. Ore mining tips frequently contain significant quantities of metal sulphides. Exposure to atmospheric oxygen and water slowly convert metal sulphides, such as the minerals pyrite (FeS_2) and chalcopyrite ($CuFeS_2$), to sulphuric acid containing dissolved heavy metals. This acid mine drainage (AMD) is a serious environmental problem. Microorganisms within the mine heaps play a crucial role in the formation of AMD because they can speed up the chemical reactions by several orders of magnitude.

Understanding and quantifying the bio-geochemical processes taking place in mine heaps is vital for implementing suitable measures to combat the formation of AMD. A spoil heap at the copper, nickel and cobalt mine in Selebi-Phikwe, Botswana, was therefore intensively sampled in co-operation with the department of Environmental Geology and the drilling crew of the Geological Survey of Botswana. This sampling was conducted in November 2003 as part of a technical co-operation project with Botswana. Three boreholes were drilled down to a depth of 25 m. 66 samples were extracted from these boreholes and geochemically, mineralogically and microbiologically analysed.

Large quantities of *Acidithiobacillus ferrooxidans* bacteria were found down to depths of 25 m in the tip. They are thought to be responsible for the breakdown of the metal sulphides and the formation of AMD. Their presence also explains the low pH of 3 – 5 found in all the samples. Because of the very rapid biological oxidation of the mineral pyrrhotite (FeS), most of this mineral is already broken down into sulphuric acid and iron oxide within a few years of the material being dumped on the heaps after ore processing. Pyrrhotite should therefore be removed in the future before mine waste is dumped, and separately stored in the absence of atmospheric oxygen.

As part of the formulation of the "Mine closure plans", measures for securing the spoil heaps were discussed and presented at a "Technical co-operation workshop" in Botswana in November 2004.

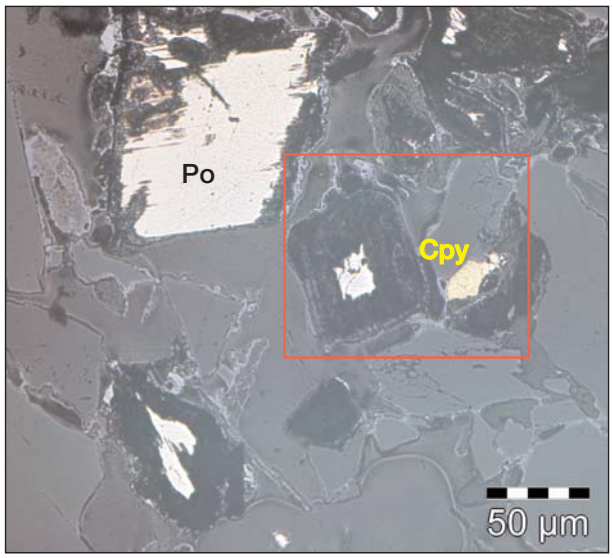
Drilling crew of the Botswana Geological Survey taking samples up to a depth of 25 m.

Modern Analytical Methods
– Quantitative and Qualitative Description of **Active Surface Areas** in Environmental Samples

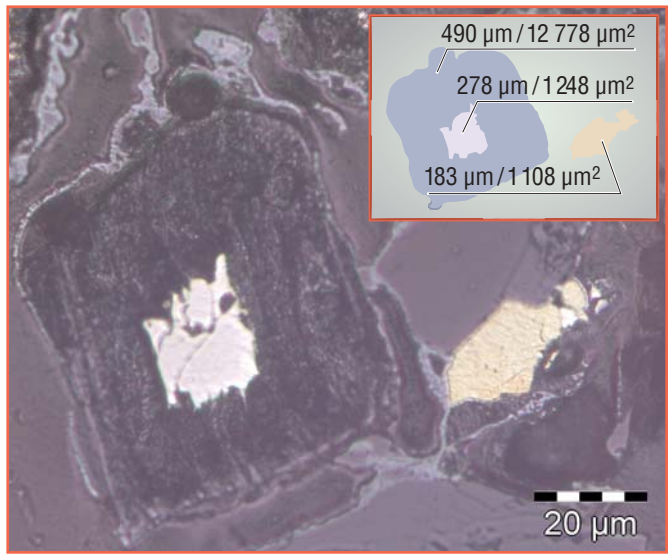
Microorganisms such as Fe^{2+}-oxidising bacteria of the *Acidithiobacillus* and *Leptospirillum* strains play a significant role in the generation of acid mine drainage (AMD) in sulphidic mineral heaps. One way of estimating the potential risk from bacterial alteration is to determine the proportion of sulphidic sulphur within the investigation area. The quantitative calorimetric method (absorption photometry) is a very good means of very precisely analysing the total concentrations. However, it provides no information on the spatial distribution of the sulphide minerals in the area of investigation or whether they are even accessible to microorganisms. This accessibility is characterised by factors such as grain size, grain shape and the degree of intergrowth of the minerals. These parameters ultimately determine the speed and proportion of bacterial metabolism.

The grain size and specific surface area of all mineral components available for reaction in a sample can be determined by sieving and subsequent adsorption analysis, for instance, determining the specific surface area according to the BET theory, a multilayer adsorption model already in use for a long time. However, this method only determines the total surface area of the mineral components. It does not detect and identify the phases which are important for bacteria. The surfaces are therefore overestimated. These time-consuming methods are also only directly usable on unconsolidated samples. Well-cemented samples first need to be crushed and ground. This changes the true grain association and therefore produces false results.

Image analytical methods do allow the separate characterisation of relevant components (e.g. pyrrhotine, pyrite) in a coherent series of samples. These statistical methods are similar to the point-counting method which has already been used for a very long time and in which the selected phases are counted where they fall on the points of a previously defined grid. In addition to the percentile portions of a phase within the total volume, it is also possible to mathematically determine other parameters such as their spatial distribution, adjacency relationships, grain surfaces, as well as their dominant grain shape and circumference. The results can be derived and evaluated using special software.



Polished sample from the Selebi Phikwe spoil heap in a reflected light microscope. Fragments of pyrrhotine (Po-FeS) and chalcopyrite (Cpy-$CuFeS_2$) float together with silicate fragments in an araldite matrix. The Po edges are strongly corroded. The original grain size of the Po is marked by the iron oxide alteration fringe. Chalcopyrite has only been slightly altered.



Detail. The figures represent the measured circumference : area ratios. The circumference : area ratio is increased by a factor of 5.5 in the residual pyrrhotine compared to the original state.

The accessibility of the surface of each reactive phase (e.g. pyrrhotite) and the individual toxicity of the reactive phase (raised Co, Ni, and Cu concentration, determined by electron microprobe analysis) influences the activity of the microorganisms. Such extremely detailed image-analytical investigations allow the microbial activities to be compared on different sulphide phases.

Image-analytical methods allow reliable conclusions to be drawn from the method used, which in this case involved studying polished samples from a borehole in a spoil heap and analysing the surfaces, structures and textures using simple two-dimensional models. This method is technically relatively simple and can therefore be put into practice easily. The surfaces of individual minerals can be determined to provide a better understanding of the weathering and alteration processes taking place in mine heaps.

Soil

Soil – Vital for Life, Economic Resource, and in Need of Protection

In common with air and water, soil is essential for life, a vital medium with numerous functions: soils fundamentally support the life of humans, animals, plants, and soil organisms. With their water and material cycles, they are part of our natural environment. Substances – including harmful substances – are stored and transformed by soils. Soils therefore function as buffers and filters. In this way, they enable the growth of plants, protect groundwater, and therefore maintain our food production.

Ever since the development of permanent settlements, humans have used soils in many ways. The traces of this activity have had a permanent impact on the soil, as have climatic fluctuations in the past. Thus soils are also archives of natural and cultural heritage. Moreover, soils perform economic functions: they provide raw materials and accomodate areas for building, recreation, agriculture and forestry, as well as for transport infrastructure, and public supply and disposal systems.

Soils are formed when rocks weather and air and water together with the altered fine rock particles form a medium supporting animal and plant life.

The substances and their concentrations in soils vary considerably depending on the composition of the rock from which the soils formed and the processes taking place within the soil. Soils develop very slowly. Depending on the climate and the rock type, it takes between 100 to 400 years to form one centimetre of soil. Soil scientists therefore classify soils as a scarce, barely renewable natural resource.

Because of the dependence of the development of soils on the type of underlying rock, and the diversity and different functions of soils, especially their economic uses, and the fact that they are a scarce resource, "soil" is one of the key fields of activity of the geoscientifically focused BGR.

In addition to the economic aspects, the sustainable use of our environment also plays a particularly important role – not only at a national level – but also within the European context. In this regard, in the past two years, four of BGR's soil scientists were members of different panels of experts involved in elaborating a European soil protection strategy for the European Commission.

Against the background of the increasing importance of soils for sustainable development, standardised analysis, evaluation and application of soil information becomes ever more important. This applies to Germany as well as Europe as a whole. The drafting and provision of cross-border European base maps is managed by the European Soil Bureau, a European association in which BGR is not only a member, but also made a major contribution by producing the Soil Regions Map of the European Union and Adjacent Countries.

The standardised collection, evaluation and application of pedological data in Germany mainly involves the standardisation of the already existing soil databases held by the various authorities, universities, and others. BGR works towards this goal together with the national Geological Surveys of the German states. One example is the 1 : 200,000 Soil Base Map for the whole of Germany being drafted by BGR together with the German states on behalf of the Federal/State Geological Committee (BLA-GEO, a board established by the conference of German economics ministers). Conversion rules for comparing recent German pedological mapping instructions (KA3 & KA4), and FAO and WRB nomenclatures were published in 2004, and the fifth edition (KA5) of the pedological mapping instructions was presented.

The Federal Soil Protection Act (Bundes-Bodenschutzgesetz, BBodSchG) in combination with the Federal Soil Protection and Contaminated Sites Ordinance (Bundes-Bodenschutz- und Altlastenverordnung BBodSchV) came into force in 1999 to ensure the long-term protection of the soil in Germany. However, since applying the regulations, some open questions on a few aspects have arisen, which require further elaboration. The application-oriented research projects on seepage water prognosis for example aim to investigate the dispersion paths of percolation water in the soil and to study and estimate the associated transport of contaminants. This will provide a geoscientific basis for amendment of the legislation. This example highlights the close interaction of soil and water, which also applies to the experts in each discipline. They not only work together on national research projects, but also on technical co-operation programmes looking at the long-term maintenance of drinking water supplies in developing countries. One example is the Kalahari, where BGR water experts together with soil experts tackle the problem of raised nitrate concentrations in groundwater in Botswana (cf. Water).

The projects referred to above provide the information required to advise the political committees which decide on the future development of our economic and natural environment. The German government, the European Commission and decision makers in developing countries must always be well informed about the opportunities for using soil and the need to protect it as a limited and barely renewable resource. Only then can their citizens live in a sustainably managed environment.

Soil Regions Map of the European Union and Adjacent Countries **1 : 5,000,000**

Comparable georeferenced soil data are a prerequisite for joint European agro-environmental policy. Therefore, the *European Soil Bureau (ESB)* with the involvement of BGR issued working instructions back in 1998 describing the methods used to create a co-ordinated European Soil Database. This *"Manual of Procedures of the Georeferenced Soil Database for Europe"* also contains a first version of the Soil Regions Map of Europe.

The recently published Version 2.0 was significantly modified and expanded for three main reasons:

- In 1998, the international soil classification was changed from the *"FAO Soil Map of the World – Revised Legend"* to the nomenclature in the "World Reference Base for Soil Resources (WRB)", which is now also incorporated in the new soil regions map.
- The *"Soil Geographical Database of Europe 1 : 1,000,000"*, which is currently the most important basis for evaluating soils in Europe was greatly improved and extended to include eastern Europe, the whole of Russia, Mongolia as well as the whole of the Mediterranean area. This makes available the basic data required for the new EU member states, eastern Europe, and Turkey, which are now integrated within the map. It also corrects the presentation errors in the first version.
- The topographic base had to be converted to the *Digital Chart of the World* to enable intersections with maps from other countries and graphs from the EU soil database.

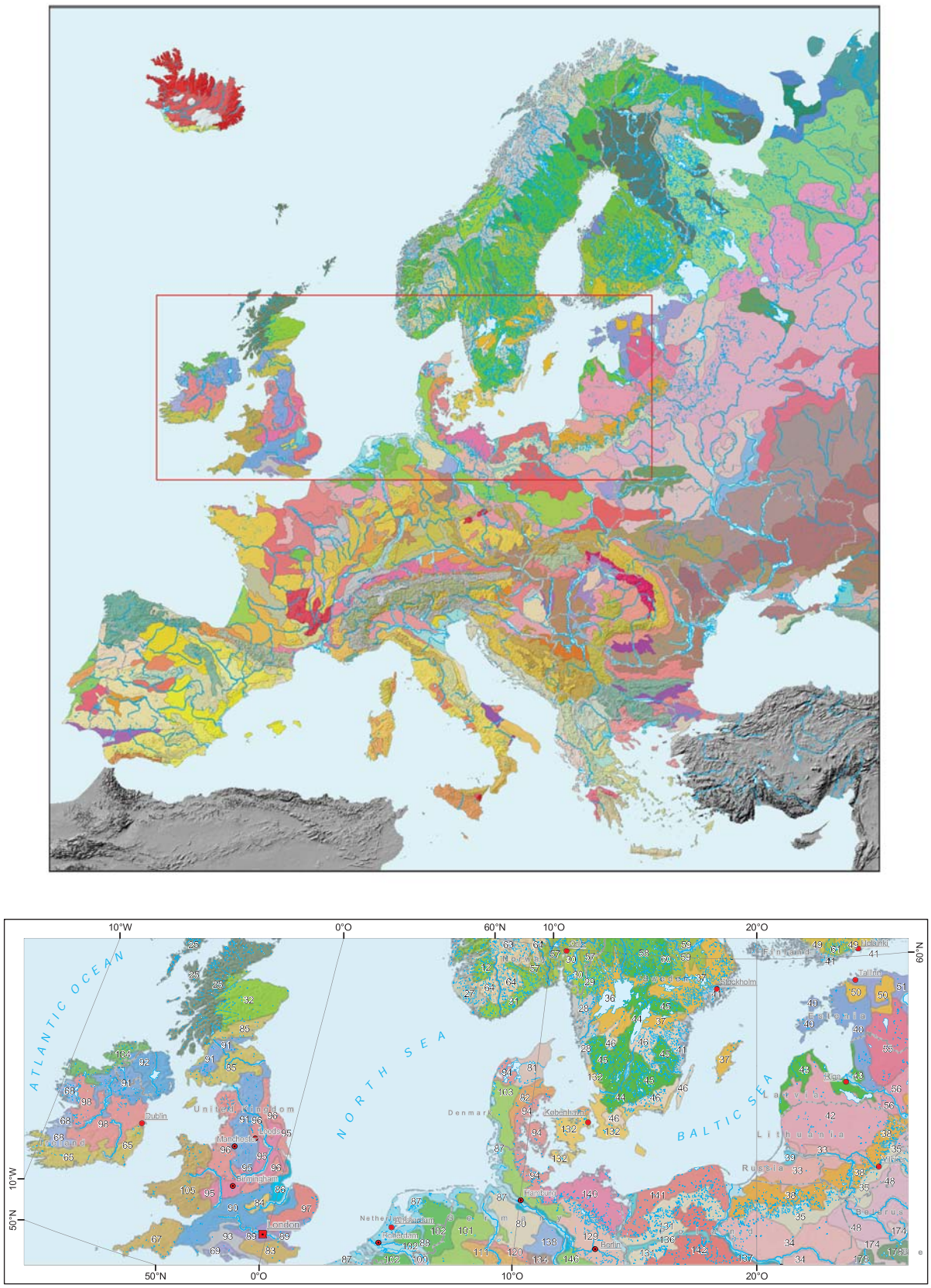
General Designation of Soil Regions

Within a national framework, as well as at an EU level, the soil regions form the uppermost level of soil mapping. As natural soil geographic units in which the soil formation conditions are very similar, they form the highest level of generalisation. Pedological details are deliberately avoided in their delineation and description.

Soil regions are supra-regional soil units. Their delineation is mainly based on geological, morphological and climatic criteria. Geological-morphological factors control the features and distribution of forms of relief and determine the substrate compositions in each of the soil regions. Climatic factors have a major impact on the pedogenetic processes and thus determine the characteristics and trends in the soil types. They are also of major importance for their potential yield. Because of their level of generalisation, soil regions also contain inliers of areas with atypical soils, "foreign areas".

The associated soils are described very generally in soil regions by referring to the most important soil types differentiated according to dominant and associated soils, and to the dominant parent material. There is generally no compilation according to soils as a combination of soil type and substrate type. However, it is possible to indirectly derive the substrate composition from many soil names in the nomenclature of the *World Reference Base for Soil Resources (WRB).*

By definition, a soil regions map only contains general aggregated information on each type of soil. Because of the small scale of the map, the boundaries of the soil regions are strongly generalised and only appropriate for small scale presentations and applications.



The Soil Regions Map of the European Union and Adjacent Countries. The upper part of the figure shows the whole map at a very reduced scale, below there is a section at a scale of 1 : 15 million.

Extrapolation to a larger scale for presentation purposes must always be associated with adaptation to the adequate topographical base. Using the soil regions at larger scales is of limited use because of their frequent heterogeneous composition. However, if this is demanded by a user, it should be done by incorporating a higher level of resolution of the soil data.

Purpose of the Soil Regions

Soil regions are not only soil units with very strong areal and compositional generalisations, they are also a classification category in legends and soil databases. In this context, they fulfil several tasks simultaneously:

- Their representation on maps means that the soil regions provide the quickest and most comprehensive overview of soil distribution in a supra-regional or cross-border area.
- They are the first source of information for the evaluation and classification of soils in Europe.
- The soil regions allow a comparison between the soil formation conditions in different European climatic areas.
- As a classification category in a soil database, the soil regions can be assigned to typical soil associations (e.g. as legend units).
- They form the basis for the selection of pilot areas for the elaboration of the *Georeferenced Soil Database for Europe at a scale of 1 : 250,000.*
- The soil regions provide the comparative framework for soils in cross-border projects.

The new Soil Regions Map is currently the only graphical representation of soils in Europe which evaluates all of the basic data from the same point of view, and separates the soil units according to uniform criteria. It is a working tool that will be fully integrated into the existing databases and will be of use for purposes involving the environment in particular.

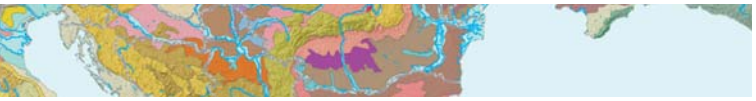
Delineation of the Soil Regions

The most important basis for the classification of the soils in the soil regions was the *Soil Geographical Database of Europe 1 : 1,000,000*, because this provides the necessary data on the dominant and associated soils. For some of the old EU member countries, the Soil Map of the European Communities 1 : 1,000,000 forms the basis for this database. European-wide soil information is also contained in the *Soil map of the world, Volume V, Europe, the World Map on Status of Human-induced Soil Degradation – Global Assessment of Soil Degradation*, as well as other general soil maps, e.g. the base maps of the *FAO World Soil Resources and Global Soil Regions*.

Almost as important as the soil maps for the delineation of soil regions are the geological and geo-morphological maps. They are used to identify areas with more or less uniform parent material, similar relief and water conditions, comparable transport conditions for nutrients and pollutants, as well as for soil erosion and accumulations.

The *Map of the Natural Vegetation of Europe 1 : 2,500,000* is also very useful for the delineation of soil regions. It provides a good summary of the vegetation conditions in Europe – which also excellently reflects the natural soil forming conditions – and the climatic conditions which affect the pedogenetic processes as well as plant growth.

However, because all of this documentation is still inadequate to delineate the soil regions, there is also direct collaboration with soil scientists from the countries involved. Nevertheless, there are still major differences in the structure and degree of detail in the drafts provided by the different countries. They were often broken down into very small areas, particularly in the case of small countries, and were therefore largely unsuitable for extrapolation to the overall European level. Adaptation to the base map character of the Soil Regions Map was therefore essential in these cases.



Map Structure

The "Soil Regions Map of the European Union and Adjacent Countries" project consists of three main parts:

- 1 – the map with the margin legend
- 2 – the explanatory text
- 3 – the database

The map and the explanatory text have now been completed, but the setting up of the database has only just begun. Completion of this part is expected in the second half of 2005.

The 1 : 5,000,000 Map

This map contains the soil regions marked by boundaries, colours and code numbers, as well as a background depiction of relief. This allows a direct visual connection between soils, elevation, and major land forms.

The boundaries of the soil regions are adjusted to correspond to the topographic features at a scale of 1 : 5,000,000. The topographic base is a generalised version of the *Digital Chart of the World (DCW)* which has a superimposed background relief. The names of countries, cities, lakes, rivers and oceans are provided for geographical orientation.

The colours reflect the most important dominant soils and are adjusted to the *Soil Map for Europe 1 : 4,500,000*. It is important to note here that the colours only reflect the general tendency of the soil associations in each soil region, and therefore, that a second or a third dominant soil will always appear to be under-represented. The colours of the soil regions must always be compared with the relevant legend units.

The successive identification numbers allow allocation of the mapping units described in the legend to the areas of the map, and reference to the soil region descriptions.

A graticule simplifies orientation on the map. The map projection is a Lambert conformal (isogonal) conic projection. This is particularly good for presenting European countries and displays larger areas with relatively little distortion.

The Margin Legend

The legend in the margin of the map sheet is divided up into climatic areas because Europe is a continent with very different climatic zones which have a very different influence on soil formation. It contains a brief labelling of the soil regions according to dominant and associated soils and according to the dominant parent material.

The dominant and associated soils in each soil region are classified according to the nomenclature in the *World Reference Base for Soil Resources (WRB)*. The number of soils which are present is an indirect measure of the homogeneity or the heterogeneity of soil regions, and also largely depends on the complexity of the parent material.

The legend includes an explanation of the symbolic colours of the main soil types so that their areal distribution can be quickly determined without having to consult the details in the description. In addition, it also incorporates the most important base data as well as a selection of special references used to delineate the soil regions.

Map Contents

The climatic areas of Europe

Many soil parameters and soil properties are influenced by the climate, e.g. the climatic water regime, the groundwater regeneration rate, or the water-logging typical of many soils in spring in large areas in Europe. A map of the climatic areas in Europe, including their labelling, is attached in the explanatory text. This shows the climatic zones as they occur from north to south, and their further subdivision into climate types with oceanic to continental influences. There are 35 climatic areas in total with clear differences in average temperatures, annual precipitation and length of the vegetation periods.

The soils

The legend in the soil region map lists the dominant soils and associated soils for each soil region according to their dominance, i.e. the most important soil first followed by the second, and so on. Soil associations are always described in each soil region. The lower the number of soil types in a region, the more uniform the structure of the region with respect to climate, relief, parent material, water conditions and land use. Regions with more soil types and greater differences between the soils have more differentiated soil formation conditions and are more fragmented.

The Soil Regions Map presents over 120 different dominant soil associations. Because there are 284 soil regions, this means that almost one in two has the same sequence of dominant soils. However, the differences in soil associations are due to the associated soils, the parent material or because they belong to a different climatic area.

If the distribution of soils across Europe is considered in general, one sees that large areas of northern and eastern Europe have very uniform soils. Central, western and southern Europe in contrast have a more varied soil coverage. The soil formation factors responsible for this differentiation are the geological structures and the associated parent material.

Parent material

The geological conditions – which include the parent material – have a major effect on the character of a soil region. They have an influence on relief and the topographic elevation of a region and are of enormous significance for the mineralogical composition, chemistry and structure of the soils. Parent material influences the soil texture and has a major impact on soil fertility and nutrient supply because the length of root penetration, the presence of pore spaces to accommodate water and air, and the weathering properties of the minerals which release the important trace elements, all depend on the parent material and differ according to rock type. Rock composition also has an influence on soil use to some extent because very weathering-resistant rocks give rise to very thin soils which are largely unsuitable for farming and therefore tend to be used for forestry or as grazing land.

The classification of dominant parent material in soil regions reflects rock associations which often consist of very different types of rock. It is important at this level of aggregation to clearly highlight whether the rock involved is unconsolidated or consolidated, and whether it consists of igneous, metamorphic or sedimentary rock. This information is supplemented by the rock chemistry (acid, intermediate or alkaline), the texture (clayey, sandy or loamy) and information on geogenesis and stratigraphy.

A compilation of 18 rock complexes was elaborated to present the *Associations of Dominant Parent Material* in an extra map. These rock complexes combine rocks which share the same geological-paleogeographical development, or have been brought together by various geological processes so that they now occur alongside one another in a particular landscape. When evaluating them, it should be noted that the soils do not usually form directly on the rock itself, but on its weathering products. As a result of an enormous spectrum of movement processes such as landslides, vertical and lateral material transport, solifluction, and cryogenic mixing in periglacial areas, not to mention the aeolian transport of loess and aeolian sand, this weathering material not only includes the originally underlying parent rock, but also numerous foreign components. Many layers of superficial strata formed largely under periglacial conditions. The vertical sequence and material composition of these superficial strata have a major influence on soil structure and soil properties.

■ Relief

Relief is a geo-component with almost unchangeable properties. It has a major influence on the properties of soils as well as the delineation of soil and landscape units. It is particularly closely associated with the hydromorphology of the soils because, depending on the substrate, it determines the position of the groundwater or impounded water bodies. Relief also has a strong influence on soil erosion – and on water erosion especially.

Ancillary maps first present the basic relief of Europe. This is then extrapolated to the soil regions as a combination of 7 elevation and slope classes. For the soil regions, the elevation and slope factors are areally weighted and grouped, and presented in a way similar to the SOTER programme. The map shows the typical effects of these two factors in the soil regions. It reveals a clear relationship between relief and soil type.

■ Land use

In addition to the natural vegetation, an important role in the evaluation of European soils is played by the current land use as derived from the CORINE land cover *(co-ordinated information on the environment)* and the PELCOM programme *(pan-European land use and land cover monitoring)*. The ancillary map shows the dominant patterns of use and their wide range in each soil region. 21 classes are shown in all arising from 10 different land uses and five levels of heterogeneity. The land use pattern provides an insight into the natural soil distribution in Europe.

Summary

The Soil Regions Map of the European Union and Adjacent Countries is integrated within the programme of the European Soil Bureau Network which has the objective of improving the understanding of soils in Europe and the Mediterranean area. The corresponding soil database has different levels of aggregation and generalisation so that information in the required amount of detail is available to soil scientists and to support political decisions made on agro-environmental issues at a European level. The present map contains 284 soil regions and a legend. An accompanying booklet describes the content and explains the purpose behind the Soil Regions Map, and includes ancillary maps on the European climatic areas, parent material, relief and land use.

Seepage **Water Prognosis** for Inorganic Contaminants

The development of methods aimed at preventative soil and groundwater protection has to be based on reliable science. Experts from the BGR are involved in a research project on the prediction of contaminant transport in the vadose zone funded by the Federal Ministry of Education and Research. This "seepage water prognosis" looks at ways of forecasting the transport of contaminants from the source (site of sampling) via the vadose zone, into the groundwater (site of assessment). Seepage water is defined as the proportion of rainwater which percolates through the soil down to the groundwater and can thus transport contaminants from polluted surface soil into the groundwater.

Measures to protect groundwater must be implemented well in advance of the occurrence of damage to the groundwater. This requires the development of forecasting methods which can predict the expected transport of contaminants from a source to the groundwater within the foreseeable future. Models of this type are intended to be used in future by authorities and engineering consultants when carrying out expert evaluations of future soil and groundwater contamination.

Scientists at BGR are developing a model of this kind. The model's scope of application is the transport of trace elements such as antimony, lead, cadmium, chromium, copper, molybdenum, nickel, thallium and zinc. The major aspect being looked at as part of this development is the broad applicability of the model to a whole range of locations and the assessment of uncertainty in the forecast.

Soils can prevent the transport of contaminants.

Soils are able to slow down contaminant transport to a varying degree and reduce the risk of contamination. This buffering and filtering effect of soils varies depending on the properties of the soil involved. Understanding these processes is vital for the development of a generally viable forecasting method. In this context, approx. 390 representative soil samples from Germany were analysed to determine their ability to bind the aforementioned trace elements. Analysis of the soils involved adding increasing amounts of contaminants to the soils and subsequently measuring the proportions bound by the solid soil phases and the proportion entering the soil percolating water – which could therefore be washed out into the groundwater. The results of these laboratory tests were used to produce "adsorption isotherms".

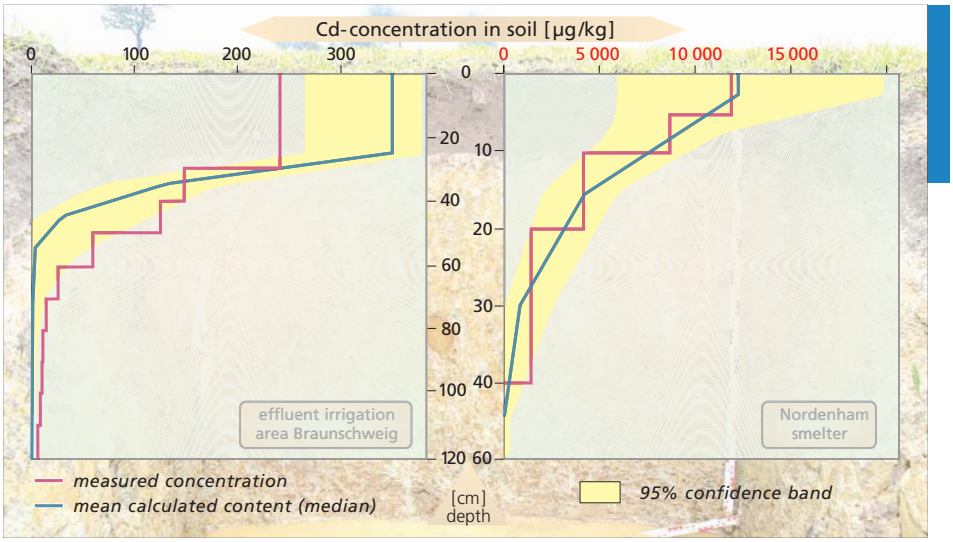
Multiple regression methods can then be used to extrapolate the adsorption isotherms to general functions ("pedotransfer functions"). These pedotransfer functions allow analysts to derive the contaminant retention capacity of a soil with a known degree of statistical reliability from its composition and its properties. Expensive sampling and analysis programmes are therefore no longer necessary and the amount of time involved in making forecasts is significantly reduced.

Model predictions correspond well with measured data.

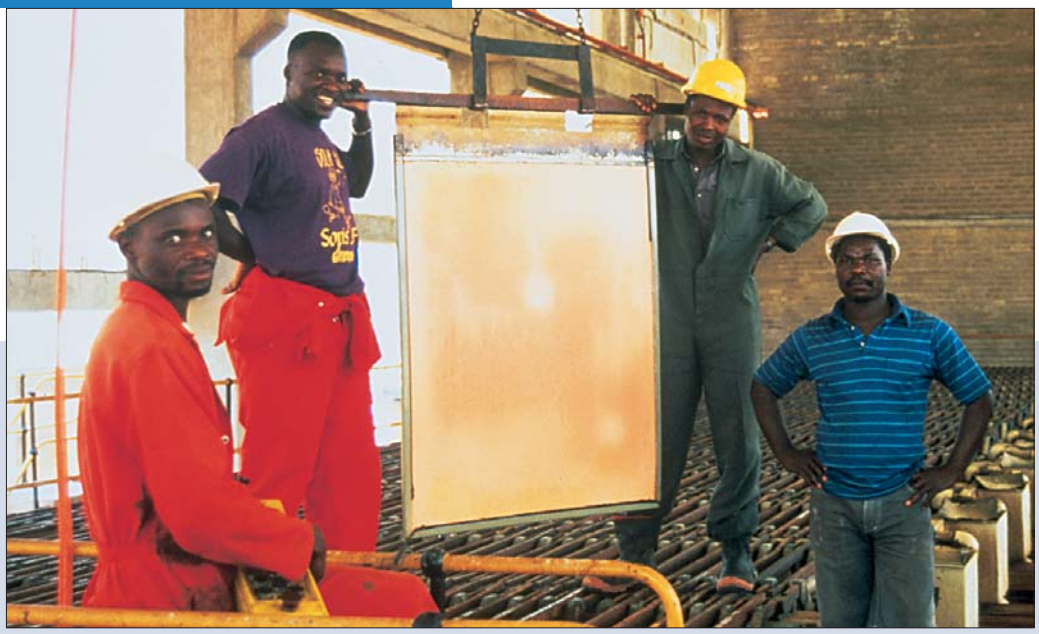
Because soils are subject to strong natural variation (and therefore also of their contaminant retention capacity) a forecast is always associated with some uncertainty. The estimation of contaminant retention capacity by using pedotransfer functions is also subject to a degree of forecast uncertainty. The developed forecast models take these uncertainties explicitly into account and express them in the forecasts.

The model developed by BGR was tested on data from areas which suffered from considerable contamination in past decades, including cadmium pollution.

The figure shows the results of this comparison for a soil profile in the vicinity of a metal smelter in Nordenham, as well as a soil profile from a wastewater irrigation area in Braunschweig. The calculated average Cd concentrations in soil correspond relatively well with the measured Cd concentrations when the 95 % confidence bands are also taken into account. The predicted breakthrough curves shown here indicate that the developed model – including the pedotransfer functions on which it is based – can be used with confidence when describing the heavy metal retention capacity of soils for a whole range of locations in Germany.



Measured and forecast cadmium concentrations in two different soil profiles.



Mineral Resources

Mineral Resources
– One of Mankind's Basic Needs

Mineral resources have been one of mankind's basic needs throughout history from the stone age, bronze age and iron age until today – and their importance to modern industry is unrivalled as evidenced by continuously increasing consumption. Anyone building a house, renovating an old building or modernising their kitchen is often surprised by recent surcharges on the planned costs: guttering has become more expensive because the price of zinc has risen, electricians have to charge more for copper cables, and even that new stainless steel sink costs more than a few years ago because of the considerable increase in raw material prices.

The consequences of supply problems and rising prices not only irritate do-it-yourself enthusiasts and house builders, they are also very serious for the producing and processing industries. Germany is completely dependent on imports for all its mineral resources with the exception of salt and construction minerals. The government provides German industry with a technical and scientific infrastructure that conducts research and provides advice on important commodities. BGR is the most important institution investigating mineral resources and monitoring the international commodity markets.

BGR is the only institution in Germany bundling a wide spectrum of knowledge, experienced staff and up-to-date databases for a large range of consulting activities on mineral resources, environmental protection in the mining industry and the consequences of mining activities. Its comprehensive consulting capacities are underpinned by technical excellence and scientific equipment which is unique in Germany, and provides the means for conducting first-class international research in a large number of disciplines covering mineral resources. BGR has set itself the important goal of safeguarding the resource base for German industry.

Most projects on mineral resources conducted by BGR are carried out in close co-operation with national and international partners at universities, research institutes, Geological Surveys or industry. This provides fast access to additional specialist know-how and technologies.

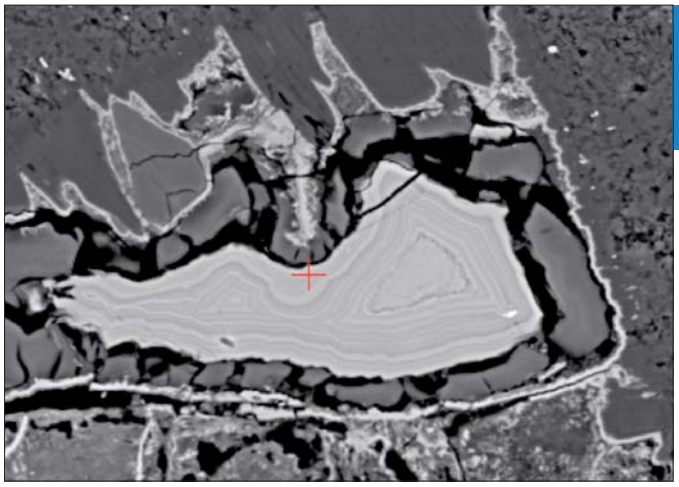
BGR's projects currently deal with a number of topics. Examples given in this report focus on industrial minerals (characterisation of bentonites and glass sands), high-tech metals such as the platinum group elements, and the development of microanalytical techniques.

Oxidised Platinum Ores

Platinum and other platinum-group elements (palladium, rhodium, ruthenium, iridium, and osmium) are produced from the processing of ore-bearing solid rock. Little information exists to date on near-surface oxidised zones. BGR is studying these oxidised platinum ores in order to identify ways for their exploitation and expand the range of potential suppliers.

The oxidised zones (weathering zones) of ore bodies containing platinum-group elements (PGE) are important PGE resources (e.g. more than 400 million tonnes in the Great Dyke, Zimbabwe). However, there are currently no treatment methods suitable for the economic extraction of the metal from these ores.

Ore deposit of the "Main Sulphide Zone" with oxidised platinum group elements, Hartley Mine, Zimbabwe.



Polished section of an oxidised platinum ore under an electron microprobe (width of figure c. 200 µm).

The economically exploitable PGE-rich horizons in the "Main Sulphide Zone" (Great Dyke) as well as the Platreef, Merensky Reef and UG2 (Bushveld Complex, South Africa) have been deeply weathered down to depths of 20 – 50 m. In the non-oxidised zones, PGEs (primarily palladium in pentlandite) are partially hosted by base-metal sulphides, or they form discrete platinum group minerals (PGM), usually compounds with the elements sulphur, arsenic, bismuth, tellurium and antimony.

In the weathered ores, the PGE concentrations in the total rock are very similar to those in the unweathered ores – with the exception of slightly lower palladium/platinum – even though the primary base-metal sulphides are largely oxidised and most of the PGMs have been either modified or dissolved.

The PGEs are present in various forms within the oxidised ores as

(1) relict PGMs and pentlandite,
(2) PGE oxides/hydroxides,
(3) secondary PGMs (< 1 µm),
(4) in secondary sheet silicates, and
(5) in Fe hydroxides and Mn-Co-Ni hydroxides.

This project involves the mineralogical and geochemical characterisation of oxidised PGE ores from Zimbabwe and South Africa. The aim is to clarify the types of bonding of the PGEs and to quantify the various PGE phases. The results will form the basis for laboratory scale experiments on mineral separation.

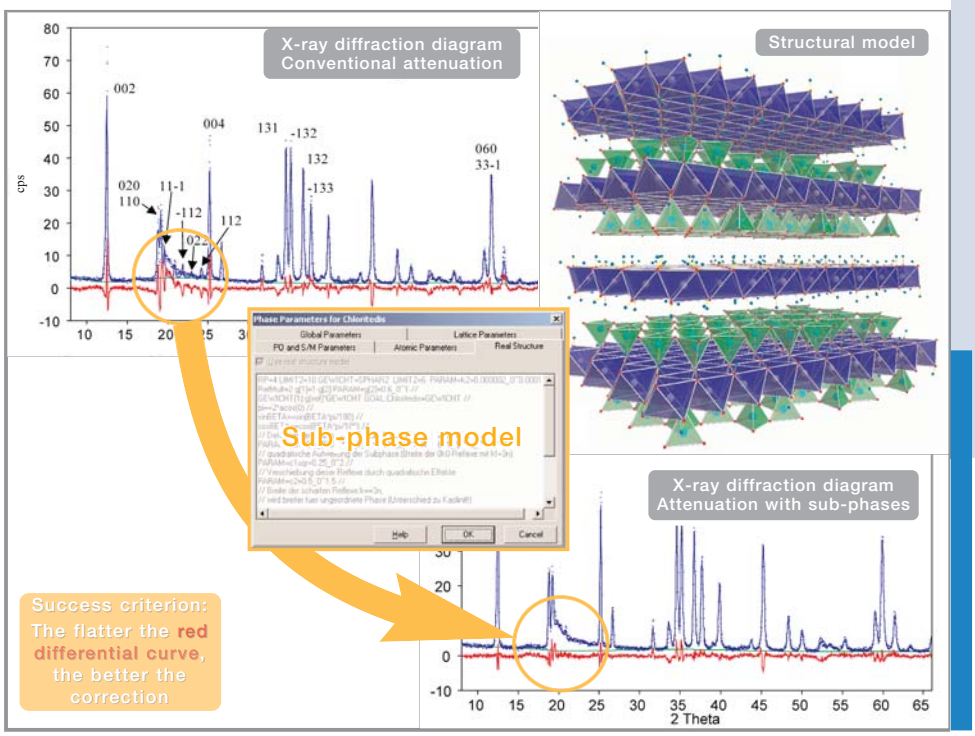
Quartz Round Robin
for German Mining Law (§ 3 Bundesberggesetz, BBergG)

In autumn 2003, the ad-hoc AG Rohstoffe (Natural Resources Working Group of the Federal/State Geoscience Committee) asked BGR to organise a round robin for the quantitative determination of quartz concentrations in sand raw materials.

This initiative was stimulated by the effort to establish standard methodological regulations which can be recommended with the support of all federal German states to guarantee reliable confirmation of the statement: "This raw material contains less than / more than / or exactly 80 weight-% quartz". This is then to be incorporated within § 3 BBergG (German Mining Law). BGR as the responsible government agency was accepted by the state Geological Surveys as a neutral institution to carry out this task.

Nine different resource samples (weight between 1 to 5 kg) were made available by eight state Geological Surveys. BGR then produced two artificial mixed samples with a known composition from suitable natural and artificial standards. These materials were then analysed by the participating laboratories. The benchmark – the BGR reference value – was the proportion determined by BGR using a combination of different analytical techniques. The best correspondence with the BGR reference values was achieved using X-ray diffraction (determining the mineral components using X-ray analysis). The best results here were achieved by a laboratory using the Rietveld method (quantitative calculation program for mineral constituents) which lay slightly ahead of a laboratory using the single line method (classical mineral determination method).

Evaluation of the results and discussion by the ad-hoc AG Rohstoffe finally put to an end a lengthy controversy. The recommendation was for X-ray diffraction analysis. The use of ortho-phosphoric acid for mineral determination is therefore now no longer recommended.



Disorder models within fundamental parameter Rietveld programs improve the description of variable peak distribution, shifted positions and asymmetric peaks. This leads to better correlation between measurements and calculations.

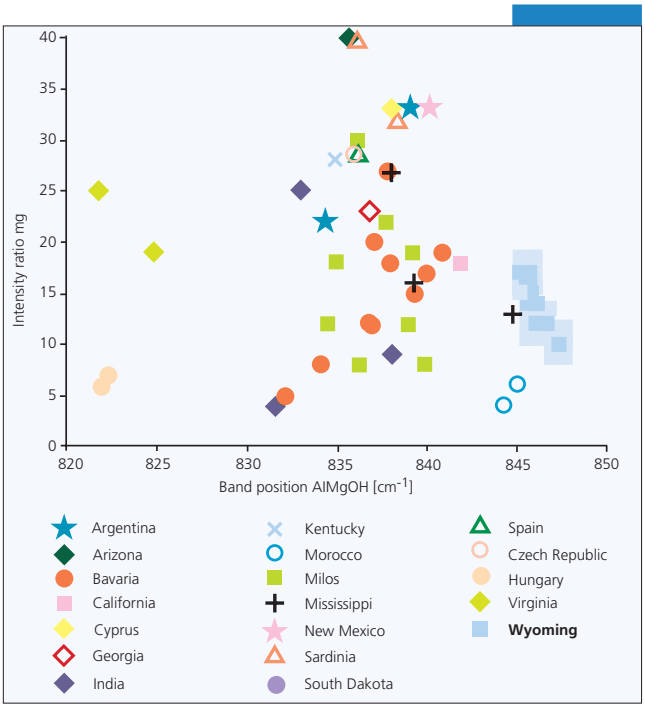
Identifying **Wyoming Bentonites** Using **Infrared Spectroscopy** as a Fast Method

Bentonites (clay minerals) are mined and used in huge quantities world-wide for a wide range of applications. The main constituent of bentonite is a clay mineral from the smectite group (usually montmorillonite). The physical properties of bentonite from different deposits vary considerably.

In many areas of application, it has not previously been possible to unequivocally explain why a particular bentonite is good and another worse or even unsuitable. Bentonites from the Wyoming and South Dakota deposits (Wyoming bentonite) have particular characteristics which have so far only rarely been attributable to measurable parameters. In general, the identification of the unknown origin of a bentonite sample is of major interest to the clay industry.

Identification of Wyoming bentonite is of particular importance. In this study carried out by BGR in co-operation with the University of Aachen (RWTH), a method was developed for determining as accurately as possible whether a bentonite is a Wyoming bentonite. This method is based on infrared spectroscopy which enables the observation of bands in the MIR range (medium infrared) which reflect the composition of the octahedral layer in smectites. It is already known that the composition of this layer varies considerably between different deposits as well as within a single deposit or district.

The intensity and position of the AlMgOH band proved to be particularly characteristic of Wyoming bentonites. A chart was developed based on the analysis of 60 bentonites which can be used to identify Wyoming bentonites even if they are in the form of reprocessed products – as long as the Wyoming bentonites are not mixed together with other bentonites.

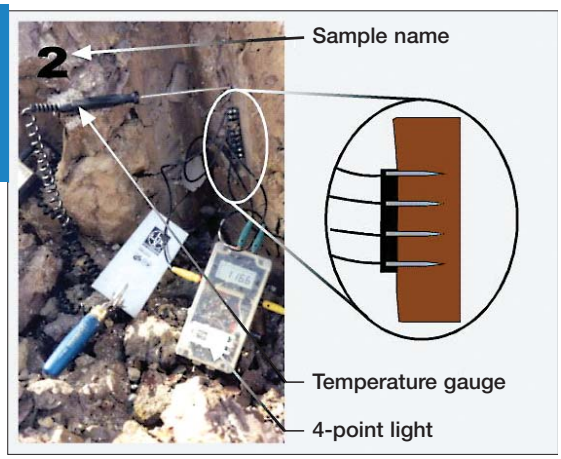


The blue "Wyoming-ATR field" can be used to differentiate Wyoming bentonites from the bentonites in most other deposits. The sample from Mississippi (black cross) indicates that this material is genetically related to the Wyoming bentonites.

Testing the **SER Method** on **Ceramic Clays**

Clays have an enormous range of applications ranging from ceramics and landfill seals to cat litters. A simple method of determining the qualities of a clay are sought to make it possible to identify the potential uses of a clay by testing directly at a clay pit.

In 1998, a method for the in-situ quality control of Bavarian bentonites was developed.



SER method: measurement of specific electrical resistance with a miniaturised Wenner arrangement (dES = 2 cm) and temperature. The water content is determined in parallel using fast drying scales.

Measuring the specific electrical resistance (SER) of rocks is used for many purposes in the geosciences (borehole geophysics, groundwater exploration, deposit prospecting or exploration, monitoring the density of landfill sealing barriers, etc.). The mechanism responsible for the conductivity of clay-poor rocks is largely understood. However, the interaction of the various conductivity mechanisms involving clay-rich rocks is still largely unknown. This is primarily because the spatial arrangement of the clay minerals varies enormously, and because it is still difficult to analytically determine all of the potentially important parameters.

Usable results can be obtained if analysis is restricted to special clays because this reduces the number of variable parameters. This makes it possible to gain more information on the conductivity mechanism of clay-rich rocks.

The specific electrical resistance of these special clays primarily depends on the cation exchange capacity (CEC), the water content and the temperature. By measuring the SER, the water content (with fast drying scales) and the temperature (penetrating sensor), the CEC can be calculated and can be converted into an approximate "commodity concentration" (smectite concentration). The commodity concentration is an important quality of bentonites. It is not known whether the smectite concentration or the cation exchange capacity is the parameter determining conductivity. Both parameters are associated with the layer charging density of the smectites which is relatively homogenous in the area of investigation. A relatively higher and lower layer charge density was measured in two single samples (out of 80 samples). If these samples are taken into consideration, it indicates that the specific electrical resistivity depends less on the cation exchange capacity than on the amount

of smectite present. However, this question cannot be unequivocally answered because of the large number of parameters involved.

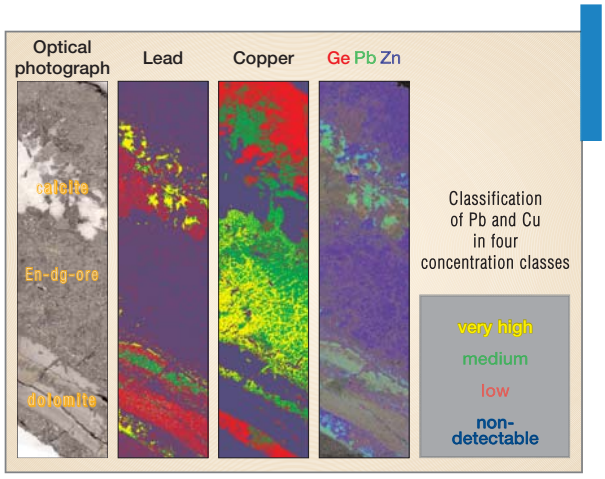
The aim of this study conducted by BGR was to assess the applicability of the SER method to ceramic clays. The conventional measure of quality is the Al_2O_3 concentration (aluminium oxide content) which is closely associated with the kaolinite concentration. 25 SER and temperature measurements were carried out in four clay pits. Samples were also taken to determine the water content. The samples were analysed to determine the chemical and mineralogical composition and the ceramic parameters. To evaluate the applicability of the SER method, a comparison was carried out between the in situ measurable parameters and the various ceramic parameters and the main quality characteristic, the Al_2O_3 concentration.

The investigations revealed that the specific electrical resistance of the ceramic clays (analogous to the Bavarian bentonites) can be described by the cation exchange capacity and the water content. However, the ceramic clays have slightly better conductivity with respect to the cation exchange capacity. It is inferred that the clay minerals kaolinite and illite which are present in addition to and in larger quantities than the smectites (which determine the cation exchange capacity) have an influence on the conductivity. For identical concentrations of clay minerals, the conductivity of kaolinite and illite are estimated to be 1/10 of the conductivity of smectites.

The cation exchange capacity of ceramic clays is not generally used as a quality characteristic. And because the ceramic parameters can be better explained by the chemical composition rather than by the SER method, the use of the SER method by the ceramic industry as a tool for determining the quality of ceramic clays is considered to be low. However, these clays are also used in part for constructing landfill seals and as cat litters. For these applications, the CEC is an important quality characteristic and one which can be approximately determined in situ using the SER method.

Microanalysis – **High-Tech Methods** Back up Classical Field Work

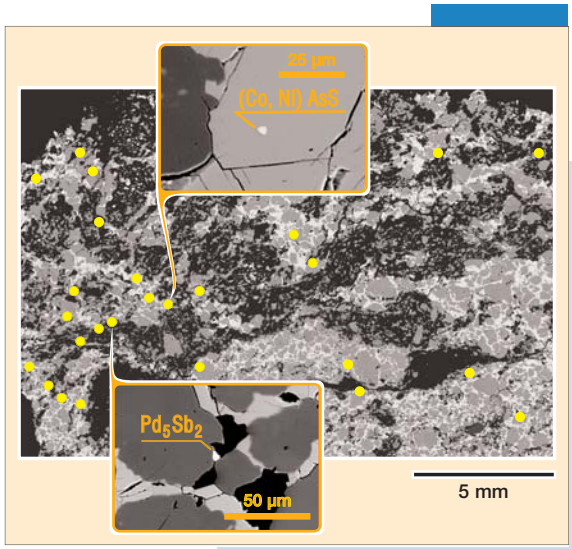
"Mente et malleo", mind and hammer, are the classic tools of geoscientists. Even in this age of modern IT and analysis techniques, these tools are still indispensable for the exploration and evaluation of mineral resources. In addition to the classic skills of mineral identification and mapping, geoscientists have in recent years used a number of high-tech methods which significantly increase the amount of information gained from field work.



Weathered ore from Tsumeb, Namibia. The geo-scanner provides images of element distribution, the ore fabric and the positions of rare minerals.

BGR makes use of many state-of-the-art analytical methods. The latest measuring and analytical techniques are tested to assess their value in the exploration and exploitation of mineral resources. Measuring and analytical techniques are also developed by BGR. BGR can provide the technical expertise required for this purpose, which often demands very specialised knowledge and equipment.

One focus is on microanalysis – the analysis of tiny parts of a sample. Electron microprobes can be used to localise even the most finely dispersed minerals and determine their composition. The X-ray microscope (EDXRF) provides an insight into the distribution of elements in large samples.



Nickel sulphide ore, Epoch Mine, Zimbabwe: the yellow points show the finely dispersed platinum group minerals which are localised and measured using the electron probe automatic search program.

And the composition of whole cores can be visualised along profiles with the geo-scanner.

The combination of high-resolution measuring techniques and modern visualisation, image analysis and image documentation methods highlights other microanalysis techniques used by BGR: an atmospheric scanning electron microscope for the detailed observation and rapid determination of the composition of wet and sensitive materials; infrared microscopy to reveal the types of chemical bonding; and cathode luminescence microscopy to reveal the internal structure of crystals.

The Microanalysis Working Group aims to use microanalytical methods rationally, economically and scientifically correctly to find answers to geoscientific questions. An important role in its work is played by the documentation and provision of comprehensive image and analytical data in a flexible and coherent database.

The Microanalysis Working Group also provides a forum for the evaluation of new developments and further developments in the field of microanalysis and acts as a consultant on complex analytical questions.

Marine and Polar Exploration

What is the Point of Carrying out Research in Polar Regions and Marine Environments?

Why is taxpayer's money used for expeditions to exotic parts of the world in expensive research ships? Why is BGR active in the Arctic and Antarctic polar regions? Geological exploration in the North Sea? These areas are already overexplored! Typical questions that may occur to some people.

One of the many tasks assigned to BGR is the geoscientific exploration of marine and polar environments. The oceans and the polar areas are among the last largely unexplored regions on our planet. They contain deposits of natural resources whose extent has not yet been estimated. BGR carries out research into these areas, which are still too uneconomic to attract industrial investment, with the aim of discovering future resources of energy and raw materials.

Many of BGR's research activities are an integral part of international co-operation agreements and treaties, some of them long-term. For instance, BGR and the Alfred Wegener Institute (AWI) maintain Germany's consultative status in the Antarctic Treaty. Therefore, BGR is obliged to conduct regular research expeditions within the Antarctic. Similarly, BGR holds the German mining rights for manganese nodules in the Pacific, and reserves these for German industry. Maintaining these mining rights also requires regular research activities to be carried out.

But the activities of the BGR's marine and polar scientists are not restricted to the commodity aspects and international obligations.

BGR scientists also make important contributions to investigate the earth's climatic history. They make a contribution here to enhancing our understanding of the causes behind today's climatic changes. Natural events such as submarine landslides and submarine earthquakes can generate catastrophic tsunamis. BGR's research activities on continental margins around the world provide essential data to improve the monitoring of such risk factors.

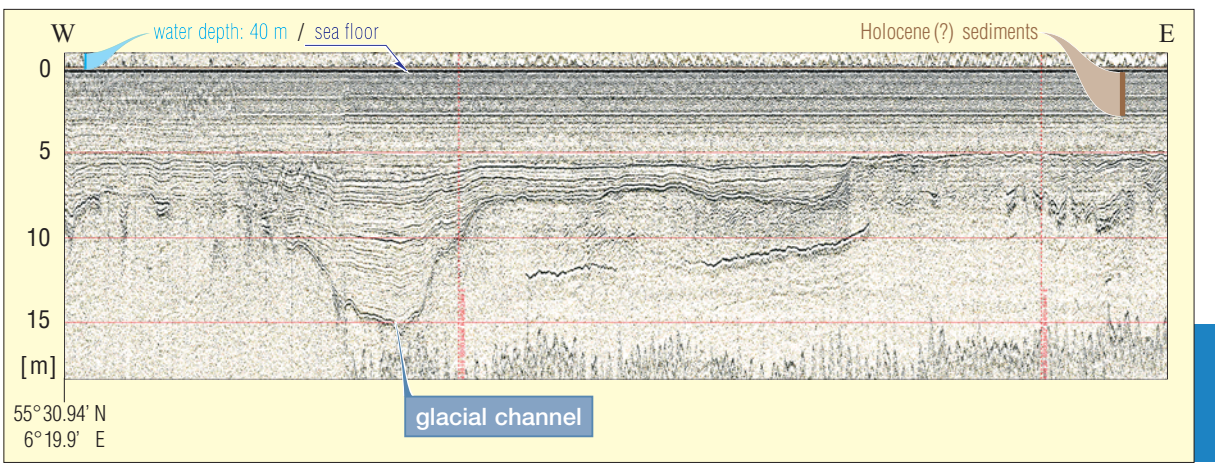
The ocean floor is also largely commercially unexploited. However, the floor of shallow marine areas can be used for the construction of wind parks to generate renewable wind power out of sight of the coast. Marine scientists at BGR are also active in this field and are exploring the geology of the North Sea.

BGR's **North Sea Project – Geo Database** for the German Exclusive Economic Zone (EEZ)

The North Sea on our doorstep is already put to extremely varied use: buried cables provide connections, sand and gravel are extracted for construction activities; it is an extremely busy transport and trading route; fisheries are a major source of food; pipelines pump oil and gas offshore; and offshore wind parks are planned in future to generate power and hydrogen. The North Sea is also an area where people live and go on holiday. It also includes important nature conservation sites.

The BGR's North Sea project began in the middle of 2002 to systematically compile the previously incomplete geo-database for the shallow subsurface. This geo-database is to serve as the reference base for all types of planning and utilisation. This involves integrating already digitised seismic lines and drilling data within an interpretation system, together with new high-resolution data, with the aim of making information on the whole area available in the form of a geo-information system (GIS).

The deep geology of the North Sea is already well-known from oil and gas exploration, just as the natural seafloor itself which is already well explored by the systematic mapping carried out by the Federal Maritime and Hydrographic Agency (BSH) and the inshore and marine agencies which are responsible for shipping safety. However, there was no widespread coverage previously of the geology of the shallow subsurface: for instance, the precise position of the system of glacial channels has only been partially mapped. These channel systems are often around 100 – 250 m deep and can also cut down as much as 500 m into the underlying layers. The channels formed during the Pleistocene glaciation which took place starting around 1.8 million years ago and continued until the end of the last glacial around 18,000 years ago.



Boomer seismic: AUR_09 line (swell filter).

In three expeditions with the charter ship MV Aurelia, new lines were surveyed in 2003 and 2004 using the BGR's seismic system and various other methods (Boomer, Sparker and CHIRP seismic systems). The vibro-coring system was used to extract up to 6 m long cores for the classification and dating of near-surface sediments.

Thick glaciers advanced into the area covered by the present day North Sea because sea level dropped by up to 120 m. The melt water beneath the glaciers dug out the channels. These former open channels are now completely filled with an irregular sequence of sands, clays and large boulders which were transported along with the glaciers.

These channel sediments cut into older sequences deposited during the early Tertiary (= Neogene, between 12 million to 2 million years ago). These Neogene sediments primarily consist of deposits laid down in a huge river delta which drained NE Europe before the start of the ice ages. They are accompanied by smaller filled channels cut by rivers which drained the area of the present day North Sea at the end of the last ice age until sea level rose again and re-established a marine environment. There are also truncated sediment bodies, terminal moraines and glacial outwash plains laid down during the glacials.

New Information on the **Opening History** of the **South Atlantic** – Marine Geophysical Surveys along the **Continental Margin** of **South Africa**

Marine geoscientific research in advance of industrial exploration to provide information and support decision making for long-term German energy policy, was one of the original responsibilities of the BGR. The main target area for marine research has long been the continental margins and the adjacent deep sea areas with their currently poorly understood potential for exploitation and risks.

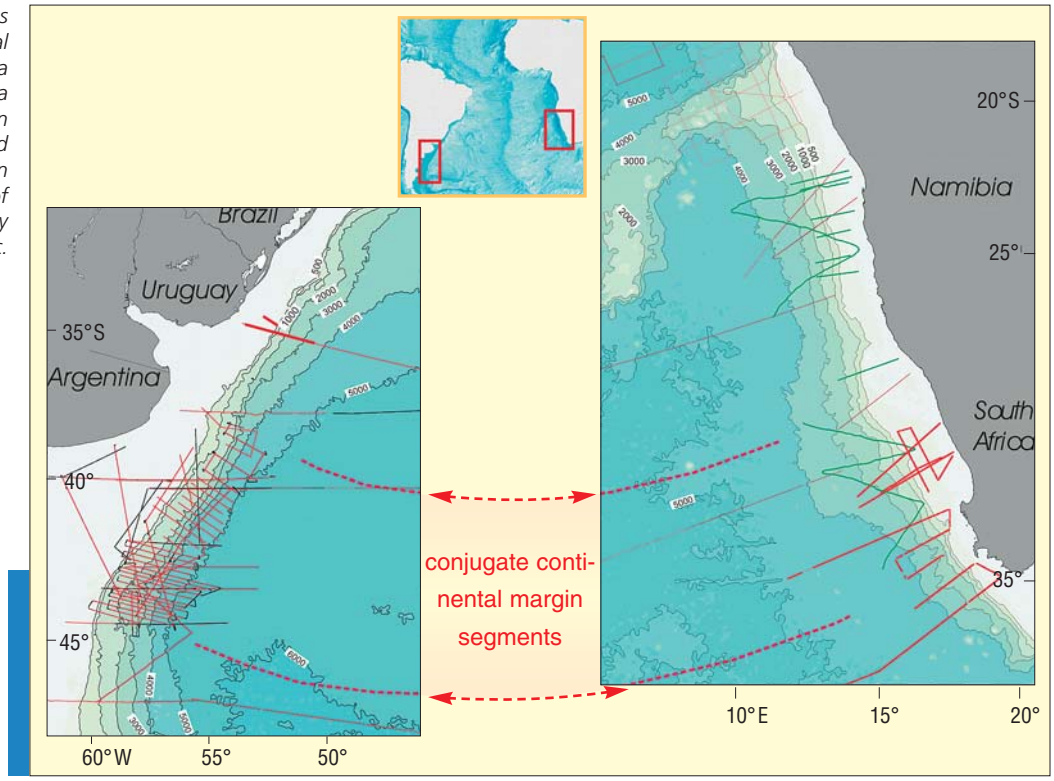
The marine geoscientific work conducted by BGR since 1978 off the coast of Brazil, Uruguay, Argentina and Namibia, has shown that large parts of these continental margins are of "volcanic passive continental margin" type.

A seismic survey ship shooting seismic lines.

Evidence has been found that the opening of the South Atlantic took place over 130 million years ago and was accompanied by extremely strong but short-lived volcanism. This volcanism was several orders of magnitude more intense than any known historical event on the planet. These volcanic rocks along the continental margins of the South Atlantic are now covered by very thick packages of sediment. Very little is presently understood of the precise temporal and spatial relationships of the deposition of these volcanites and the impact of the geo-dynamic processes on sedimentation, hydrocarbon formation and hydrocarbon potential.

Marine geophysical surveys were carried out offshore South Africa in early 2003 to add to the information already gathered by the BGR which was primarily collected along the South American continental margin. A geophysical grid of multichannel seismic, magnetic, gravimetric and bathymetric surveys was acquired, and an ocean floor hydrophone was installed. Investigations on the conjugate parts of the South Atlantic continental margins, i.e. Argentina and South Africa on opposite sides of the South Atlantic, which originally formed part of one land mass prior to the development of the Atlantic (Gondwana continent), are particularly interesting because the results can reveal important new findings (1) on the geodynamic processes involved in continental break-up and (2) for an initial estimate of the resource potential.

BGR seismic lines along the continental margins of South Africa and South America showing the position of the interpreted continental margin blocks – relicts of the opening history of the South Atlantic.



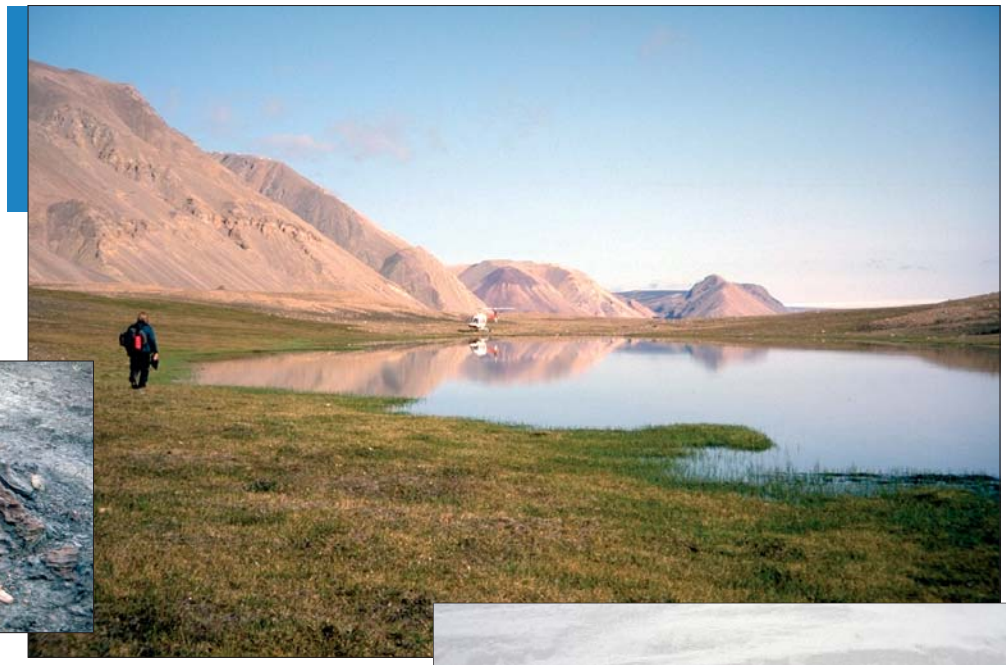
The results show the presence of Cretaceous black shale deposits, which are potential oil source rocks, and also reveal that the volcanites which formed during the opening of the South Atlantic are spread equally along both continental margins. Both of the continental margins are broken up into segments characterised by multi or single phase volcanism.

Detailed analysis of the seismic lines revealed that the volcanites have a highly variable internal structure (thickness and width orthogonal to the continental margin). The northerly survey lines have wider volcanite sequences than the southern lines. This disparity indicates the presence of a transform fault which correlates with the Argentinean continental margin (Colorado Offset).

CASE 8, Ellesmere Island – Vendom Fiord

Geologists at the BGR have been investigating the development and deformation of Arctic continental margins since 1992 in co-operation with German universities and Norwegian, Danish, Russian and Canadian institutes, as part of the "Circum-Arctic Structural Events" (CASE) project. The aim is to find out more about the processes involved in the formation of the Arctic Ocean after the break-up of the northern continent Laurasia. After expeditions to Spitsbergen, North Greenland, Siberia and the northern part of Ellesmere Island, CASE 8 in summer 2004 was scheduled to investigate a 70 km wide fault zone (Vendom Fiord Fault Zone – VFFZ) on the southern part of Ellesmere Island which was active for a short time in the Tertiary at the Palaeocene/Eocene boundary.

The sedimentological and paleontological work carried out during CASE 8 revealed that the Palaeocene clays, silts and sands were laid down in a broad shallow basin along the VFFZ prior to the active tectonic phase. This shallow depositional area favoured the formation of extensive coal swamps. The numerous coal seams and fine-grained river sediments indicate a long period of tectonic inactivity in a moderate to subtropical climate, even though the area of investigation had already reached its current geographical latitude of around 78° north during the early Tertiary.



During the field work, red to yellow siltstones and claystones were found in some Tertiary basins which were burned from the originally unconsolidated Tertiary sediments by baking and impregnation. The centres of these deposits have outcrops of metre-wide vents with weathered dark, massive, partially vesicular and highly magnetic rocks. Although the results of initial laboratory analysis indicated that these lavas had a volcanic origin, the evidence which has been gathered in the meantime suggests that these melts are paralavas created by the burning of self-ignited Tertiary coal seams.

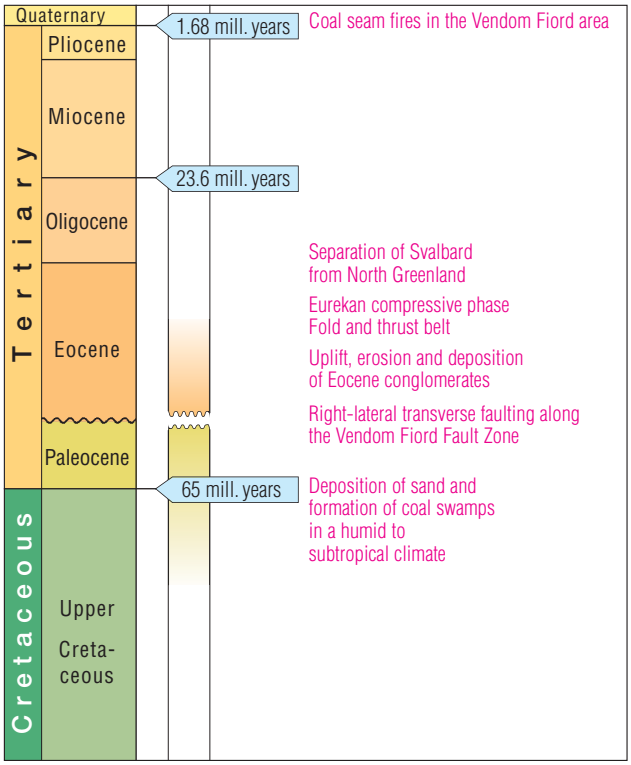
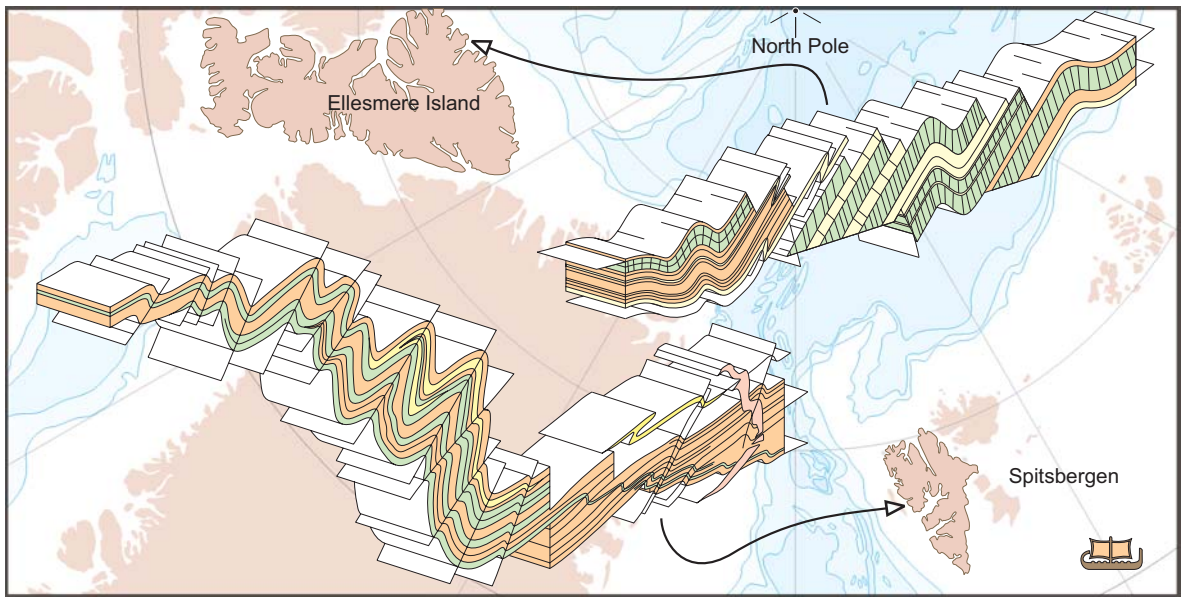


Table of geological chronology of the major events in the Vendom Fiord area in the last 100 million years.



Although separated today, they were originally joined: the analogous structures in the Caledonian deformed metasedimentary series in Spitsbergen and on the north coast of America, indicate that these two areas were formally plate-tectonic neighbours.

To understand the chronological and spatial nature of the processes involved in the Cretaceous and Tertiary plate tectonic restructuring of the Artic, which led to the creation of the circum-Artic fold belt and ultimately to the opening of the Artic Ocean, it is essential to first establish their original positions and their relationships. This reconstruction depends on the whole spectrum of geological and geophysical research. In addition to paleontological, stratigraphic and petrographic comparisons, structural geology is another of the most important tools for comparing and possibly correlating the differences and similarities between the geological development of the continental plates which are now separated and isolated from one another. In this way, the similar structures in metasedimentary series in Spitsbergen and on the north coast of America (Pearya terrane) deformed during the Caledonian confirm that the two continental fragments underwent similar development and thus lay directly adjacent to one another long before their separation in the Tertiary.

Permafrost in Canada

Flight over a measuring field in the permafrost at the east coast of Hudson Bay/Canada. One of several palsas is located right in the centre of the picture.

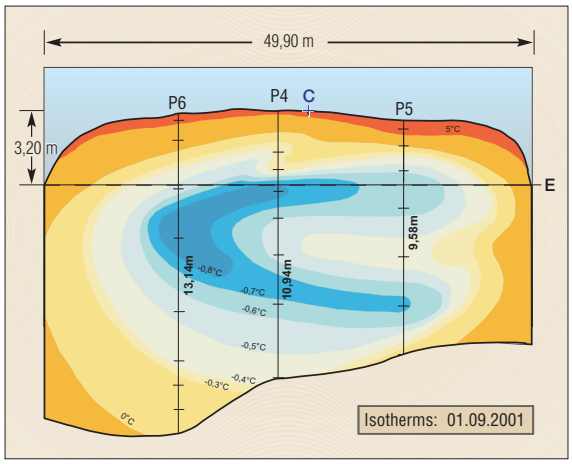
The clear warming of the Canadian Arctic observed in the last 20 years is reported in publications as an important indicator of global warming. This goes hand in hand with predictions of the rapid breakdown of the permafrost zone and changes to the appearance of the Arctic Tundra. BGR set up a measuring station in the permafrost in co-operation with the University of Laval/Quebec in 2000, to monitor the reaction of the permafrost to climatic change.

In addition to the climatic aspect, the study is also being carried out to provide more information on the physical properties of permafrost, with which a more reliable calculation model for permafrost growth and destruction may be developed. This approach is also important for the analysis of poorly accessible gas hydrates in the oceans around the world because permafrost and gas hydrates have very similar physical behaviour.

The survey area is near the eastern coast of Hudson Bay. A ring-shaped ice structure which is raised approx. 3 m above the surrounding area has been investigated. Such structures are called palsas. Temperature measurements which have taken place in the permafrost since 2000 have shown a steady slowdown in warming since 2002 caused by the influence of increasingly severe winters, particularly the winter of 2002/2003. However, the warming caused partial melting of the palsa. The surface of the palsa has dropped approx. 30 cm on average since 2000.

Three observations were particularly surprising: sudden opening of cracks at the base of the permafrost through which groundwater penetrates the palsa, and lateral flow, obviously involving slightly mineralised water that can therefore not freeze and which moves along preferential paths. The third observation was that of strongly reduced pressure in the unfrozen residual water of the permafrost. This latter effect is attributable to the "cryo-suction process" which is associated with the preferential attachment of water molecules to ice at the expense of the surrounding clay material. Palsas therefore behave like slow water pumps which draw water out of the surrounding area which then slowly freezes over time, and gives rise to further growth. Another aspect which strongly influences the temperature field around the palsa is the fluctuation in winter snow cover.

All of these processes give rise to an amazingly fluctuating temperature field within the palsa. According to our findings, the thickness and the formation of temperate permafrost – i.e. permafrost existing close to the melting point – are primarily influenced by fluid movements. Modelling the reaction of permafrost and the heat exchange processes can therefore not be conducted reliably using a simplified model of the melting process.



Vertical section of a palsa showing the temperature field. It shows the obvious positive temperature anomaly in the palsa caused by the lateral penetration of water.

German Activities within the **International Ocean Drilling Programme (IODP)** – Co-ordinated by BGR

The increasingly intensive use and exploitation of the earth by man demands a much better understanding of naturally occurring geodynamic processes. The International Integrated Ocean Drilling Programme (IODP) is an innovative research project investigating the diversity of the environment, and the genesis of geo-risks and geo-resources. Its overall aim is to improve the geo-management of our planet.

Following up the outstanding success of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Project (ODP), the IODP research initiatives are defined by the following research areas and main fields of research:

- the almost unknown wide-ranging microbial microcosm in the earth beneath the oceans,
- the gas hydrates – huge frozen carbon reservoirs deposited on the continental margins,
- the earthquakes under the continental margins where their crustal plates plunge deep into the earth,
- the drilling of a complete section of the earth's crust under the oceans to reach the earth's mantle. (This initiative in the form of the "MOHOLE project of the 21st century" pursues the long felt desire of scientists to completely penetrate the oceanic crust, which is the most common type of crust on the planet.)
- the Earth's long and short-term environmental changes, including the previously inaccessible Arctic Ocean, to test the sensitivity of the climate system, also as a result of anthropogenic emissions,
- to investigate the extremely warm periods of the earth's history to define variations in the earth's climate under greenhouse conditions,
- the fluid circulation and material cycles within the mid-ocean ridges and in deep sea trenches, where oceanic crust is formed or dives down into the earth's mantle respectively,
- the development of thick sedimentary basins during continental break-up, and new concepts in the search for the last major energy reservoirs.

The programme has a pure scientific agenda and the defined research objectives can only be realised as part of a long-term internationally organised programme which brings together the best scientific concepts and the latest drilling methods.

The Ocean Drilling Programme is of enormous importance for German geosciences. Around 250 German scientists are currently involved in ODP/IODP-related activities and have always participated at the cutting edge of international geosciences (1186 ODP publications alone in the last five years with German involvement). Almost every one of the younger generation of German geoscientists and a large number of today's professors have directly or indirectly benefited from ODP during their careers.

The German ODP/IODP co-ordination office has been part of the Geozentrum Hannover for over 20 years and was headed for much of this time by Professor Helmut Beiersdorf who passed away on 30.05.2004. We shall long remember this honourable international representative of the interests of German geosciences.

Prof. Dr. Helmut Beiersdorf

SPECIAL TOPIC

"Climate"

SPECIAL TOPIC **"Climate"**

Climate, Kyoto and Carbon Dioxide

Climate and climate change is a volatile topic amongst the general public and in the media.

However, emotional images often get in the way of an objective representation of climate issues. Nevertheless, the key question is still:

are we causing a global change in climate because of our high emissions of greenhouse gases into the atmosphere or are we merely living within one of the numerous natural climate fluctuations which mankind has experienced repeatedly in the historical past?

Answering this question conclusively may still take a long time.

This is why governments are already endeavouring to counteract the potential risks caused by climate change, or to protect society from the consequences by introducing measures such as the reduction in emissions included within the framework of the Kyoto Protocol.

Because climate policy always involves economic policy measures, one of BGR's tasks is to provide policy makers, industry and the public with competent and objective advice and information on climate issues.

Anthropogenic carbon emissions undoubtedly have an impact on the global carbon cycle. Climate scientists also believe that this could give rise to larger climatic changes. Both of these aspects need to be evaluated carefully in the context of providing advice to policy makers.

In a priority research project, scenarios for the possible future consumption of fossil fuel and the resulting carbon emissions were developed. These were then assessed with the help of a carbon cycle model and a climate model to determine their impact on the environment and the climate.

The CO_2 emission reduction targets laid down in the Kyoto Protocol have so far not been achieved by the environmental policy measures introduced within national and international programmes. CO_2 sequestration underground could therefore be an additional option for the reduction of emissions.

To fulfil its consultation responsibilities with respect to the German government and industry, BGR has therefore been actively investigating "CO_2 sequestration in underground formations" since 2000 to analyse the sequestration potential of the geological underground for the possible burial of carbon dioxide. In this context, BGR is also investigating the behaviour of underground storage structures by looking at natural CO_2 deposits as analogues for storages that might be suitable for filling with carbon dioxide in future. These existing natural storage structures can also be used to develop methods to detect CO_2 leaks. Assessing CO_2 sequestration is not only based on geotechnical aspects, but also includes environmental and socio-economic factors as well as power station and safety technology. In addition, scenario modelling is carried out to evaluate the impact of carbon dioxide sequestration measures on the climate.

Anthropogenic CO_2 Emissions within the Carbon Cycle

Natural climate changes and their potential superimposition by anthropogenic effects are particularly important for the research carried out by the BGR. The combustion of fossil fuels releases large amounts of carbon dioxide into the earth's atmosphere every year. In addition, changes in land use and clearance of vegetation by burning (slash-and-burn) also add to the carbon dioxide emissions from human activities.

8.8 billion tonnes of carbon (in CO_2) were released in 2000. However, only part of the anthropogenically released carbon remains in the atmosphere because most of it is absorbed by sinks such as oceans and forests. Since 1960, there have, however, been increasing annual fluctuations in the amount of carbon uptake which can reach up to 6.5 billion tonnes C per year. Unfortunately, the causes of these fluctuations in carbon uptake are only partially understood.

BGR operates a complex carbon cycle model to assess the influence of future anthropogenic emissions on the carbon cycle and the climate. History matching underlines how well the model describes the atmospheric volumes of carbon and the absorption of carbon by the sinks. However, it is currently not possible to model the strong annual variations in the sinks as the causes of these fluctuations are not yet understood in enough detail.

Nevertheless, the model can be used to draw general conclusions on the development of the volumes of carbon in the atmosphere and the sinks on the basis of emission scenarios.

Figure 1 shows the emission scenario "IPCC-IS92a" for atmosphere and sink development over the next 100 years. This example includes a constant annual contribution from forest burning of approx. 2 billion tonnes C per year within the overall emissions.

The frequently expressed fear that the carbon sinks could reach the limits of their uptake capacities within this century because of the continuing emissions is not supported by BGR's model calculations. Quite the reverse, the capacity of the sinks will continue to increase in future. The "IPCC-IS92a" scenario is one of the conservative business-as-usual (BaU) scenarios and therefore resembles the maximum future volumes of emissions.

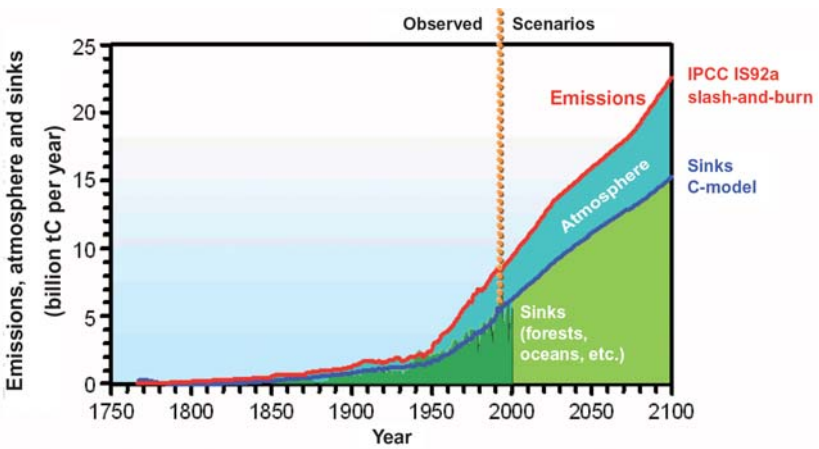


Fig. 1:

The uptake capacity of sinks has been subject to major annual fluctuations since approx. 1960 (dark green areas). The uptake capacity of sinks will increase further over the next 100 years (blue line and light-green areas) if anthropogenic emissions increase (red line).

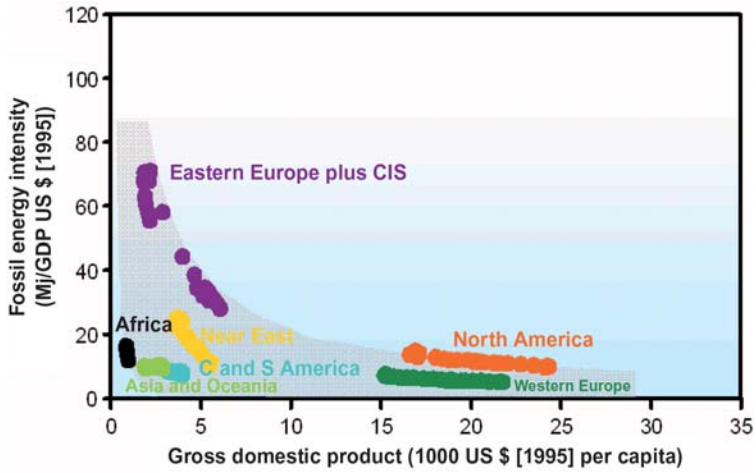


Fig. 2:

In different socio-economic regions around the world, the growth in gross domestic product (GDP per capita) is associated with a decrease in fossil energy intensity (energy consumption per unit of generated GDP).

Scenarios for Future Anthropogenic CO_2 Emissions

Fossil energy production scenarios indicate that the associated emissions will also continue to rise in future. The scenarios shown here are business-as-usual scenarios which reflect minor technical advances and low levels of energy efficiency in the future. The Kyoto scenario also belongs to this scenario category because it is derived from the "IPCC-IS92a" scenario.

The question of the relevance of these future scenarios arises because they are based on the extrapolation of energy use since 1950. Conventional business-as-usual scenarios reflect obsolete energy trends because they overlook the considerable advances in technological development and energy efficiency which have been achieved over the last 30 years. Promoting this trend for the increasingly efficient use of fossil fuels in future means in effect the sustainable use of non-renewable resources. However, technical further development is not realised at the same pace throughout the world and differs from region to region.

The major socio-economic regions of the earth (Fig. 2) have experienced considerable differences in their development over the last 20 years. However, one thing the regions all have in common is that growth in their gross domestic product (GDP per capita) has been accompanied by a reduction in the consumption of fossil fuels per unit of GDP. These relationships need to be taken into consideration when estimating the future global energy production from fossil fuels. It is therefore essential that the separate regional trends are incorporated in the computations of future potential fossil energy consumption.

Business-as-usual scenarios determined on the basis of the observed socio-economic development of specific regions and BGR's reserves and resource data indicate that there will be a further rise in future in global energy demand. Whilst Western Europe, Central and South America, Africa and the Near East could nearly stabilise their moderate emissions by the end of the 21st century, it is forecast that North America and the region of Asia and Oceania in particular will increase their already extreme emissions even further. The emissions from Asian countries already exceed those of North America. Asia and Oceania will also be responsible in future for the strongest carbon emissions. However, the scenarios for North America, Asia and Oceania assume that the emissions from these areas could stabilise from 2080. The total of the regional scenarios gives the possible global emissions.

The development shown in Figure 3 based on the total of the regional approaches shows a range of emissions reflecting the different energy mixes in the sub-scenarios. High carbon emissions are based on the assumption that coal will continue to play an important role in power generation, whilst low carbon emissions are associated with scenarios assuming a greater use of gas.

The regional scenario shows that after an initial increase in energy demand, emissions stabilise by the end of the current century. However, the overall picture (Fig. 4) indicates that global fossil energy consumption per capita could rise again in future. This trend already seems to be inevitable given the enormous energy demand in Asia.

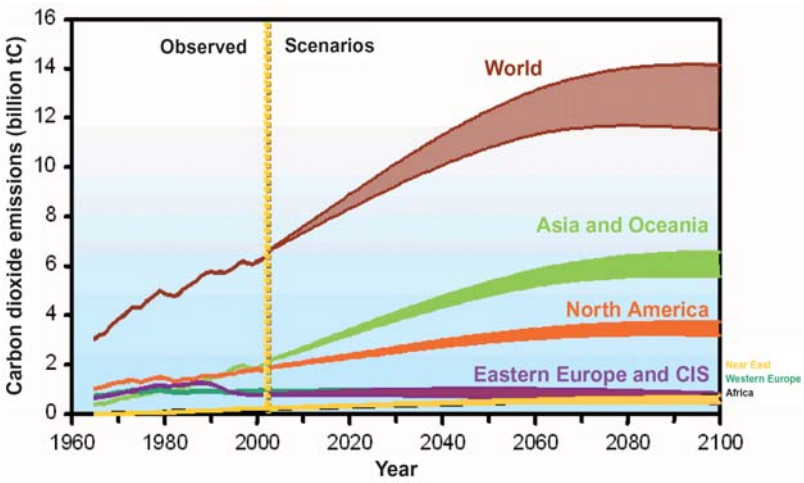


Fig. 3:

Global carbon dioxide emissions will continue to rise during the 21st century.

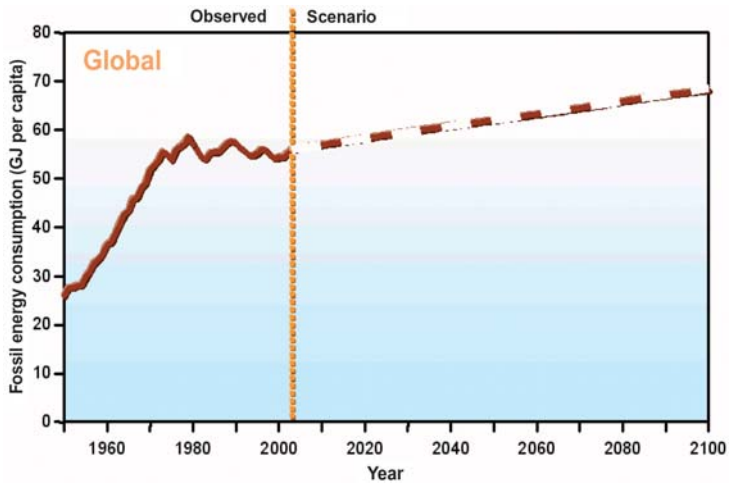


Fig. 4:

Adding up the separate regional scenarios reveals that the global fossil energy consumption (per capita) will rise in future.

BGR's "BaU Regional Scenario" derived from data covering the last 30 years differs considerably from the "IPCC-92a" and "Kyoto" scenarios because of its lower emissions (Fig. 5). Because the "IPCC IS92a" and "Kyoto" scenarios are influenced by basic assumptions which are considered to have been obsolete for three decades, the BaU Regional Scenario is considered to be the most probable projection for future energy consumption and the associated potential emissions.

To assess the hypothetical effect on the climate of the BGR BaU scenario, the potential rise in atmospheric carbon dioxide caused by anthropogenic emissions was determined using the BGR carbon-cycle model. The computed rise in atmospheric carbon dioxide during the 21st century is much lower for the "BaU scenario" than in the comparable "IPCC-IS92a" scenario and its aligned "Kyoto" scenario (Fig. 6). The "BaU Regional Scenario" indicates a lower future influence on the climate of carbon dioxide emissions than the "IPCC-IS92a" and "Kyoto" scenarios.

Comparative model calculations for the "IPCC-IS92a" scenario and the "Kyoto" scenario clearly demonstrate that no significant climatic effects will be achieved by the potential measures incorporated within the Kyoto Protocol (Fig. 7). The scenarios indicate a similar global temperature increase of approx. 2 °C compared to 1990. The computed temperature reduction of the "Kyoto" scenario compared to the "IPCC-IS92a" scenario in 2100 is approx. 0.16 °C and has therefore no climatic significance. The BGR "BaU Regional Scenario" differs considerably from the "IPCC IS92a" and "Kyoto" scenarios because of its much lower temperature increase compared to 1990 (Fig. 7): it is approx. 1.2 °C for the regional approach with respect to the global average temperature. Major climatic changes compared to today are not expected on the basis of the "BaU Regional Scenario".

Scenarios of Future Anthropogenic CO_2 Emissions Assuming CO_2 Sequestration

Promising ideas for the reduction of carbon dioxide emissions include measures to sequestrate carbon dioxide in deep underground storages. To test the hypothetical impact on the climate of these technically complex measures, scenarios with and without CO_2 sequestration were compared.

The basic scenario for the possible future energy demand is the "BaU Regional". A scenario incorporating CO_2 sequestration strategies ("BaU CO_2minus") differs from the previously discussed BaU Regional scenario as follows:

It is assumed that from 2012, 5 % of global CO_2 emissions from coal power stations are trapped by underground sequestration, and that this percentage rises to 10 % by 2020. This is followed by an assumed increase of 10 percentage points per decade up to 2100. A fixed amount of max. 30 % was assumed for the additional energy required for CO_2 sequestration. This extra energy demand is covered by additional coal-fired electricity production in the "BaU CO_2minus" scenario.

It should be noted here that the "Bau CO_2minus" scenario assumes very optimistic conditions for the installation of CO_2 separation and storage technology (starting 2012!).

Compared to "BaU Regional", the assumptions in "BaU CO_2minus" incorporate the very much higher global energy demand for CO_2 sequestration measures up to the end of the century of approx. 100 EJ (Fig. 8). The range of this energy demand is calculated from the discrete scenarios for the fossil energy mix on which "BaU Regional" is based. The difference between the two scenarios becomes clear after 2030.

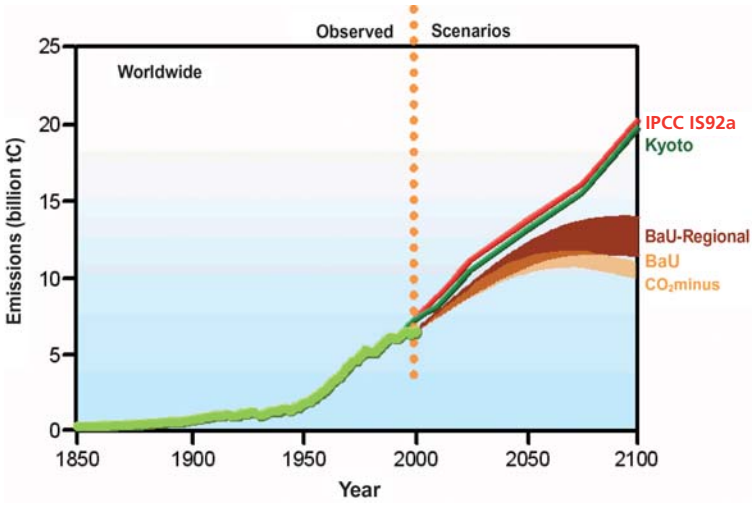


Fig. 5:

The "BaU regional" and "BaU CO_2minus" scenarios have lower emissions and therefore differ in a significant way from the "IPCC IS92a" and "Kyoto" BaU scenarios.

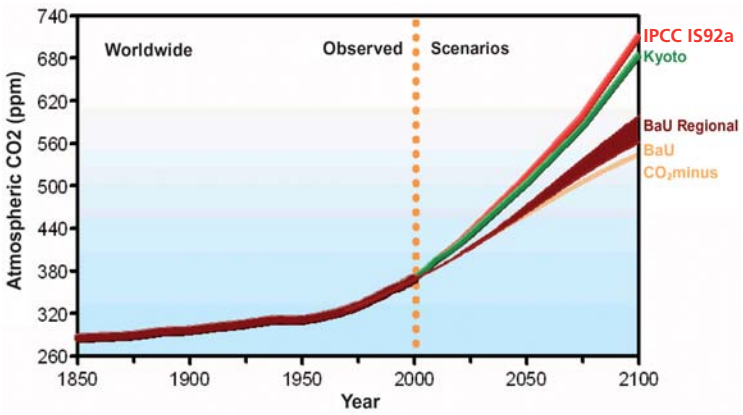


Fig. 6:

The "BaU regional" and "BaU CO_2minus" scenarios have lower atmospheric CO_2 concentrations and therefore differ considerably from the IPCC IS92a" and "Kyoto" BaU scenarios.

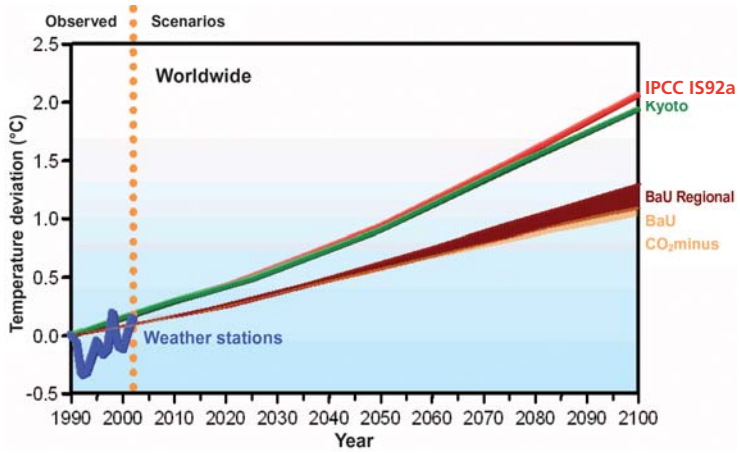


Fig. 7:

The "BaU regional" and "BaU CO_2minus" scenarios have lower temperature rises and therefore differ from the "IPCC IS92a" and "Kyoto" scenarios (reference year: 1990).

The carbon dioxide emissions associated with "BaU CO_2minus" are lower compared to "BauRegional" after 2030. They drop to about 10.5 billion t carbon by the end of the century after reaching a maximum of approx. 11.5 billion t C in 2070 (Fig. 5). The emissions of "BaU CO_2minus" are therefore about half those of the Kyoto scenario.

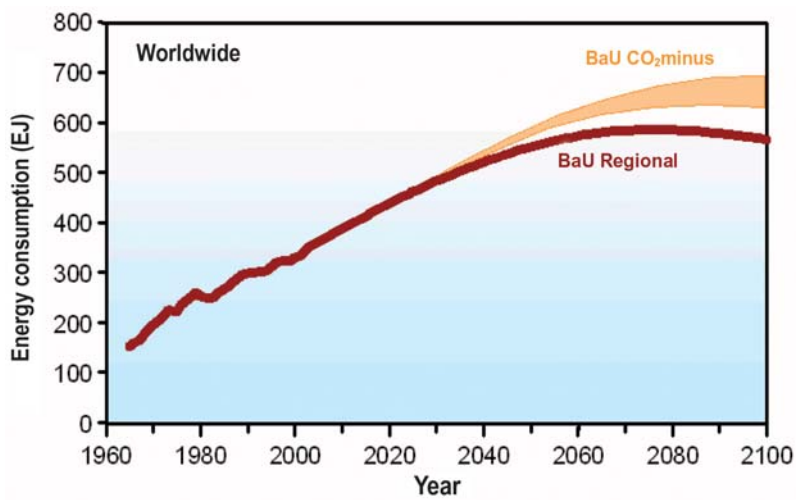
To assess the hypothetical impact of the two BGR BaU scenarios on climate, the BGR carbon-cycle model was initially used to determine the rise in atmospheric carbon dioxide arising from anthropogenic emissions. The calculated atmospheric carbon dioxide concentration is considerably lower during the course of the 21st century in both scenarios in comparison with the "IPCC-IS92a" and "Kyoto" scenarios (Fig. 6).

With their much lower temperature rise (related to 1990 temperatures), the BGR BaU scenarios differ considerably from the results calculated using the "IPCC-IS92a" and "Kyoto" scenarios. The temperature rise for "BaU Regional" is approx. 1.2 °C by 2100, and the "BaU CO_2minus" scenario gives average values of approx. 1.1 °C at the end of the century (Fig. 7).

Major climatic changes compared to today are not to be expected on the basis of the BGR BaU scenarios. Furthermore, they make clear that the effort and expense involved in carbon dioxide sequestration does not have any significant influence on climate.

Fig. 8:

The "BaU regional" and "BaU CO_2minus" scenarios differ significantly in their assumptions of future fossil energy consumption.



SPECIAL TOPIC

“Geothermal Energy”

thermal
Energy G

SPECIAL TOPIC **"Geothermal Energy"**

Power Generation from the **Depths** of the **Earth**

The term "geothermal energy" generally conjures up images of hot springs, steaming geysers, and volcanoes. And there are indeed many areas around the world where hot springs bubble up out of the earth or where the temperatures of the underground rocks are anomalously high. The use of geothermal energy for power and heat production is particularly relevant in volcanically active regions and has already been pursued in such regions for a long time: in countries such as Iceland, the Philippines or Indonesia, a considerable proportion of power production is covered by geothermal energy.

Less obvious, however, is the fact that geothermal energy production can also play a role in "normal geological regions" like Germany. The temperature of the earth in central Europe increases with depth by approx. 30 °C per kilometre on average. Drilling boreholes to a depth of five kilometres is technically feasible, which means that temperatures of more than 100 °C are also achievable in central Europe.

The use of alternative energy sources has been given a strong boost in Germany in recent years. One of the main arguments for promoting the use of geothermal energy as an alternative source of power is its ability to provide base load energy. Unlike wind and solar energy, geothermal energy is completely independent of seasonal or daily fluctuations and climatic conditions.

The coming into force of the renewable energy law in particular, and the associated guaranteed payment for geothermally generated power has stimulated and continues to stimulate the initiation of numerous projects in Germany. These are primarily concentrated on areas with good hydraulic permeability within deep geological formations, or where there are above average subsurface temperatures. The geothermally favoured areas in Germany are primarily the upper Rhine Graben and the Molasse Basin in the Alpine foreland.

Geothermal heat is produced by extracting water that is circulating in the underground. Geothermal energy production therefore requires a minimum hydraulic permeability of the rock. The generally low hydraulic permeability of deep underground rocks in Germany can limit the nationwide harnessing of geothermal energy.

Widespread use of geothermal energy therefore requires methods to be developed which artificially enhance the hydraulic permeability of deep underground formations. The most promising approach here is the stimulation of boreholes by hydraulic fracturing. By injecting large volumes of water (water frac) or other fluids under high pressure the rock is fractured at great depth and very extensive cracks are produced. These artificial cracks allow water to circulate between two neighbouring boreholes. Hot water is produced from one borehole. This is used to generate power or for space heating on the surface, and is subsequently reinjected at a lower temperature into the second borehole. This water becomes reheated underground to complete the cycle.

BGR is involved in several research projects focussing on the artificial exploitation of geothermal energy by hydraulic fracture generation.

Since investigations began in 1987, BGR has played a major part in the European Hot-Dry-Rock (HDR) research project at Soultz. This project in the Alsace investigates the production of geothermal energy from deep crystalline rock formations (granite) through artificial fracture generation.

The overall project achieved a major milestone in 1997 when it successfully demonstrated energy generation from a 3000 m deep reservoir with 10 MW thermal capacity during a long-term circulation test.

During the reporting period, three boreholes have been drilled down to 5000 m to create an artificial heat exchanger at this depth. Two production and one injection borehole are now available for the development of the reservoir. Stimulation experiments helped considerably enhance the hydraulic connection between these boreholes.

The next project phase includes circulation experiments during which water at a temperature of 200 °C is to be produced at a flow rate of 100 l/s. The aim is to achieve a geothermal power production of 5 MW.

The good results from the Soultz HDR project have encouraged BGR, the Lower Saxony Geological Survey (NLfB), and the Leibniz Institute for Applied Geosciences (GGA Institute) at the Geozentrum Hannover to test the applicability of the water frac technique to sedimentary rocks. The main objective of the joint "GeneSys" project is to produce geothermal heat from tight sedimentary rocks. The project is being conducted in two phases: the first involves hydraulic experiments in a test borehole (Horstberg Z1 well near Unterlüß approx. 80 km north of Hannover) with the aim of testing basic concepts for the production of heat from tight sedimentary rocks. These concepts are "one well concepts", which means, that the water is produced and reinjected in the same borehole. Experience gained from these experiments is later to be used when drilling a borehole on the Geozentrum site in Hannover with the aim of heating the Geozentrum offices with geothermal energy.

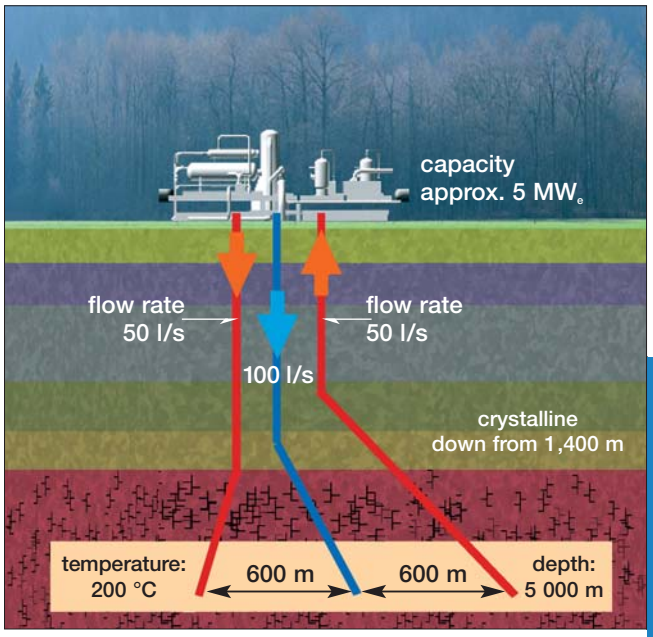


Diagram of the planned pilot plant at Soultz for the geothermal generation of electricity.

The main focus of the investigations in the Horstberg Z1 well was the massive stimulation of the Detfurth sandstone beds in the Middle Bunter by water fracing at a depth of 3800 m. This resulted in the generation of a large fracture (some 100,000 m2 surface area) within a "quasi" tight rock matrix. The good hydraulic properties of the artificial fracture allowed two different single borehole concepts to be tested.

The "Cyclic Concept" consists of three stages. During the injection period, cold water is injected into the fracture. During the shut-in stage the water is heated up by the hot rock in the vicinity of the fracture, and during the production period the hot water is vented from the fracture. Daily and weekly cycles of this kind were tested with good success in the Horstberg Z1 borehole. Numerical modelling performed by the GGA

Degassing the suction manifold (Horstberg Z 1).

Night time photo of the Horstberg Z 1 well site during the massive stimulation tests in autumn 2003.

High pressure pumps, suction manifold and well head during the stimulation tests at the Groß Schönebeck borehole in January/ February 2003.

Institute proved that a fracture of the size created in the Horstberg Z1 borehole can produce heat for a consumer the size of the Geozentrum Hannover for several centuries (> 1MW).

The "Deep Vertical Circulation Concept" assumes that the vertical fracture created by the waterfrac test connects two sandstone layers of moderate permeability at different depths. Heat is recovered by injecting cold water into one of these layers. This is heated up within the fracture and is produced from the second layer. This concept was also tested successfully in the Horstberg Z1 borehole .

The positive review of the test results by an external team of experts encouraged the project team to start with preparations for drilling on the campus of the Geozentrum Hannover. The start of the drilling operation is scheduled for summer 2006. The costs for the 3800 m deep well are already allocated in the budget of the BGR. In the "GeneSys" project BGR is responsible for the operative and technical aspects, whereas the GGA Institute is responsible for the scientific aspects of the project.

The BGR also continues to participate in the testing of the "Groß Schönebeck" well approx. 50 km north of Berlin which is co-ordinated by the GeoForschungsZentrum Potsdam. In this borehole, the zones of interest are a porous formation (Rotliegendes sandstone) as well as a partially fractured formation (Rotliegendes volcanites). Both formations are common throughout the North German Basin and are therefore interesting targets for geothermal production. Massive stimulation experiments at a depth of approx. 4300 m were conducted in this borehole in 2003 with the aim of boosting productivity to economically viable levels. Water fracing was also used here to achieve this increase in production and flow rate. The stimulation resulted in a considerable improvement in the hydraulic properties of the borehole as well as opening up a hydraulic pathway between the porous sandstone beds. The intention is now to drill a second well to establish a circulation system.

As in the "Soultz" project, the main focus of BGR's activities in the "Groß Schönebeck" project is the planning and evaluation of hydraulic tests and stimulation experiments. The operative work involved is supported both technically and by the provision of staff.

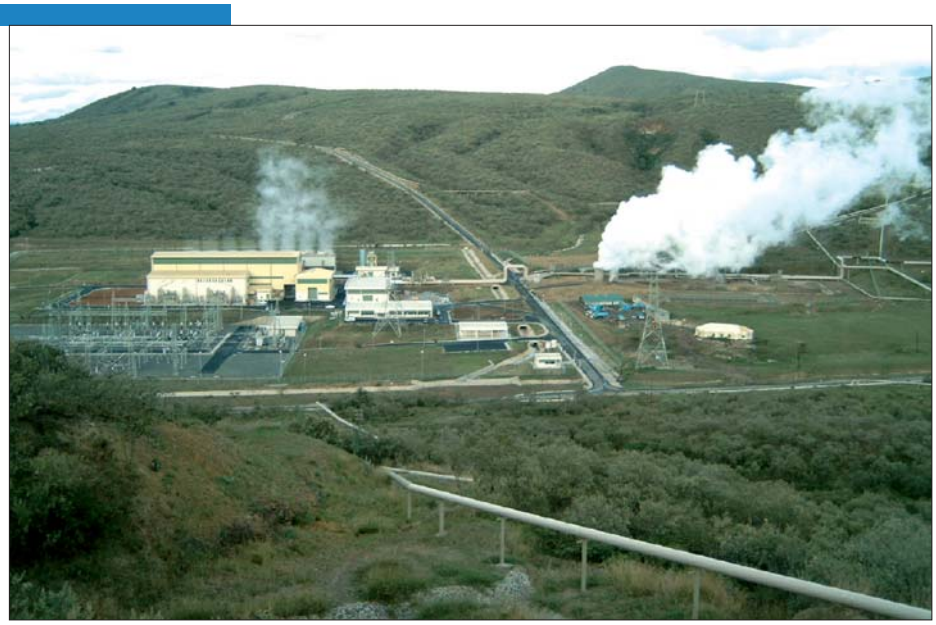
The GEOTHERM programme has opened up a new area of activity for BGR in the technical cooperation sector.

GEOTHERM is a technical cooperation programme aimed at promoting the use of geothermal energy in developing countries. Funding is provided by the Federal Ministry for Economic Co-operation and Development. The programme supports partner countries worldwide, preferably in areas with high geothermal potential (e. g. active volcanism). The aim is to minimise the risk associated with the development of geothermal resources at selected sites.

GEOTHERM supports partner countries in

- geoscientific assessment of geothermal resources
- ranking of prospects
- ecological evaluation, environmental impact studies
- finance options
- economic and socio-economic analyses
- risk analyses

Different activities take place in various countries. BGR is currently active in Eritrea, Kenya, Uganda and Chile.



Geothermal steam power plant at Olkaria II, Kenya, with approx. 70 MW electrical output.

Other countries are to be provided with support in future as part of the GEOTHERM programme. However, the GEOTHERM project funding is not adequate for the financing of exploration boreholes. Collaboration will therefore be sought with other funding agencies with the aim of developing specific geothermal sites as thoroughly as possible.

For example, GEOTHERM is part of the ARGeo Project (African Rift Geothermal Development Facility). The aim of ARGeo is to intensify the use and promotion of environmentally friendly geothermal energy in East African countries. ARGeo is funded by the Global Environment Facility (GEF) and several involved countries.

The ARGeo project is an integrated approach to the development of geothermal power plants. Right at the start of geothermal development programmes, political support, and economic and financing aspects are already put on the agenda with the aim of speeding up the overall realisation process. The approaches of the ARGeo and GEOTHERM projects support each other in this context and jointly improve the chances of assistance leading to success. Within this approach, GEOTHERM will mainly provide geoscientific advice on site evaluation and risk minimisation, as well as the transfer of know-how (in the run up to project financing).

Hot spring at the potential geothermal location in Buranga, Uganda.

Up to now, the GEOTHERM programme has supported three East African countries in the framework of ARGeo:

There are already three geothermal power plants in Kenya (Olkaria I, II, III). Kenya has by far the most experience in geothermal exploration of any country in Africa. The government intends to considerably expand geothermal energy exploitation in future. The geothermal potential in the area around the Menengai volcano has been assessed jointly with KenGen (Kenya Electricity Generating Company Ltd.) within the framework of GEOTHERM. This will be followed by the comparative evaluation of this area and the already explored Suswa and Longonot locations. Exploration wells are then to be drilled at the most promising site.

There is very little experience in Eritrea of the exploration of geothermal production sites, and there are no geothermal power stations. GEOTHERM funding was used to send a geologist and a chemist for six months training to the University of the United Nations in Iceland. With the know-how of the Eritrean scientists, the State Geological Survey can start its own programme to search for geothermal energy sites.

There are no geothermal power plants yet in Uganda and there is only limited experience in the country of geothermal exploration. The country's three potential geothermal sites (Katwe, Kibiro and Buranga) lie in the western arm of the East African Rift. A feasibility study of the Buranga site has been conducted as part of the GEOTHERM project. When the report is finalised, the three potential sites will be compared with the aim of further developing the most promising location.

SPECIAL TOPIC

“Public Relations”

ublic Rel
Relation

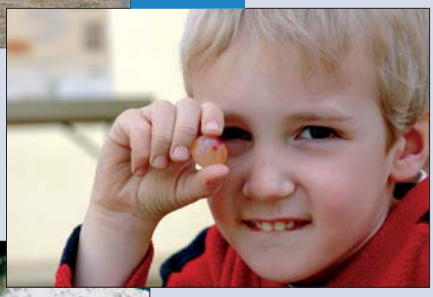
Festival of Science in Hannover.

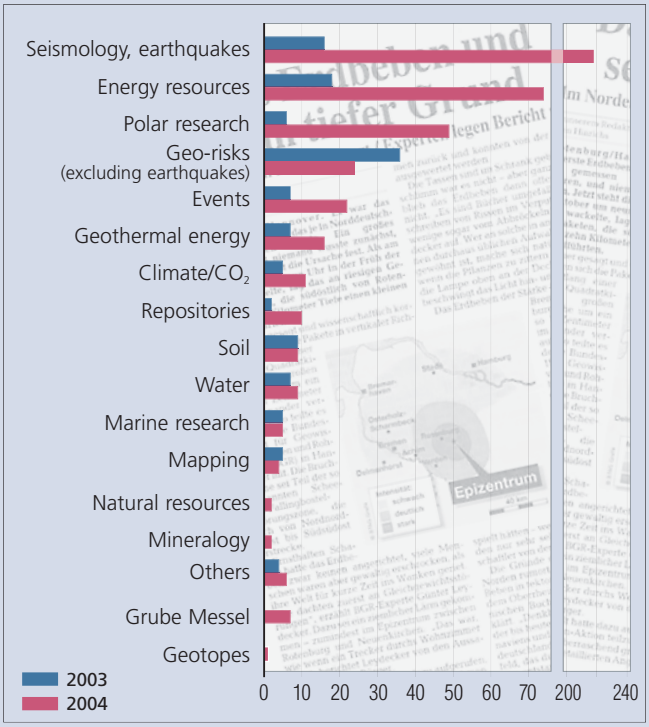
Geosciences for **Society**

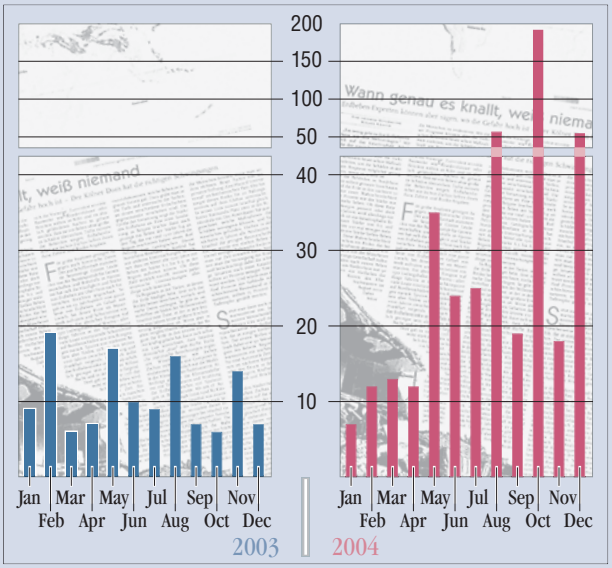
Uninitiated observers and taxpayers are not always aware of how a geoscientific institute benefits society as a whole. Strange, because geosciences are a vital pillar of everyday life – more than many people are probably aware.

Clean drinking water, salt for cooking, clay and sand for building houses, energy and heat are just as much a part of geoscientific research as protecting human lives from geo-risks and environmental degradation. BGR works on all of these issues – mostly behind the scenes with other experts and therefore largely unknown to the public.

The aim of our press and public relations work is to give people an insight into the highlights and daily activities of geoscientific research and consulting. And there is no doubt that people are interested in the condition of our planet – from floods to earthquakes and climate change. The large amount of reporting in the media and the rise in the number of visitors to the public events reflect the high level of interest in BGR's work.







BGR in the Media

The results of the technical work, and the opinions and positions held by BGR were quoted in press, radio and TV over 500 times in 2003/2004. The statistics show a considerable overall growth of media interest in our activities.

Open day at the Berlin-Spandau branch office.

"Science on tour" exhibition at Münster-Osnabrück Airport.

The biggest focus of media interest in BGR's work is associated with the issue of "geo-risks", which particularly caught the public eye in connection with two events in 2004: the North German earthquake at Rotenburg/Wümme and the catastrophic tsunami in the Indian Ocean. BGR's earthquake monitoring expertise in particular was called upon here by the media and incorporated in its reporting.

BGR also gained a great deal of media coverage within the context of "energy resources", and specifically, the availability of oil and gas. The interest of the media here again mirrors the headline grabbing events of the time: the start of the second Gulf war in February 2003 and the strong increase in oil and petrol prices in the first half of 2004.

BGR itself raised the public profile of polar research, geothermal energy, soil and water in the media. The reports on polar research captured a great deal of interest in the local press in Hannover and significantly boosted BGR's positive image. And geothermal energy, where BGR is pushing forward cutting-edge research into the development of pro-environment energy sources, is also gaining an increasing amount of media interest. The issues of soil and water were publicised in a few detailed articles. The aim here is to keep people informed and to maintain the awareness of the media and the general public in the more unspectacular but no less important work of the experts in Hannover in areas which have an influence on maintaining our standard of life.

International Geological Congress in Florence.

Science as a Fun Event

Inspired by the positive experience of the "Year of Geosciences 2002" BGR also placed a high priority on publicrelations work in the following years. The "Geo-ambassador campaign" was a direct follow-up to the Geo-year and involved scientists from the Geozentrum visiting schools to devote one lesson to the geosciences. Children thoroughly enjoyed analysing soil samples with all their senses and learning how to use the tectonic compass. And on the "Girls' Day" which takes place every year in spring, the focus was on giving girls an insight into what goes on behind the scenes at the Geozentrum.

Girls' Day.

The absolute highlight was BGR's first involvement at the Hannover "Festival of the sciences" on 25 April 2004 at which all of the research institutes in Hannover opened their doors to an interested public. The Geozentrum premiere attracted over 2000 visitors to the outdoor exhibition area where seven pavilions contained hands-on experiments and geosciences for young and old. The Berlin office opened its doors to the public on 11 September 2004. The major attraction here proved to be the rock collection which drew a crowd of over 500 who gained a greater insight into our activities.

BGR also presented its work at numerous trade fairs, conferences and exhibitions. Just a few of the highlights were the Hannover Industrial Fair 2003, INTERGEO 2003 and 2004 in Hamburg, the International Geological Congress in Florence 2004, and the "Science on Tour" exhibition at Münster-Osnabrück airport in October 2004.

BGR Special

The **Commission of Geoinformation Business Set up**
– BGR Operating GIW Management Office

The economic potential of Germany's georeferenced and spatial data, i.e. geoinformation, held by administrative bodies is estimated at Euro 8 billion in the medium-term. According to a study, up to 14,000 new jobs will be created in an enormous range of sectors in just the first year after activating a geoinformation market. Established companies will benefit and new business models will be founded. It will also stimulate new start-ups. The market positions of companies dealing with geoinformation will be strengthened. Geoinformation means any data which can be defined by location and elevation co-ordinates. The spectrum ranges for example from nationwide property-related house numbers, to pharmacy distribution in Bavaria, or to the geothermal potential of Berlin. It also has the objective of making all public sector geo-information held by federal and state agencies, as well as local authorities, available for commercial use. The proportion of geoscience-related information falling into this category is estimated at around 10 %.

The German government represented by the Federal Ministry of Economics and Labour (BMWA), has charted the course for this economic-political development process by setting up the Commission of Geoinformation Business (GIW Commission).

Under the auspices of the parliamentary permanent secretary REZZO SCHLAUCH, the GIW Commission began its work on 17 November 2004.

Members of the Commission are representatives from almost all sectors with an interest in geoinformation data. Included are representatives from IT, waste disposal, agriculture, water and energy utilities, chambers of trade and industry, mining, oil and gas, craft, tourism, insurance and advertising. The aim of the commission is to organise joint activities to elaborate sector-specific nationwide business models. This will only succeed with close co-operation with government agencies and the Steering Committee for Geo-data Infrastructure in Germany (GDI-DE).

The number of sectors involved in the GIW Commission clearly highlights the wide range of applications and demand for geoinformation. The signs are promising that the GIW Commission will enable the hidden potential of administrative geoinformation in Germany to be utilised to a much greater extent. These activities are co-ordinated at the Management Office of the Commission of Geoinformation at the Federal Institute for Geosciences and Natural Resources (BGR).

Permanent Secretary REZZO SCHLAUCH opening the constituting meeting of the Commission of Geoinformation Business on 17 November 2004.

www.geoinformationswirtschaft.de

BGR **Professional Training Initiative**

"In the past one learned
to become a better person;
now, people learn
to improve their standing in society"
(Confucius 551 – 479 BC)

The idea behind this saying from Confucius is still firmly fixed in the minds of many people today.

To acquire a positive social standing and run one's life autonomously and independent of the helping hand of parents or the "nanny state", many young people today make use of the opportunities of learning a job by becoming an "apprentice".

The demand for trainee positions has continuously risen in recent years along with the number of school leavers. Businesses should have a clear interest in increasing the number of positions for trainees for their own benefit. With this aim in mind, the Federal Minister of Education and Research Edelgard Bulmahn, alongside the President of the German Chambers of Industry and Commerce (DIHK), Ludwig Georg Braun, and the Chairman of the German Trade Unions Confederation (DGB) Michael Sommer, reached agreement on an apprenticeship campaign with the aim of making apprenticeships available to all interested school leavers.

All of the BGR trainees.

Trainees of the 1st training year in summer 2004.

BGR also joined in the spirit of the agreement and did its utmost to create additional positions for trainees, even in areas completely new to BGR. From 18 trainees in 2002, the number rose to 21 in 2003 and to 27 in 2004. And the trend continues unbroken with plans for over 30 trainees at BGR in 2005.

BGR currently trains young people in six different professions: cartographers, office communication assistants, vehicle mechatronic technicians, precision mechanics, chemical laboratory assistants and electricians. There are a different number of trainees for each of these jobs.

The frequent comparison of the female : male employee ratio again demonstrates a positive and exemplary situation:
2003: 11 female, 10 male
2004: 15 female, 12 male

Training in each profession is carried out responsibly and with enormous commitment. The quality of the training by BGR is highlighted by the many successfully completed training courses – some with commendations.

Facts and Figures

Budget (planned expenditure)

2003 61.8 million budget,
including 11.5 million third-party funding
for external co-operation activities
and projects.

2004 61.5 million
including 10.1 million for
third-party projects.

Staff

2003 725 of which 307 scientists
New staff:
16 female and 36 male staff and
7 female and 9 male trainees.

2004 762 of which 331 scientists
New staff:
24 female and 37 male staff and
15 female and 12 male trainees.

Trainees

2003 20 trainees,
11 female and 9 male

2004 27 trainees,
15 female and 12 male.

Training areas:

- *Chemical laboratory assistant*
- *Electrician*
- *Office communications assistant*
- *Vehicle mechatronic technician*
- *Precision mechanic*
- *Cartographer*

The BGR website

2003 11,076,496 page impressions
Average 30,347 per day.
Visitors 651,699
average 964 per day.

2004 10,572,865 page impressions
Average 28,967 per day.
Visitors 690,524
average 1070 per day.

Reference library

One of the largest geoscientific reference libraries
in the world with more than 355,000 books and
journals and 100,000 map sheets.
4000 new acquisitions per year;
more than 1000 exchange partners world-wide.

The collections

One of the largest geoscientific collections in
Germany;
60,000 type specimens;
more than 100,000 reference specimens
(fossils, rocks, minerals);
65 km core samples.

GeoAthletics

200 staff members regularly use the organised
sporting arrangements. The SBL Sports Association
at BGR organises:

- *Badminton*
- *Football*
- *Posture training*
- *Running*
- *Swimming*
- *Sailing*
- *Table tennis*
- *Volleyball*
- *Walking*
- *Yoga*

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- Z.3 Organization
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- Z.5 Purchasing, Stores
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... you can

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1 Stadtbahn- und Bushaltestelle / Tram and bus stop Lahe

Buslinie / Bus line 127 133

2 Bushaltestelle / Bus stop Pappelwiese/Geozentrum

Ab Hauptbahnhof Stadtbahnlinie **U3** bis **Lahe** (Endpunkt), Buslinie 127 oder 133 bis Haltestelle **Pappelwiese/Geozentrum**

From main railway station, take tram no. **U3** to **Lahe** (terminus) and then bus 127 or 133 to bus stop **Pappelwiese/Geozentrum**

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