

Federal Institute for  
Geosciences and  
Natural Resources



**Biennial Report 2009/2010**

Hanover, November 2011

The Biennial Report is free and can be obtained from:

**Bundesanstalt für Geowissenschaften  
und Rohstoffe (BGR),  
[Federal Institute for Geosciences  
and Natural Resources]**

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ISSN 2193-5076

**Info.**

# Foreword

from the President of the BGR

## Dear Readers,

as the old saying goes: The only thing that never changes is continuous change. Following the last BGR biennial report which shed light on our activities in 2007 and 2008 – and had articles on particularly memorable events in the period since our establishment in 1958 to commemorate BGR's 50th anniversary – the current 2009/2010 report appears with a new look.

BGR's public relations work has gained further in importance, as reflected in the numerous press releases, not to mention the quarterly publication of our electronic newsletter since the middle of 2009. Alongside the press releases and the now routinely published newsletter, the BGR biennial report is one of our signboards. The objective of all of these channels is to provide politics, industry, science, the media and interested members of the public with information on the fascinating aspects of BGR's work, such as the main findings of its work programmes, and outstanding achievements and incidents.

We have therefore included in the traditional biennial report the items first dealt with as the news was breaking in the press releases and newsletters. One of the approved features of the biennial report though is that the results of our work are organised according to specific topics and presented in a structured way. Many articles also look at the topics in greater depth.

The biennial report as a whole is a working reference book for those who are interested in operational geosciences; a recreational read for after work, the weekend or during holidays; a source of comprehensive insights for teachers, pupils and students about our exciting and often complex fields of activity and it retrospectively highlights to future employees the societal challenges tackled by BGR.



This brings me to two events which took place in 2009/2010 and will have a significant long-term impact on BGR and its work. The first is the restructuring of BGR's organisational units into newly configured departments and divisions with a primarily topic-oriented configuration. The restructuring and the various accompanying measures were implemented at the start of 2009 with the very intense commitment of almost all of BGR's employees. This restructuring enables the tasks demanded by one of the federal government's modern departmental research institutions to be carried out even more efficiently and in a more focused way than before, and to enable a smoother implementation of the findings. The second event was the start-up of the Deutsche Rohstoffagentur (German Natural Resources Agency; DERA) at BGR by the Minister of Economics, Rainer Bruederle, on 4 October 2010. The Agency has the task of supporting German industry in facilitating the supplies of important commodities. This aspect is looked at in more detail in this volume.

I hope you enjoy the 2009/2010 biennial report. I would also recommend a look at our website at [www.bgr.bund.de](http://www.bgr.bund.de), where you can subscribe to the BGR newsletter which is sent out regularly by e-mail. And please do not hesitate to contact me if you have any questions on specific topics.

A handwritten signature in blue ink, which appears to read 'H.-J. Kuempel'.

Prof. Dr. Hans-Joachim Kuempel  
President of the BGR

# Message of greeting

from the Federal Minister of Economics and Technology



## Dear Readers,

this year's biennial report again reflects the technical breadth and interdisciplinary integration within the Federal Institute for Geosciences and Natural Resources (BGR). These qualities enable the BGR to react quickly and professionally to economic and social developments with a geological context. I am convinced that the BGR will continue to provide the Federal Ministry of Economics and Technology with expert advice in the future.

Commodities markets in particular have recently experienced changes that are likely to intensify in the future and that represent a serious challenge to German industry. In a joint measure implemented with the BGR, the Federal Economics Ministry responded to this challenge last year by establishing the German Natural Resources Agency within the BGR. Using scientific findings and up-to-date market analyses, this agency will develop new approaches to the commodities sector that will enable it to provide new advisory services to industry as a whole. Integrating the agency within the BGR enables the existing know-how and infrastructure to be used in an optimal way. One of the main deciding factors here was the BGR's excellent networking resources and regional commodities sector expertise. This important issue for safeguarding our interests in the future is therefore in good hands.

The BGR's GeneSys project is also doing real pioneering work in the development of concepts for the direct utilisation of geothermal energy. This project involves the drilling of a 3,900 m deep borehole directly outside the Geozentrum in Hannover, which will then be used for a geothermal plant to heat the Geozentrum. The borehole has already been completed, and one of the positive surprises was that the formation temperature of approx. 170 °C measured at the base of the borehole was slightly higher than originally predicted. However, more technical challenges have to be mastered before the geothermal heating plant can be commissioned. This project is literally in its "hot stage", and I am following its progress with great interest.

With its research and development work on the safe and environmentally compatible storage of CO<sub>2</sub> in deep underground geological formations, BGR also shows another way in which geosciences can make an important contribution to solving the problems of climate change. CO<sub>2</sub> storage represents a potential option for the energy sector and energy-intensive industries to minimise CO<sub>2</sub> emissions from the combustion of fossil fuels.

The BGR has reinforced its outstanding position in the German and international research environment through numerous additional reports, including studies on the final disposal of radioactive waste, the Global Earth Observation System of System (GEOSS), and the helicopter-supported geophysical surveys to protect soil and groundwater from salination along the north German coast.

The high-quality advisory services provided by the BGR would not be possible without its excellent research work. I wish the BGR and its employees continued success in the future as they carry out their many varied duties.

A handwritten signature in blue ink, appearing to read 'Philipp Rösler'.

Philipp Roesler  
Federal Minister of Economics and Technology

# Board of Trustees

of the Federal Institute for Geosciences and Natural Resources

The Federal Minister of Economics and Technology established 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.

The Board of Trustees is made up of geoscientific representatives from industry and commerce, universities and non-university research organisations.

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## Minister Bruederle establishes the German Natural Resources Agency

Germany's supplies of commodities are increasingly at risk because the country is so dependent on imports and because of the growing distortions of trade and competition on the world markets. The Federal Institute for Geosciences and Natural Resources (BGR) has therefore been asked to focus more on supporting and advising German industry on safeguarding and using natural resources. The Federal Minister of Economics and Technology Rainer Bruederle launched a German Natural Resources Agency at the (BGR) in Hanover in October 2010. The new agency can draw on all the BGR's expertise on issues relating to geosciences and raw materials so that it can provide customised advice and assistance to companies and business

associations. Support is geared especially towards small and medium-sized companies to help them reduce their commodity supply risks, with information on availability, market development and the sustainable use of raw materials.

Federal Minister Bruederle stated: "The Federal Institute for Geosciences and Natural Resources (BGR), which is based at the Geozentrum Hannover, offers ideal conditions for the German Natural Resources Agency. Over many decades, it has built up special scientific expertise on raw materials. It has developed excellent links to all the international institutions in this field. The new German Natural Resources Agency will help to further pool the existing expertise and skills in the provision of consulting services on raw materials. I am convinced that this is an important step towards safeguarding Germany's industrial competitiveness in the long term."

As scientific and technical agency of the Federal Ministry of Economics and Technology (BMWi) the BGR undertook important conceptual preparatory work in the run-up to establishing the Natural Resources Agency, including the setting up of a liaison office as the first point of call for industry.

"The core of the agency is to be a raw materials information system relating to availability of natural resources, built up on the basis of the comprehensive data and many years of experience gained by BGR in this sector. We will be keeping an eye on all natural resources, but will focus particularly on natural resources for high-tech applications which are vital for the development of tomorrow's key technologies," said Prof. Dr. Hans-Joachim Kuempel, BGR President.

Although Germany has a significant potential of domestic natural resources available such as non-metallic minerals, potash salts, rock salt and lignite, it is strongly dependent on the import of energy resources such as oil and gas, and almost entirely dependent on imports of ore and the use of recycled resources for its metallic natural resources. This is of key importance in particular for the automotive and mechanical engineering sectors, as well as for future technologies in the energy, electronics and IT industries. The value of natural resources imported by Germany in 2009 was around € 84 billion, of which approx. € 66 billion was spent on energy resources and approx. € 22 billion on metallic commodities.

The strong dependency on global georesource markets and the increasing distortions of trade and competition affecting the global economy can cause problems in particular with the development and launch of innovative products. In collaboration with industry, the Federal government is therefore elaborating a national commodities strategy under the auspices of the Ministry of Economics. The German Natural Resources Agency is one of the elements of this strategy.



*Dr. Thomas Oberthuer, BGR-project manager "Deposits and confirming the origin of mineral resources", shows Federal Minister Bruederle specimens of different ores.*



*Federal Minister Bruederle and BGR President Prof. Dr. Hans-Joachim Kuempel (right) with two specimens of rare earths.*

The agency is intended to tap the advantages arising from the BGR's active involvement in national and international networks of geological surveys, natural resource associations and research institutes, not to mention the enormous wealth of experience from its more than 50 years of international cooperation with emerging and developing countries – which has enabled the BGR to develop excellent networks and regional commodities-sector expertise.

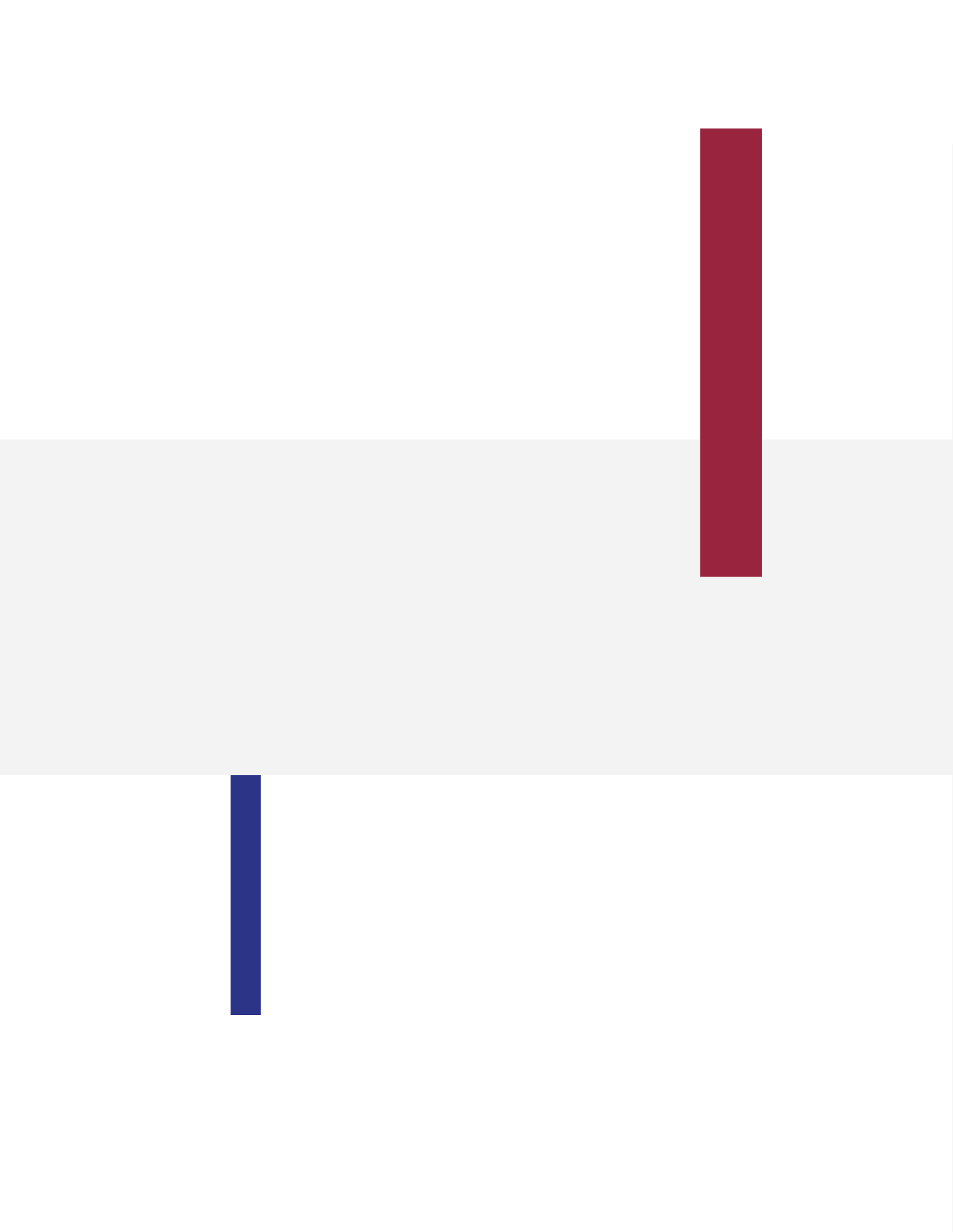
“The Natural Resources Agency will be able to provide an entirely new quality of information about the commodities sector and to highlight new approaches and solutions to safeguarding the supply of natural resources,” says Dr. Volker Steinbach, Head of the Natural Resources Department at the BGR and the German Natural Resources Agency.

The aim is to enhance transparency on the commodity markets. This will provide a better decision-making basis for industry and support it in its efforts to safeguard supplies of raw materials. The new agency also intends to provide German

industry with the information it requires to diversify its sources of supply, particularly with respect to long-term resource supply relationships with important raw material producers as well as the direct involvement by companies in the exploration or extraction of natural resources. As part of the natural resources support programme operated by the Federal government, the agency will also look at the methodological aspects of developing and exploiting mineral deposits more efficiently as well as identifying natural resources and highlighting the potential for using materials more efficiently.

**The German Natural Resources Agency liaison office can be reached as follows:**

**Telephone (0049)-(0)511/643 3200,  
Fax: (0049)-(0)511/643 53 3200 or  
email: kontaktbuero-rohstoffe@bgr.de**





# *Energy Resources*



# Introduction

The start of the 21st century heralded a rapid rise in global primary energy consumption. While the importance of nuclear energy remained largely constant so far, the importance of crude oil, coal and natural gas gained further significance as fuels. As an industrialized country, Germany depends on reliable supplies of cost-effective energy. Energy demand in Germany is also largely covered by crude oil, natural gas, coal and uranium. Germany is largely dependent on imports of energy resources. Although geothermal energy has major potential in Germany to contribute to energy supplies, the expansion of renewable energies overall will still take some time until they can cover a significant proportion of the energy base load.

From a geological point of view, there are still large deposits of energy resources. Examples of resources of crude oil in this category include heavy oil, oil sands and oil shales, as well as oil from deep water regions and in the Arctic. In the case of natural gas, the focus in recent years has increasingly been on the use of non-conventional deposits such as shale gas

and coal gas. The future exploitation of these energy resource deposits will not be decided on purely based on the geological situation and the technical feasibility: economic demands have to be harmonised with a responsible interaction of the environment.

The BGR deals with the exploration of fossil fuels including crude oil, natural gas, coal and uranium, as well as deep geothermal energy sources. The BGR performs research into the potentials and risks associated with the possible future use of these energy resource deposits. This also includes research into non-conventional natural resource deposits in Germany. Around the world, the BGR carries out research on continental margins to evaluate the potential of oil and gas deposits in regions which have not yet been targeted seriously by industry. The scientific competence acquired in this way enables the BGR to provide advice to the German government, industry and the public on issues concerning the future availability of energy resources. The BGR also distributes regular reports on fossil fuels in the form of publications and reports.



Drilling site during the drilling activity in 2009 with the Innova drilling rig in the centre.

## GeneSys: BGR intends to heat its offices with geothermal energy

**T**he GEOZENTRUM Hannover is to be heated in future with geothermal energy drawn from a depth of almost 4,000 metres. The basis for this plan is the GeneSys geothermal project run by BGR. The approx. Euro 25 million project is financed by the Federal Ministry of Economics and Technology. Important accompanying scientific investigations are conducted by the Leibniz Institute for Applied Geophysics (LIAG) and funded by the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU).

Geothermal energy is an almost inexhaustible energy source. With its GeneSys demonstration project, BGR makes a contribution to establish sustainable energy supplies. Geothermal energy is not only an environmentally compatible energy source, GeneSys also involves a new approach to the exploitation of geothermal energy. A new concept for the extraction of geothermal heat from previously unusable low permeability sandstones is being implemented.

The target horizon of the GeneSys borehole is the Middle Bunter Sandstone: This thick rock formation has a temperature of approx. 160 °C at depths between 3,400 and 3,700 metres below ground level. Formations of this kind are common throughout north Germany. However, their hydraulic permeability is usually inadequate for the conventional production of thermal water. A very large artificial fracture is therefore created underground to create an artificial heat exchanger. Cold water is injected into this artificial fracture, where it heats up, and can then be produced as hot water after remaining underground for a certain period of time.

The heat stored in the hot water when it is produced back to the surface is extracted by a surface heat exchanger and transferred to a heating circuit. The cooled water is then stored temporarily at a much higher horizon in a shallower borehole. This intermediate storage takes place in sandstones located at the base of the Lower Cretaceous at a depth of approx. 1,200 m ('Wealden' Formation). The planned cycle used in the

process will be seasonal: The cold water will be injected into the deep borehole in the summer where it warms up. During the winter months when buildings have to be heated, this hot water will be produced again.

The successful conclusion of the GeneSys project will open the door to the geothermal use of the widely occurring low permeable sedimentary rocks in north Germany.

The cyclic process referred to above has already been successfully tested in the around 4,100 m deep BGR research borehole 'Horstberg Z1' located in the southern Lüneburg Heath. The tests carried out at Horstberg Z1 revealed that thanks to the great depth and the geological conditions, the creation of the artificial fracture will not be expected to have any impact on the surface.

## GeneSys: From borehole to geothermal heat

The borehole was drilled on the BGR premises from June to November 2009. The borehole was successfully drilled through sedimentary rocks of Cretaceous, Jurassic and Tertiary age to the target horizon in the Lower Bunter Sandstone at a depth of approx. 3,900 metres. The final section of the borehole was drilled at an angle of approx. 25° from the vertical to optimise the creation of an artificial fracture. Cores were cut in three rock layers of most interest for the subsequent geothermal heat production or water storage. In addition, a comprehensive logging programme was run in the borehole to precisely characterise the sandstone horizons in particular. Final depth was reached in the borehole in November 2009.

The low-noise Innova TI 350 drilling rig was used to drill the well. This rig was specially developed for drilling deep holes in built-up areas. The houses in the neighbouring residential areas were protected by a 10-metre high moveable sound barrier to limit the more serious noise emissions. Around 6,500 visitors including many direct neighbours came to the info centre at the drilling site to inform themselves about the project and take part in guided tours.

The formation temperature at the bottom of the hole was measured after completion of the drilling activity. These measurements revealed a temperature of approx. 170 °C at the deepest point in the borehole (approx. 3,900 metres). This was much higher than originally expected. The higher temperature will simplify the subsequent geothermal exploitation because the intended thermal capacity can be achieved at a lower flow rate. This reduces the specifications for the artificial fracturing process and therefore the overall risk.

Test and development work began in spring 2010. A 6-metre long section of the borehole in the Middle Bunter Sandstone was perforated at a depth of around 3,700 metres in the borehole to allow access to the surrounding rock. Minifrac's were then carried out to measure the mechanical and hydraulic properties of the surrounding rock.

These minifrac's confirmed that the surrounding rocks were basically hydraulically tight. The most important finding, however, was that the frac pressure, i.e. the force required to create an artificial fracture in the rock, would need to be much higher than initially thought.

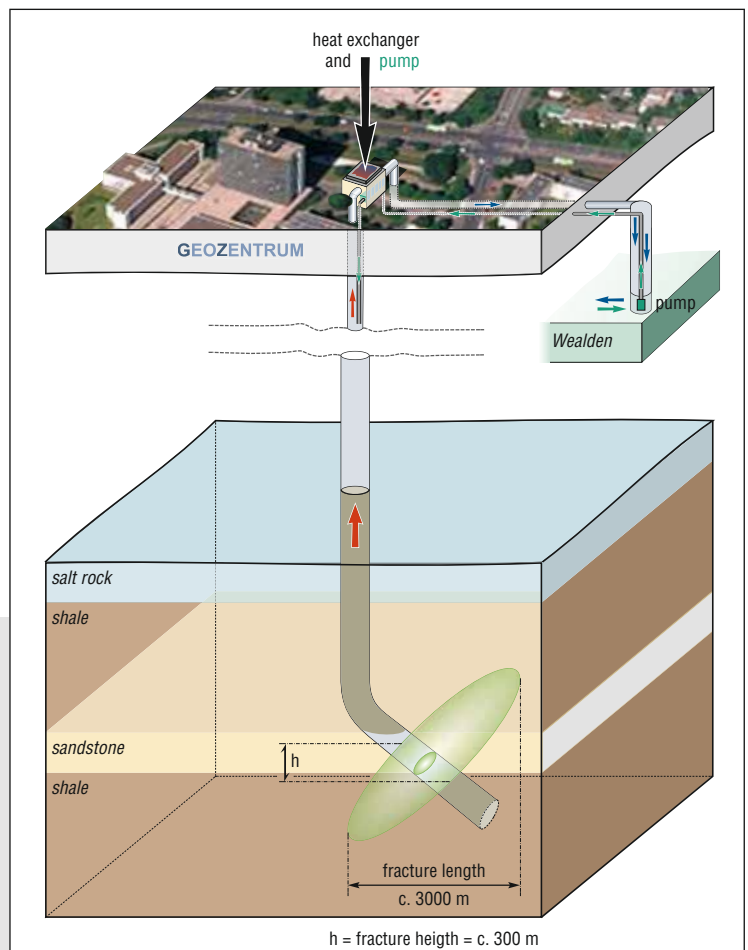


Diagram showing the cyclic concept for extracting geothermal heat using an extensive artificial fracture created in the Middle Bunter Sandstone (approx. 3,400 – 3,700 metres deep).

Cold water is pumped from the "shallow" borehole into the artificial fracture in the deep borehole. After remaining at depth for some time to heat up, the hot water is then produced out of the fracture, cooled down in a heat exchanger to extract the warmth, and then pumped back into the shallow borehole again.

This meant that an additional casing – a liner extension – had to be installed from a depth of approx. 2,700 metres to the surface. This liner extension is used to protect the walls of the borehole against the expected higher pressures during the subsequent frac operation. The liner extension was installed in the beginning of 2011.

Injection tests were also carried out to investigate the hydraulic properties of the Wealden Sandstone Formation. These tests were conducted via the annulus of the borehole between the 13 3/8" and 9 5/8" casings. The findings are very promising for the subsequent use of this formation as an interim storage for the returned and cooled water.

In addition to the aforementioned tests and logging, a detailed measurement and investigation programme was also conducted in 2010 to characterise the rock samples and evaluate the borehole logs.

Simulation calculations are used to model various scenarios including the extent of the artificial fracture and the long-term thermal capacity of the borehole. These simulations are essential for deciding how to optimise the geothermal exploitation of the borehole.

The work planned for 2011 initially included the installation of the liner extension and the massive frac operation. During the frac operation, it is planned to inject approx. 20,000 cubic metres of treated fresh water to generate an artificial fracture over a large area. The subsequent development work is dependent on the results of this operation.

After successful fracturing, the next step is to construct a central geothermal heating plant which is then due to be commissioned in 2014. The plant will probably be designed with a thermal capacity of two megawatts.

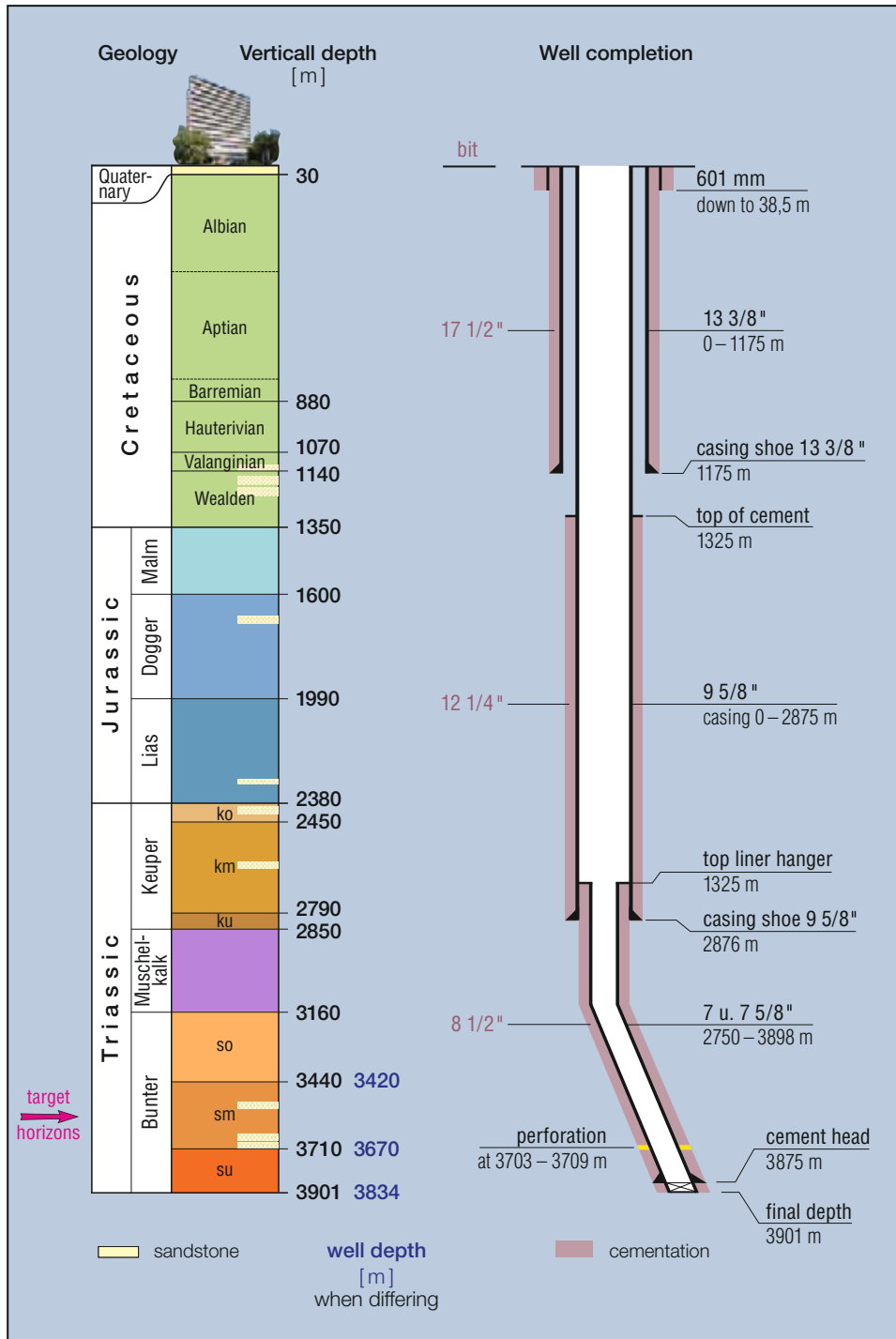
## Parliamentary State Secretary visits the GeneSys project

Berlin VIP at BGR: Peter Hintze, Parliamentary State Secretary at the Federal Ministry of Economics and Technology came along personally to see the drilling progress at the 'GeneSys' geothermal pilot project at BGR.

The Parliamentary State Secretary expressed his enormous satisfaction over the course of the project to date financed by the Federal Ministry of Economics and Technology. "Geothermal energy is an almost inexhaustible, and particularly environmentally friendly source of energy. The GeneSys pilot project can therefore make a major contribution to renewable energy supplies," says Hintze.



*Being informed on site about the progress of drilling activity:  
(from left to right) Dr. Michael Kosinowski, Prof. Dr. Hans-Joachim Kuempel, Dr. Maria Flachsbath, Peter Hintze, Rita Pawelski.*



Borehole and stratigraphy of the GeneSys borehole.

The true depth shows the vertical depth of the borehole, while the drilling depth shows the length of the borehole at any particular point. In deviated boreholes, the drilling depth is greater than the vertical depth.

## In the collision zone between two continents

### Investigating the hydrocarbon potential of continental margins in the Eastern Mediterranean

**A**s part of its marine exploration to estimate the hydrocarbon potential on different types of continental margin, BGR carried out a research expedition with the German research vessel 'Maria S. Merian' in the waters south of the Mediterranean Island of Cyprus.

14 scientists and technicians boarded the vessel in Limassol (Cyprus) on 16 January 2010 to take part in the six-week long expedition on the most recent and the most modern German research vessel. The use of the 'Maria S. Merian' was facilitated by the German Research Foundation (DFG).

The exploration cruise was focused on the area around the submarine Eratosthenes Seamount using geophysical techniques which are also used by industry.

The main priority of the ongoing research programme is to estimate the extent to which the tectonic regime overprinted by collision processes could have created new migration paths and trap structures for oil and gas (and hydrocarbons in general).

The background to this exploration is the special constellation of geological units brought together by the collision of the African/Arabian continental plates in the South, with the

Eurasian Plate in the North. Today's relatively small and almost land-locked Mediterranean developed slowly, as a result of the northwards movement of Africa, from the originally huge Tethys Ocean which was open to the east. Deep sedimentary basins were filled over the course of millions of years by sediments brought in by the Nile River. In addition, the whole Mediterranean area is underlain by a massive salt deposit with a thickness of approx. 2,000 metres, formed during the so-called Messinian Crisis when the connection between the Mediterranean and the Atlantic Ocean was blocked around 5 to 6 million years ago.

During this process, the Eratosthenes Seamount was continually pushed towards the continental Cyprus block. Of course, the collision of these continental fragments had a direct impact on the close by surrounding because of the increasing compression, however it also had an significant impact on the whole Eastern Mediterranean.

In order to investigate these processes, multichannel seismic measurements were carried out aboard the RV 'Maria S. Merian'. This involves generating acoustic signals in the water which are then reflected by geological boundaries. These reflections are recorded by thousands of small sensors positioned along a 4,000 metre long towed surveying cable, and subsequently digitally stored.



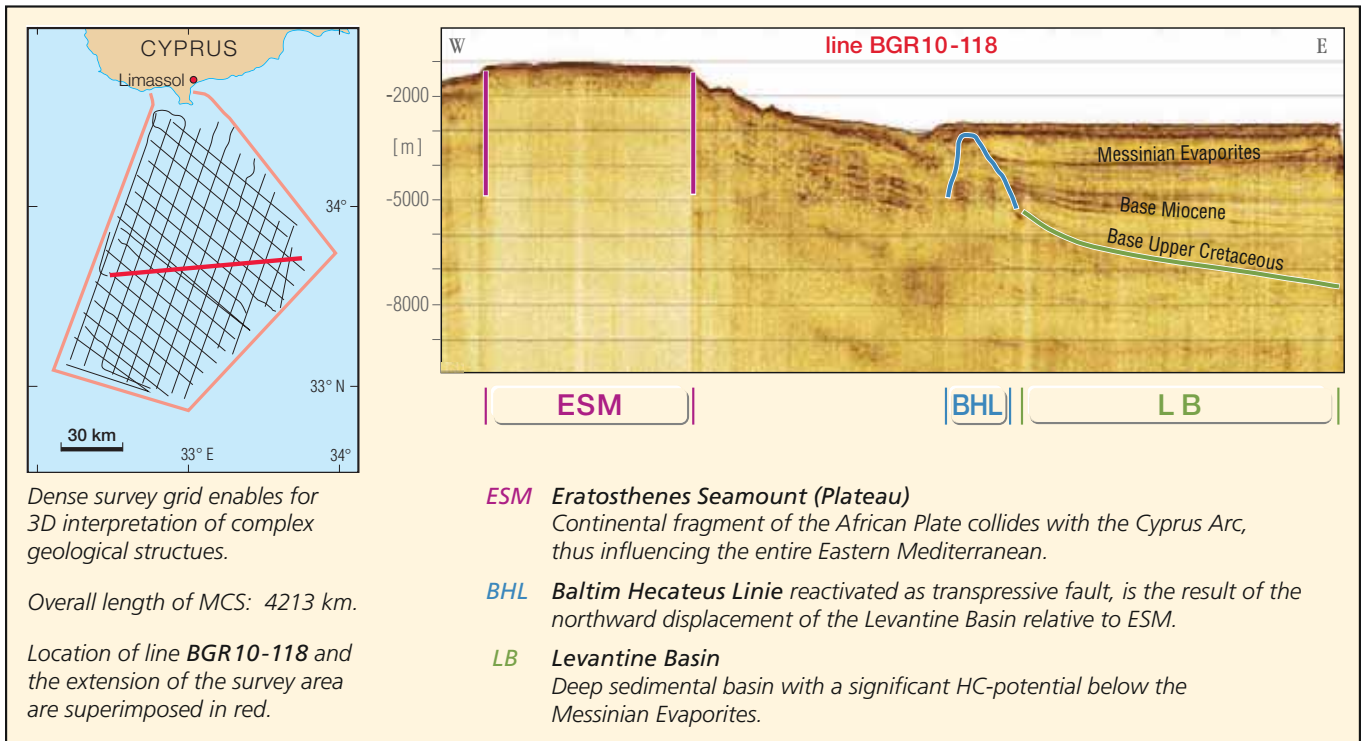
The 'MS Merian' research ship on an exploration expedition off the coast of Cyprus.

When this data is processed it reveals a cross-section of the subsurface layers enabling the sedimentary sequences and geological fault patterns to be mapped and analysed.

The investigation programme included other special seismic measuring tools which were placed on the sea floor to provide information on the sound velocities in the rock layers, and thus improve the depth conversions to pinpoint the positions of the rock boundaries and faults.

Additional surveys of the magnetic field and the gravity field of the investigation area also assist the interpretation of the seismic data. In addition magneto-telluric devices which were operated in cooperation with the Leibniz Institute for Maritime Sciences at the University of Kiel (IfM-Geomar) were deployed. The data provided by the ship's own systems – a multibeam echosounder and a sediment echosounder – provided important additional information on the most recent sedimentation and the morphology of the sea floor.

Because the strong compression processes in the region have significantly deformed the involved geological structures, a three dimensional mapping is a crucial factor in interpreting them properly. A dense grid of seismic lines with a total length of more than 4,200 kilometres was therefore acquired over the Eratosthenes Seamount and the western Levantine Basin. High quality geophysical data was consequently acquired during the 42 day surveying expedition, and this data is still being evaluated today.



Surveying area and seismic line southwest of Cyprus.

West to east seismic line (right). The red line (left) marks the geographical location.



## North German Geothermal Meeting at the GEOZENTRUM Hannover

The North German Geothermal Meeting 'Hotspot Hannover – Geothermal energy: where innovation promotes economic efficiency' at the GEOZENTRUM Hannover provides information on the latest developments in the geothermal energy sector. The meeting is organised by the regional business promotion company 'hannoverimpuls' along with the three institutes at the GEOZENTRUM Hannover: the Federal Institute for Geosciences and Natural Resources (BGR), the Lower Saxony State Office for Mining, Energy and Geology (LBEG) and the Leibniz Institute for Applied Geophysics (LIAG).

At the Geothermal Meeting 2009, the presentations included concepts on the efficient use of shallow geothermal energy down to depths of around 100 metres. Shallow geothermal heat is primarily used for heating private houses, and increasingly also for heating and cooling large building complexes (office buildings, shopping centres, etc.). Other presentations provided information on concrete deep geothermal energy projects in north Germany: where the objective is to exploit geothermal energy at depths of several 1,000 metres to extract heat and generate electricity.

The focus of the geothermal meeting 2010 was also the further expansion of geothermal energy to make an environmentally-compatible, base load-capable, and domestic contribution to the overall supply of energy. Around 200 experts and potential users came together to discuss the latest projects and innovative concepts. In addition to papers presented on concepts and the latest trends in the shallow geothermal energy sector (down to depths of 400 metres), experts took part in a podium discussion to discuss potential conflicts of interest in exploiting deep underground geological resources.

This subsurface economic zone is already used by mining, for the storage of crude oil and natural gas, and the disposal of waste. These industrial activities will be joined in future by the extraction of geothermal energy, the storage of carbon dioxide (CO<sub>2</sub>), and the utilisation of renewable energy sources (compressed air, hydrogen, underground pumped-hydro power plants).

The event was also the occasion for commissioning the LBEG's new internet portal "Geothermal energy – is that practical for me?". This internet service allows home owners in Niedersachsen to quickly check whether their property is suitable for harnessing shallow geothermal energy. More than 6,000 buildings in Niedersachsen are already heated by shallow geothermal energy via heat pumps.



*Around 200 visitors were informed at the Geothermal Meeting 2010 about various methods for exploiting geothermal energy.*

## BGR-expertise for the petroleum geological atlas of the southern Permian Basin

BGR is the co-publisher of a new petroleum geological reference work. The "Petroleum geological atlas of the southern Permian Basin area" contains 350 large format pages presenting information on all aspects of oil and gas exploration: from the North German Plain in the south to Denmark in the north, England in the west and the Baltic in the east.

The atlas is a joint project of the geological surveys of Belgium, Denmark, the United Kingdom, the Netherlands, Poland, and BGR as the national geological survey in Germany. Other major contributions came from the Lower Saxony State Office for Mining, Energy and Geology (LBEG), the competent authorities in the participating countries, as well as numerous acclaimed technical authors from universities, research institutions and industry.

Around 150 specialists compiled their knowledge over a period of five years from the 150 years of exploration of the southern Permian Basin to produce this mammoth volume. "The atlas is therefore a new reference work for the geology and fossil fuels in our region," says BGR geologist and co-author Dr. Thomas Pletsch. "With hundreds of geological maps, cross-sections and diagrams, this atlas provides an ideal foundation for work aimed at exploring and developing new fossil fuel deposits."

The atlas reflects the current status of exploration of conventional fields as well as unconventional deposits such as shale oil and shale gas. A particularly large amount of space is reserved for the transnational visualisation of geological structures and updated stratigraphic descriptions and correlations.



*The petroleum geological atlas looks at all aspects of oil and gas exploration.*



**The atlas is available from EAGE in printed form (DIN A2) and in digital form (PDF):**  
[www.eage.org/bookshop](http://www.eage.org/bookshop)

## Commodity Top News 32 (2009): Quo vadis coal?

Are the world's coal reserves adequate to safeguard supplies for centuries? Or will we soon see 'peak coal' – a time when coal reserves are no longer able to satisfy the growing demand for energy? This and other questions is dealt with in the BGR newsletter 'Commodity Top News' under the title "Quo vadis coal?".

The future of coal is at the top of the agenda in current discussions on climate and energy policy. Complete and reliable data on the global coal reserves is an important planning and decision making factor in this discussion. In addition to the World Energy Council (WEC), BGR is the only institution world-wide that compiles and regularly publishes a complete data set on global coal reserves and resources. The latest issue of 'Commodity Top News' provides a concise review of this topic.

BGR's findings reveal a clear picture: coal is the non-renewable fuel with the largest total resources – by far. No global supply crisis is expected in the foreseeable future attributable to the physical shortage of this natural resource, even in the face of growing demand:



**[www.bgr.bund.de/CTN-32-kohle](http://www.bgr.bund.de/CTN-32-kohle)**

## BGR-study 'Energy Resources 2009'

On behalf of the Federal Ministry of Economics and Technology (BMWi), BGR scientists have analysed the global reserves and resources, production and consumption, costs and prices, and the latest trends and technical developments concerning non-renewable energy sources. The analysis reveals that oil, gas, coal and uranium will continue to form the backbone of energy supplies in coming decades. But there will be important shifts within this group in the long term.

This forecast is based on the findings of a projection of oil production rates up to 2050 carried out as part of the study. This analysis reveals that crude oil will be the first fossil fuel where no further increase in production will be possible because of the reserve limits.

The foreseeable long-term decline in oil production must be counteracted by renewables and the other three fossil fuels. However, the BGR study also shows that there is no risk from a geological point of view in the foreseeable future to the global availability of natural gas, coal and uranium.

In their study, the scientists also evaluated the role of possible alternatives to the conventional fuels. Projects have been launched around the world in recent years looking at the technical and economic feasibility of e.g. the wide-spread production of natural gas from gas hydrates and oil from oil shales.



**The study is available from:**  
[www.bgr.bund.de/EN/Themen/Energie](http://www.bgr.bund.de/EN/Themen/Energie)

## Annual report 2009: Reserves, resources and availability of energy resources

"The dramatic fluctuations in the price of energy resources in 2008 were not attributable to shortages of reserves of energy resources." This is the conclusion reached by the BGR experts who analysed the global availability of the energy resources oil, gas, coal and uranium in the 'Annual report 2009: Reserves, resources and availability of energy resources'.

"The study reveals that coal and uranium in particular are available in very large quantities in deposits. Even against the background of a further major increase in the use of these natural resources in the next decades, reserves would still be adequate for a long period," says BGR natural resources expert Prof. Dr. Bernhard Cramer.

A global rise in the demand for natural gas is forecast in coming years. Annual global production of 3.2 trillion m<sup>3</sup> in 2008 compares with natural gas reserves of 188 trillion m<sup>3</sup>. However, the latest study also reveals that crude oil would be the first fossil fuel to experience restrictions in supplies because of a shortage of reserves. It is already hardly possible today to boost the production rates for conventional crude oil. The annual report 2009 is an update of the comprehensive analysis 'Energy Resources 2009':



[www.bgr.bund.de/EN/Themen/Energie](http://www.bgr.bund.de/EN/Themen/Energie)

## Annual report 2010: Reserves of crude oil are not unlimited

Global production from the known oil fields is already well advanced. Although oil production can be increased by the exploitation of non-conventional reserves, e.g. oil sand, heavy oil and natural gas condensate, these will probably only slightly delay the imminent onset of peak oil production.

These are the findings of the recently published 'Annual report 2010: Reserves, resources and availability of energy resources 2010' prepared by BGR. According to this study, oil production could be boosted under optimal conditions until 2035 at the latest. However, there are many possible factors and developments which could cause this point to be reached earlier.

The study looking at the 2009 reporting year also analyses the impact of the economic development and the price fluctuations experienced by energy natural resources. For instance, uranium reserves – the known, technically and economically exploitable volumes of the natural resource – grew because this natural resource attracted higher prices on the world market. Deposits previously considered uneconomic can now be reported as economically exploitable.

The situation on the natural gas market in 2009 was one of oversupply, attributable on the one hand to the decline in demand for natural gas during the economic crisis. On the other hand, the USA boosted its production of natural gas from non-conventional deposits such as coal seam gas and shale gas. The exploration for non-conventional natural gas deposits has now already started in Germany. BGR is currently analysing on behalf of the BMWi the potential of shale gas in Germany.

Coal continues to be the fossil fuel with the largest geological availability by far. Coal reserves are adequate to cover growing global demand for many decades to come:



[www.bgr.bund.de/EN/Themen/Energie](http://www.bgr.bund.de/EN/Themen/Energie)

# Outlook

**B**ecause of the imminent global restriction in the supply of crude oil, the BGR's scientific work will focus on the monitoring, analysis and evaluation of the global availability of non-renewable fuels.

The results of this work are used in particular to provide advice to the German government, industry, and to inform the public. This will be carried out in the future in more concentrated form by the 'German Mineral Resources Agency' (DERA) recently established within the BGR.

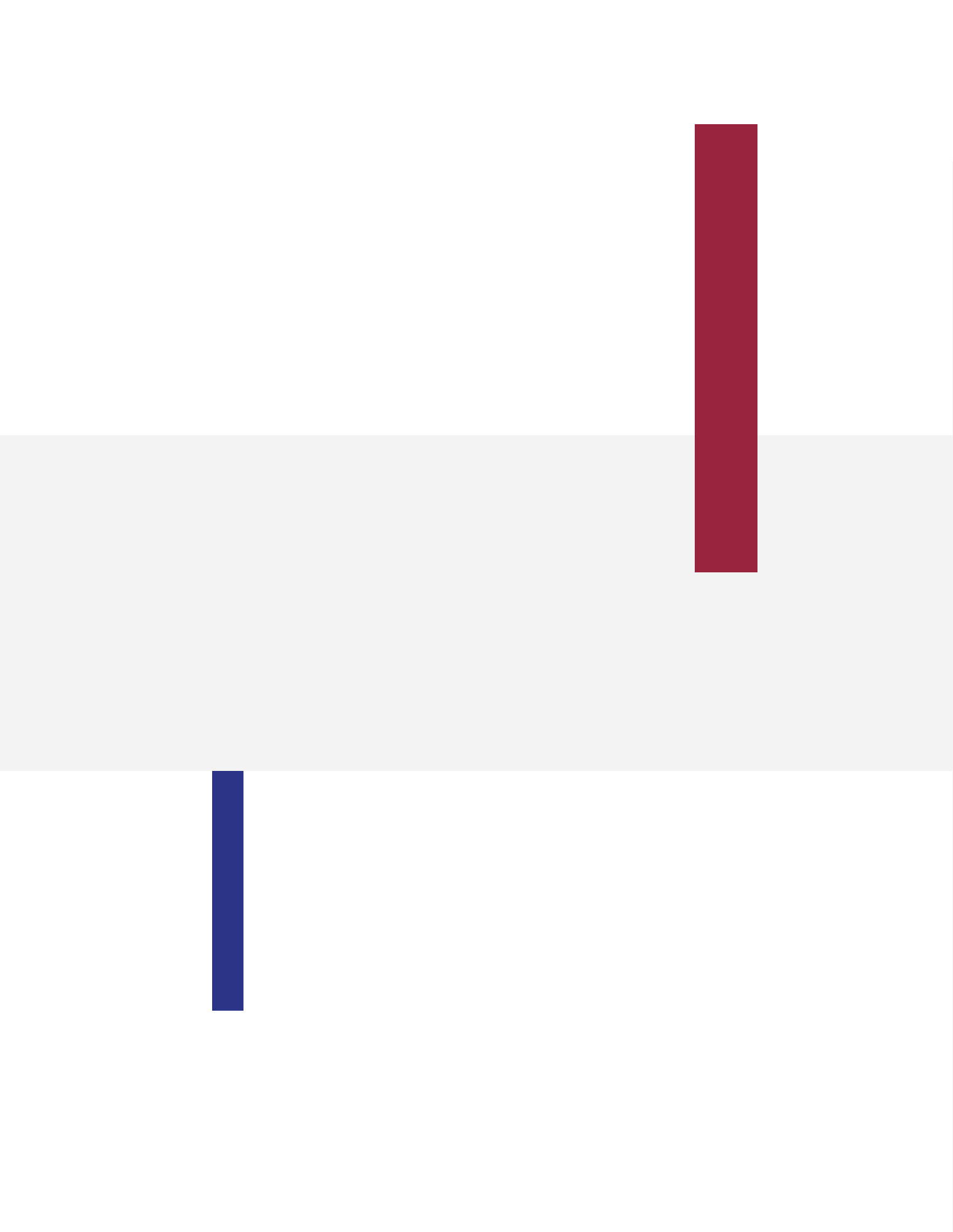
In this context, the BGR also strengthens its activities in exploring the remaining potential of oil and gas in locations which have previously not captured the imagination of industry.

For this purpose, the marine geophysical surveying of continental margins by the BGR will be expanded in future by the use

of the 3D-reflection seismic method which the BGR has at its disposal only recently, and the very promising surveying method 'Controlled Source Electromagnetic' (CSEM) – another useful tool in its armoury of logging methods. In addition to providing structural information, CSEM also provides information on the presence of oil and gas as well as the extent of oil and gas fields.

The regional focus of exploration work in the Arctic will be continued because this area is a probable future production area supplying Germany with fossil fuels.

In addition, as part of its brief to provide advice to German industry, the 'German Mineral Resources Agency' is also compiling information on non-conventional oil and gas fields in Germany, and analyses their economic potential.



# *Mineral Resources*



# Introduction

For several years, the international commodity markets have gone out of balance and no longer reflect equilibrium and favourable supply side conditions with low prices. The growing demand for natural resources and the associated rise in prices and price fluctuations are cause for concern in various sectors of the German industry. One of the government's jobs is to assist the establishment of long-term supplies of natural resources independent of economic cycles, and to ensure that the industry can rely on a functioning technical and economic infrastructure.

To meet its commitments in this regard, the former German Minister of Economics and Technology, Rainer Brüderle, established the 'German Mineral Resources Agency' (DERA) within the BGR in 2010. Its duties include monitoring developments in the commodity markets on behalf of the industry, identifying any shortages in commodity supplies, and flagging up alternative commodity potentials; evaluating mineral deposits; and providing government and industry with competent advice on all issues of interest to the sectors depending on natural resources.

The BGR regularly monitors the global commodities markets of metals, industrial minerals, and non-metallic minerals. It also undertakes research on natural resources pursuant to its

principles of "using geopotential to sustainably safeguard and improve living conditions". The BGR develops new exploration strategies, conducts own independent fieldwork, carries out laboratory analysis, and improves or develops new exploration and prospecting methods and strategies, as well as natural resource and mining instruments by taking innovative approaches. Its contribution to diversifying the supply of natural resources is to perform research into new and previously unexploited or alternative sources of raw materials. An example of this is the BGR's license for marine geoscientific investigation of manganese nodule deposits in the Pacific.

Germany is one of the world's largest consumers of natural resources, but is completely dependent on imports of metallic raw materials, and largely import-dependent on the supply of other mineral resources. Natural resource policy and natural resource economic decision makers are therefore not only responsible for domestic production but also share responsibility for the production methods in countries which supply Germany with natural resources and intermediate products. The BGR therefore supports the efforts of German and international policies aimed at the sustainable use of natural resources and more transparency on the commodities markets. The latter in particular is to be achieved by measures aimed at natural resource certification.





Artisanal coltan mining in Mozambique.

## Coltan 'fingerprint' supports the certification of trading chains

**R**ebel troops in the east of the Democratic Republic of Congo have been financing their bloody civil war for years with the illegal extraction of natural resources. At the same time, there is increasing pressure on industry in the west to only purchase "clean" natural resources. A certification system proposed by the United Nations is aimed at stopping the illegal global trade in georesources.

The most important control mechanism here could be a chemical-mineralogical fingerprint which BGR scientists have developed to confirm the place of origin, e.g. for the tantalum ore coltan. It is the first technique of this kind in the world.

The BGR scientists carried out research for three years on behalf of the German Ministry of Economic Cooperation and Development (BMZ) on how to confirm the origin of tantalum ores from Central African deposits where coltan is primarily exploited by artisanal mining. The pilot project focussed on the Congo and its neighbouring countries which account for up to 40 % of global tantalum production. The results of the research: the BGR scientists developed a forensic test which can

unequivocally localise the original deposits of traded tantalum ore concentrates based on the measured chemical and mineralogical parameters. This will enable illegal supplies from potential conflict regions to be identified.

To identify the origin of the ores, the BGR scientists examined selected production localities and gave each of the ores a signature of origin. At the same time, reference samples of the highly valued mineral were taken from industrial mines and buyers around the world.

Because of its high temperature and corrosion resistance, tantalum has many uses and is one of the main components for instance in the modern microelectronics sector for the production of ultra-miniaturised, high performance capacitors for mobile telephones, laptops and flat screens.

The ore samples were analysed in BGR laboratories using complex techniques in a range of highly sensitive instruments (scanning electron microscope, laser ablation ICP mass spectrometer). This defined the chemical-mineralogical composition of

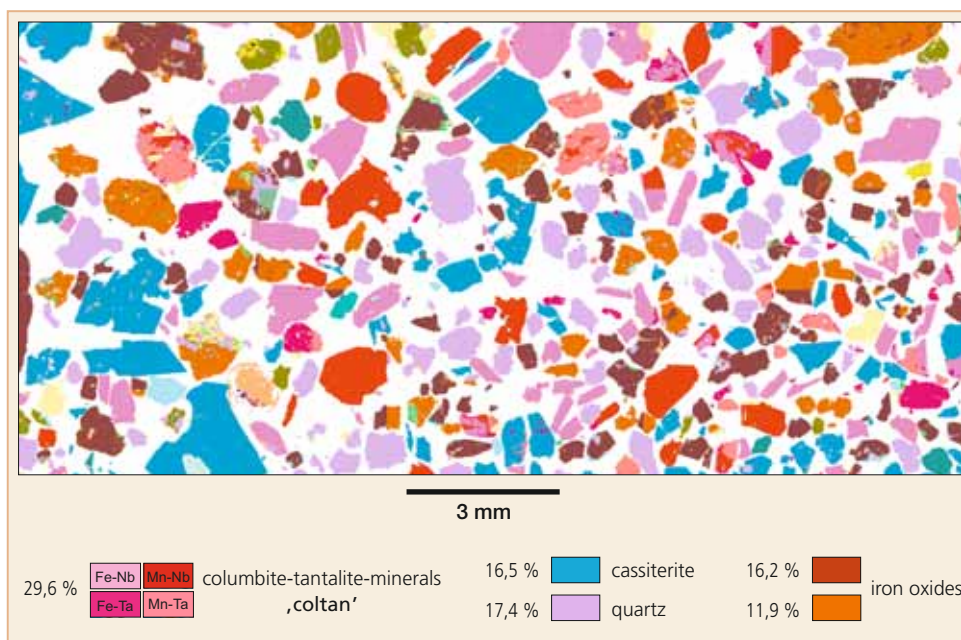
the minerals. By conducting intensive test series, the scientists were able to unequivocally identify samples of already known origin on the basis of their mineralogical and chemical composition (positive certification), and differentiate between mixtures of materials from two different supply sources. A comprehensive database helped classify the information. The database has 25,000 data sets from 200 different deposits. According to the BGR scientists, this is enough information to be able to differentiate a large number of ore provinces in Africa, even down to individual concessions.

“The results enabled us not only to assign individual test samples to a source region, but even to a specific deposit,” explains BGR expert Dr. Frank Melcher. “A functioning confirmation of origin is an important tool for improving transparency in the mining industry, especially in Africa. The electronics industry and tantalum processors are very interested in certified materials. They no longer want to be associated with the term ‘Blood Coltan’.”

The mineral resources experts at the BGR back up the work of another BGR project. This second pilot project is also focused on Africa and aims to certify the trading chains for tantalum ore in Rwanda, one of Congo’s neighbouring countries. The partner organisation in this project is the Rwanda Geology and Mines Authority (OGMR).

The aim of the project is an agreement between mineral producers in Africa and processors in Europe to become registered companies obliged to operate transparent, fair and sustainable mining and mineral processing operations which uphold minimum social and environmental standards. This project is modelled on already established certified trading chains in the forestry sector (“Forest Stewardship”) and in the food sector (“Fair Trade”).

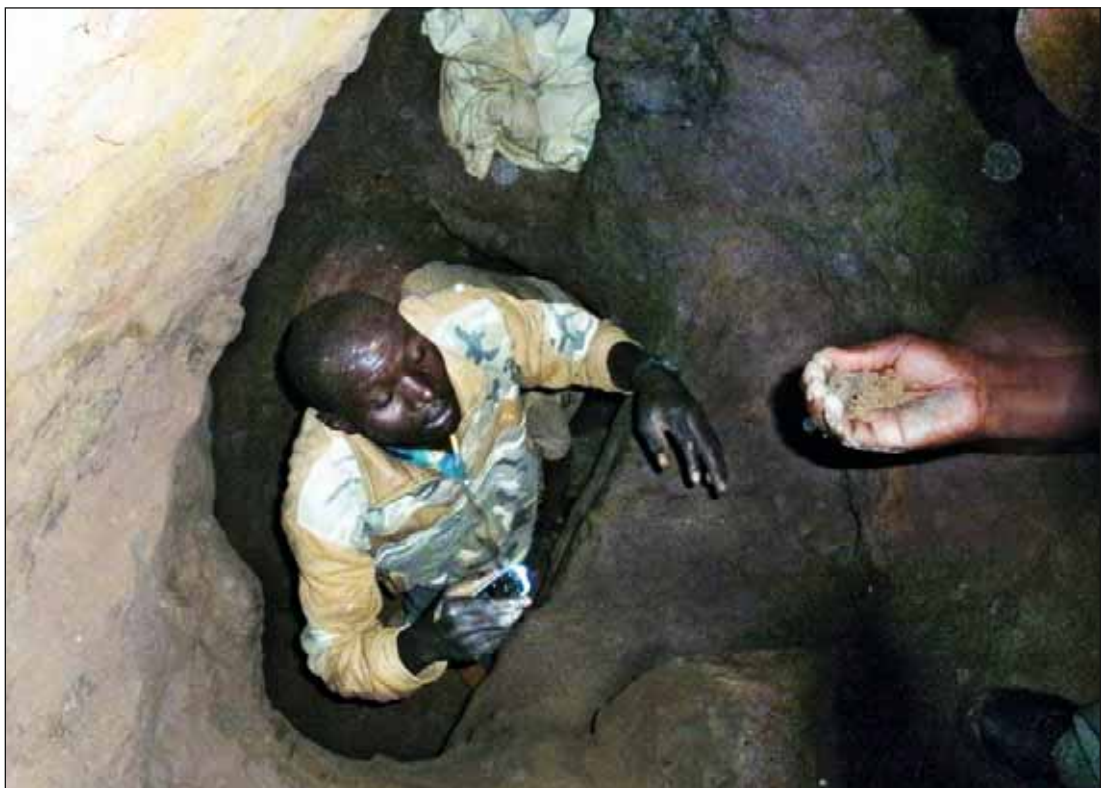
BMZ authorised BGR to support the implementation of regional certification of natural resources at the International Conference on the Great Lakes Region (ICGLR) by helping set up laboratory facilities. This measure is aimed at improving control over the flow of natural resources.



MLA (Mineral Liberation Analysis) reveals the characteristic composition of ore samples, here an example from Rwanda.



*Sample extraction for the geochemical fingerprint of a coltan mine in Rwanda.*



*Sample extraction for the geochemical fingerprint of a tungsten mine in Rwanda.*

## Certificate for more transparency

The extraction of mineral resources in Central Africa has recently been associated with armed conflicts, illegal trading and the evasion of national royalty payments. A direct association is also assumed in this context between the continuing violence in East Congo and the financing of armed groups by the illegal trade and export of ores into neighbouring countries. A group of UN experts investigating compliance with the arms embargo, recommended in 2005 that the Democratic Republic of the Congo (DR Congo) introduces a certification system for natural mineral resources as an alternative to a general ban on exports. As a consequence, eleven member states of the International Conference on the Great Lakes Region (ICGLR) signed a protocol in November 2006 condemning the illegal exploitation of natural resources. Article 11 of this protocol pledges the signatories to participate in a certification system for natural resources.

Picking up on this idea, BGR developed a concept for certified trading chains (CTC) involving natural mineral resources, and completed the draft in the run-up to the G8 summit meeting in 2007. CTC is a new weapon in the natural resources and development policy armoury which promotes transparency and compliance with ethical standards in the mineral production sector. The aim is to use the natural resource potential of developing countries to alleviate poverty, at the same time as enhancing the supply security of mineral resources on the world market.



(upper left) Coltan washing site in Mozambique.  
(upper right) "Picking" – manually separating tantalite crystals from quartz, Ethiopia  
(below) Coltan ore from Brazil



*Artisanal coltan and tin ore mining.*

## Pilot project in Rwanda: Increased transparency through certification

In cooperation with the Rwanda Geology and Mines Authority (OGMR), BGR is conducting a pilot project to certify mineral trading chains (Certified Trading Chains, CTC).

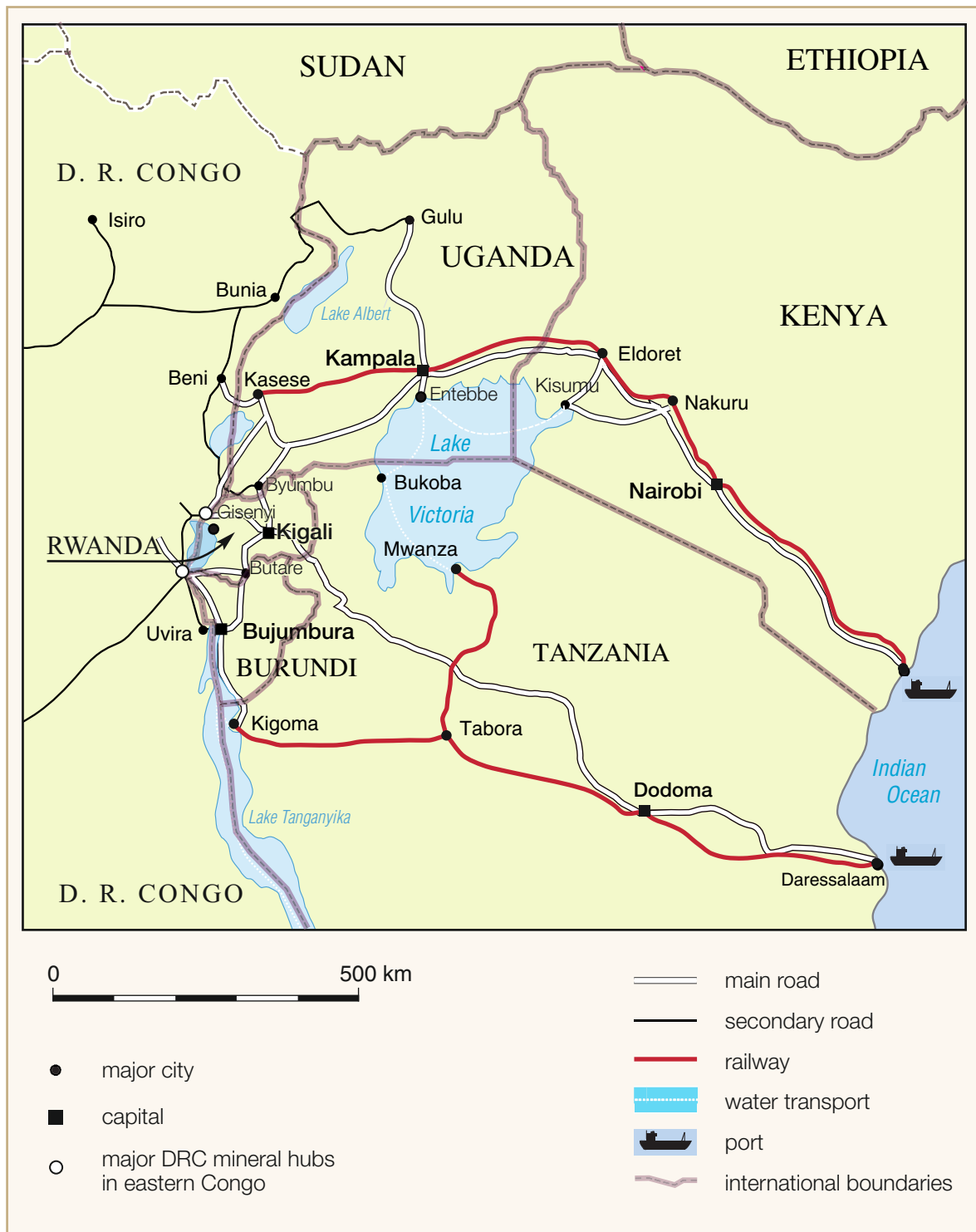
The pilot project – jointly funded by the German Federal Ministry of Economics and Technology and the German Federal Ministry of Economic Cooperation and Development – aims to support a transparent, fair and sustainable natural resources industry in the artisanal and small-scale mining sector. These certification efforts in Rwanda have become particularly relevant because of the regional correlation with mineral sourcing and trading in the neighbouring conflict regions in the Eastern Democratic Republic of the Congo.

The most important feature of the system is therefore the ability to trace produced and traded minerals back to their original source. This is investigated by an independent auditor on site taking into consideration a range of criteria (production plausibility, verifiable origin and trading chain, transparency, etc.). The Analytical Fingerprint (AFP) for coltan and other ores is available as an optional verification instrument to support these efforts. The audit simultaneously evaluates compliance with minimum social and environmental standards during mining. These standards are mainly aligned with the integrity

instruments of the Organisation for Economic Cooperation and Development (OECD).

This combined on-site inspection is a central element stipulated by the United Nations to ensure that the mineral processing industry meets its due diligence requirements, especially where their trading chains partially incorporate suppliers based in conflict regions. The audit report issued by the independent auditor forms the basis for subsequent certification.

The project is based on an initiative by G8 countries who, at the Heiligendamm summit in June 2007, decided to support a pilot project on mineral certification. “There has been no quality label to date for compliance with sustainability and development standards in the artisanal and small-scale mining sector – the pilot project in Rwanda can be a first step in this direction,” says Prof. Dr. Hans-Joachim Kümpel, BGR President. “Extraction and export of minerals are often done without state control, in particular in Central Africa. Small-scale mining which currently accounts for most of the mineral production in Rwanda, has been done illegally in part. There is often no transparency about trading or export.”



Minerals produced in the eastern parts of the Democratic Republic of the Congo are largely exported via its eastern neighbouring countries. An unambiguous origin of these minerals can therefore become blurred because they are often mixed with other minerals during transport and processing.

Rwanda produces significant quantities of tantalum, tin and wolfram ores. These mineral products have also been labelled as 'conflict minerals' because, in some cases, their production in the eastern parts of the Democratic Republic of the Congo catalyses the prevailing conflict, and is associated with human rights violations.

Rwanda is a central transit country for these 'conflict minerals'. It is not uncommon for minerals from Rwandan and Congolese production to be mixed up here – which makes the tracing of the origin of these minerals, combined with their certification, a crucial factor in verifying the legitimacy of minerals from original Rwandan production sites. This situation is particularly important in the light of a law adopted by the US Securities and Exchange Commission (SEC) in 2010 which stipulates that all companies registered at the SEC must issue an annual public report describing the processing and the origin of 'conflict minerals' in their products.

BGR project director Dr. Gudrun Franken describes the objectives of the project study as follows: "In the pilot project Rwanda, mineral certification is supported through an appropriate management and monitoring plan of participating companies." The project partners are local companies which have received concessions from the state agency REDEMI as part of the restructuring of the mining sector. Their production sites were assessed by an independent expert during several reference audits in 2009 and 2010 to check compliance with

the CTC standards. The audit findings provided the platform for assistance from external experts to improve operating processes run by the project partners. Despite the tight time schedule, a second audit phase conducted at the end of 2010 already revealed some significant improvements in the operating procedures of the involved companies.

The extended project is scheduled to run for 32 months. The costs of EUR 500,000 are shared equally between the German Federal Ministry of Economics and Technology (BMWi) and the German Federal Ministry of Economic Cooperation and Development (BMZ). The project components financed by BMWi involve the international consultation process on the certification concepts. BMZ supports the pilot project implementation of the certification scheme for mineral producers in Rwanda. In addition, further development of the CTC approach in Rwanda (and neighbouring countries) is planned within the framework of ICGLR.



*(left) Washing (ground sluicing) of the crude ore in preparation for pre-concentrate production.*

*(middle) Ore concentrate processing plant in Gisenyi/Rwanda. Ore concentrate ready for transport.*

*(right) Crude ore extracted from a tunnel prior to washing; single large blocks of tin ore in the front.*

# New microorganisms for Biomining



*Exotica open cast copper mine near Chuquicamata in Chile.*

**M**etals such as copper, zinc and nickel are increasingly extracted using biotechnological processes. 'Biomining' is now well established. The customised use of microorganisms is also an option for the clean-up of mining contamination, as BGR scientists intend to demonstrate in a research project in Chile.

BGR geomicrobiologists selected the Atacama Desert in Chile for this project which is funded by the German Research Foundation (DFG). This desert is the driest region on earth. BGR scientists together with Prof. Dr. Bernhard Dold of the University of Concepción (Chile) are investigating the behaviour of microorganisms in the waste of an abandoned copper mine lying on the coast of the Pacific Ocean.

The desert bacteria inhabiting the waste dump produce acid mine drainage because of the inflow of water from the neighbouring Pacific Ocean. This acid mine drainage is an environmental pollutant. It also contains metals released by the microorganisms from the ore residues in the mine dumps.

"The completely natural process which we observe in the waste dump in the Atacama Desert is identical to the concept behind biomining – the customised biological extraction of metals contained in ores," explains Professor Dr. Axel Schippers,

head of the BGR Geomicrobiology unit who is responsible for this project. Together with his scientific colleagues, he plans to use the microorganisms to clean up the contamination left behind after mining operations.

"If the microbes can be stimulated biologically to specifically leach out the remaining metals contained in the ore residues, we can produce a valuable resource and clean up the dump at the same time – a 'win-win' situation which is also profitable," explains Schippers.

The bioremediation concept for cleaning up contamination left behind after mining is based on the success of biomining. Around 20 to 25 per cent of copper production around the world is already based on bioextraction. This is done by piling up the ore in heaps. Microorganisms – including the genera *Acidithiobacillus*, *Acidimicrobium* and *Sulfobacillus* – biologically convert the metal sulfides in the ore within the heaps into metal sulfates. The metal therefore goes into solution ('pregnant solution') and is then extracted from the liquids captured as they leach out of the heap.

Bio-oxidation is another application of biomining. In this procedure, microbes break down an economically uninteresting mineral, e.g. arsenopyrite, to release the sought after metal. Bio-oxidation is particularly commonly used for the extraction of gold from refractory ores in large tanks.



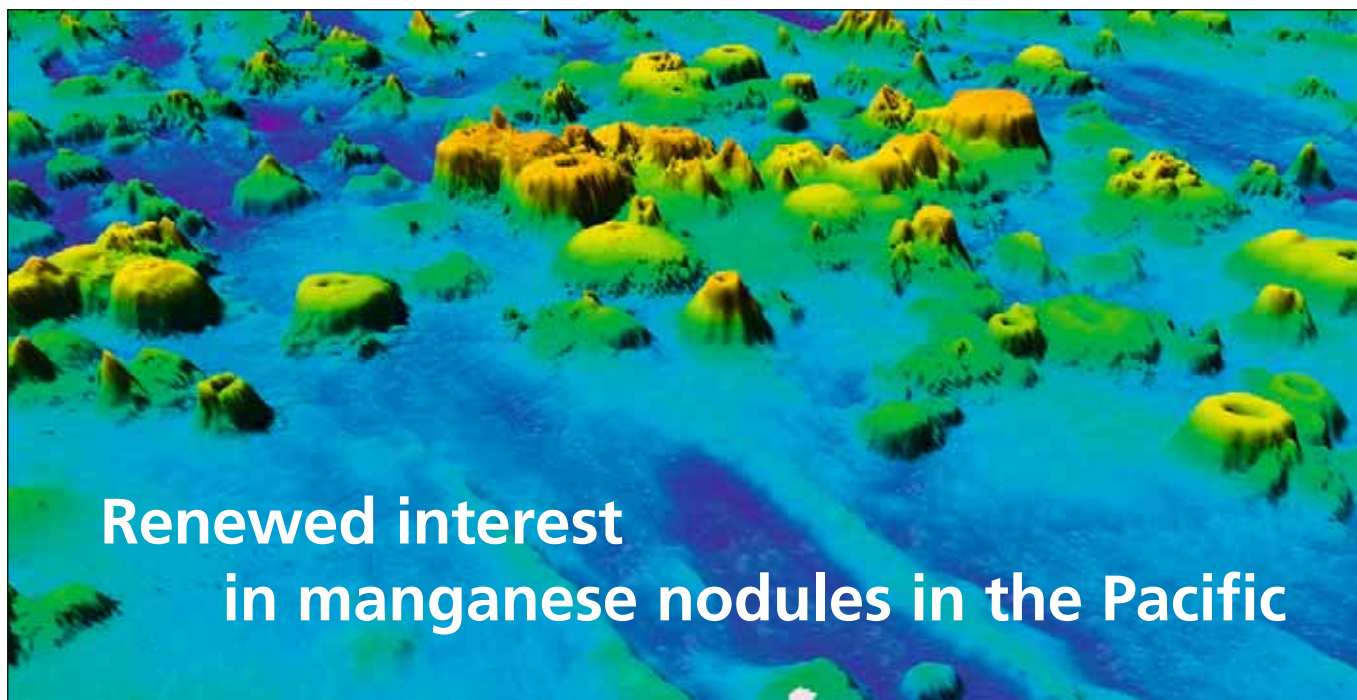


*The blue colour is caused by the precipitation of copper minerals.*

'Biomining' is more environmentally friendly and less energy intensive than the previously used method of 'smelting' which involves heating up ore concentrates to enable the further concentration of the metals. Coal is used in this process to reduce the metal salts. The chemical process involved leads to the release of sulfuric acid fumes.

The biological extraction of metals is therefore very promising. And even the highly prized 'high-tech metals' such as indium, gallium and germanium, could also possibly be extracted using this technique.

The microbes from the Atacama Desert could help promote the development of biomining in the long term. "The microbes are not only resistant to the extreme aridness, they can even metabolise in saltwater," explains Schippers. "If we succeed in cultivating the bacteria in the laboratory, they could be used for 'biomining' and the bioremediation of mine dumps all around the world – particularly in mining regions in very dry areas where there is a shortage of fresh water," says the scientist.



*3D view of a small part of the German manganese nodule concession with numerous submarine volcanoes. The subarea in the centre with its many volcanic cones is not very suitable for manganese nodule production, but the slightly darker blue-coloured areas at the margins could well be.*

**D**eep sea manganese nodules were one of the hottest issues in international research activity three decades ago. They were then largely forgotten. But now, the potential of marine georesource deposits is back on the agenda. On behalf of the German government, BGR began exploration in 2008 in the German concession for the exploration of manganese nodules in the Pacific between Hawaii and Mexico.

In the 1970s and 1980s, the nodules which are found at great depth on the floor of the oceans were discovered as a new previously unexploited source of a range of metals including copper, cobalt and nickel. Submarine exploitation appeared tantalisingly close after years of intensive research activity.

A consortium including German companies therefore acquired a production license in the Central Pacific in 1984. Unfortunately, an unforeseen slump in metal prices rang the death knell for the start of commercial manganese nodule production.

In recent years though the dramatic rise in some commodity prices has again focused attention on manganese nodules. On the basis of a continuously growing database and an improved understanding of the marine processes involved – also thanks to modern analysis methods which have only now made it possible to answer complex questions – manganese nodules and massive marine sulphides are now seen as a potential source of metals in the future. BGR's exploration programme

can therefore also be seen against this background as a measure to safeguard future supplies. The proactive research work undertaken by BGR makes a contribution to safeguarding the supply of natural resources for German industry in the future.

The ongoing BGR research projects are based on a contract closed in 2006 with the International Seabed Authority of the United Nations (ISA) on behalf of the German Ministry of Economics and Technology (BMWi). The concession gives Germany the exclusive right for 15 years to evaluate the reserves of the metal-rich manganese nodules in an area in the Central Pacific covering 75,000 km<sup>2</sup> – an area as large as Niedersachsen and Schleswig-Holstein combined – at a depth of around 4,500 metres.

The aim of the research project is to gather information on the origin, quantities and distribution of manganese nodules on the seafloor. The work also aims to assess the impact of any potential mining of such nodules on the marine environment. BGR also makes use here of the findings generated by German companies and research institutions in the 1970s and 1980s.

The economic interest in manganese nodules has less to do with their high manganese and iron concentrations, which together account for around 35 per cent, and much more because of their concentrations of more interesting metals such as nickel (1.3 %), copper (1.1 %), cobalt (0.2 %) and molybdenum (600 ppm).

During BGR's first marine expedition in October and November 2008, most of the license area was bathymetrically surveyed to provide a precise digital topographic model of the seabed. The distribution of sediments was also mapped, and representative surface samples of manganese nodules were collected. The interpretations revealed a surprisingly varied topography with numerous submarine volcanic cones in parts. Manganese nodules are found on the flat parts of the seafloor in widely varying concentrations. Large areas though show high abundances commonly around 10 to 30 kg/m<sup>2</sup>.

BGR continued its exploration work in the concession one year later with the chartered research vessel 'Kilo Moana' that lies particularly stable in the water thanks to its 'SWATH' construction. This expedition completed the bathymetric mapping and the surveying of the sedimentary distribution on the seabed. In addition, a logging tool dragged a few metres above the surface of the seafloor (side view sonar to determine the acoustic impedance) was used to determine the detailed topography and the small-scale distribution of the nodules. This data is particularly important to be able to elaborate a customised concept for potential future nodule extraction tailored to the local conditions on the seabed.

## Research expedition in the Pacific 2010: With the FS Sonne in the German concession area

The third expedition voyage in the manganese nodule concession took place in April/May 2010 and was again operated by the Federal Institute for Geosciences and Natural Resources (BGR). The five-week campaign with the German research vessel 'Sonne' started in Tahiti and ended in Mexico.

The 23 scientists on board included researchers from BGR as well as colleagues of the Leibniz Institute for Marine Sciences in Kiel, the Alfred-Wegener Institute for Polar and Marine Research in Bremerhaven, the German Centre for Marine Biodiversity Research at the Senckenberg Institute in Wilhelmshaven, and the Max-Planck Institute for Marine Microbiology in Bremen.

In addition to sampling, the expedition focussed on seabed photography and video recording. Work was carried out jointly to explore the geochemistry of the nodules and sediments, determine the structural fabric of the nodules, the microbiology, the composition of benthic communities, and paleo-oceano-

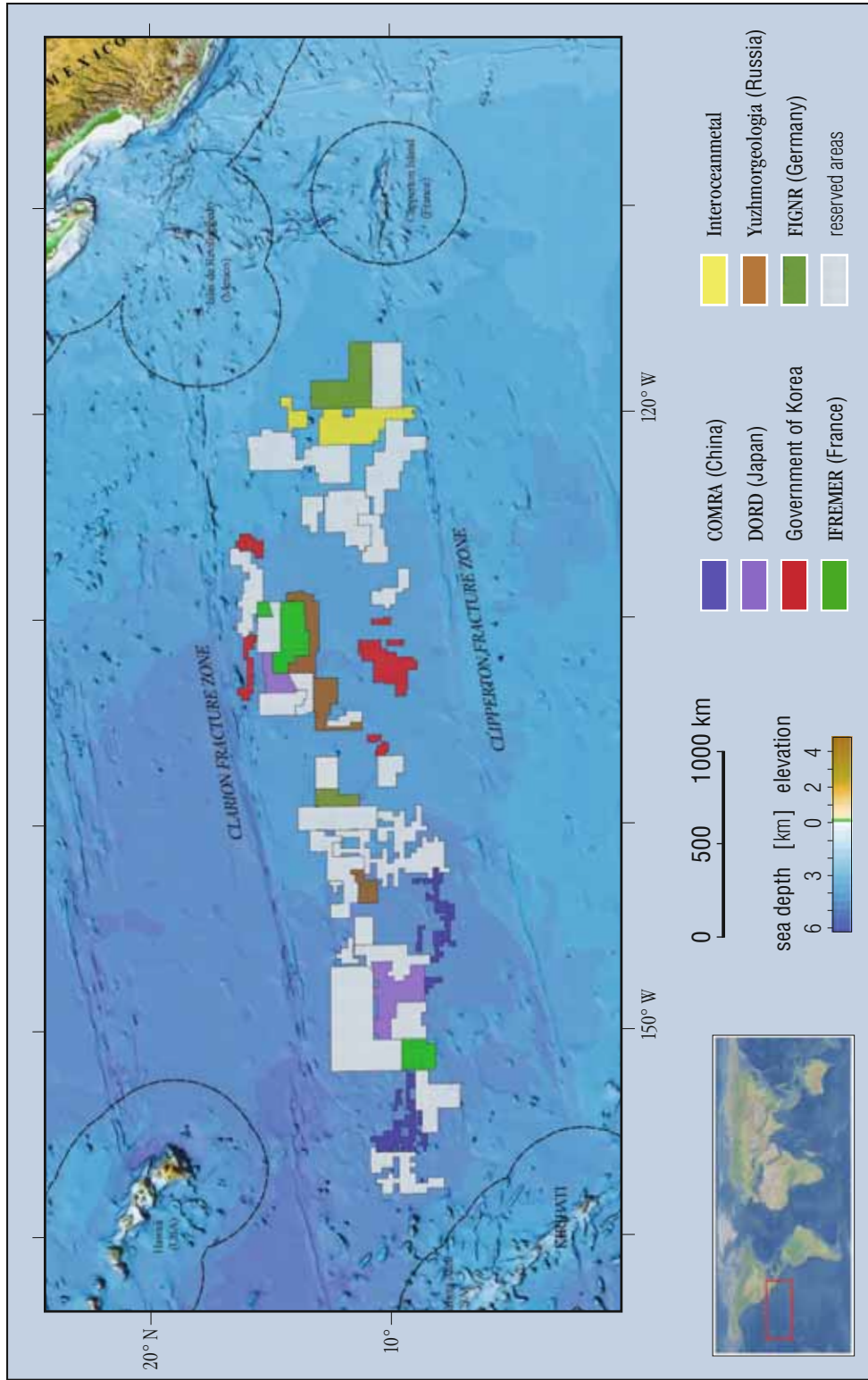
## What are manganese nodules?

Manganese nodules are fine-grained precipitates derived from seawater or the pore water within the sediment on the seafloor. The nodules mainly consist of iron and manganese oxides forming onion-like layers around a solid core. The cores are often formed by fragments of rock, shark teeth or pieces of older manganese nodules. The nodules have a black-brown colour, an irregular to rounded shape, and are mostly in the form of flattened ellipsoids. Size varies between 1 to 20 centimetres in diameter, although most of the nodules in the North Pacific have a size between 2 to 7 centimetres. In addition to the main constituents, the precipitation process also leads to the incorporation of a large number of ancillary and trace metals so that manganese nodules have economically significant concentrations of nickel, cobalt and copper. They also contain notable concentrations of titanium, molybdenum, vanadium, lithium, zircon and some rare earths elements.

The metals originated either directly from the seawater or from the sediment, where for instance, they were previously concentrated from the sunken (shell) material of dead organisms. The nodules grow extremely slowly: their diameter increases on average by 5 millimetres per one million years. Manganese nodules are found in all deep sea basins, particularly at depths of more than 4,000 metres. One region in the Pacific between Hawaii, Mexico and the Equator is considered economically particularly interesting and therefore has been labelled "manganese nodule belt". The conditions here are so favourable (e.g. low sedimentation rates, type of sediment, age of the oceanic crust, water depth) that large parts of the seafloor are paved with dense concentrations of manganese nodules with high metal contents.



*Top view of a recently recovered box corer. The box corer cuts out a small part of the seafloor measuring 50 x 50 cm including the manganese nodules lying on the surface, and brings the whole sample on board the ship. The nodules here measure around 5–10 cm in size and are often broken (irregular outline).*



Map of the manganese nodule exploration concessions in the Central Pacific. Seven countries have acquired exploration licenses in this area from the International Seabed Authority. The two subareas marked in olive-green (in the centre of the map and near Mexico) represent the German claim which is currently being explored by BGR.

graphic influences, with the aim of finding out more about the manganese nodules and their environment.

Research has been carried out to determine the part played by marine microorganisms in nodule formation, and the influence of the chemical composition of the pore water in the seabed sediments. The water between the mineral particles is the source of the metals contained in the nodules.

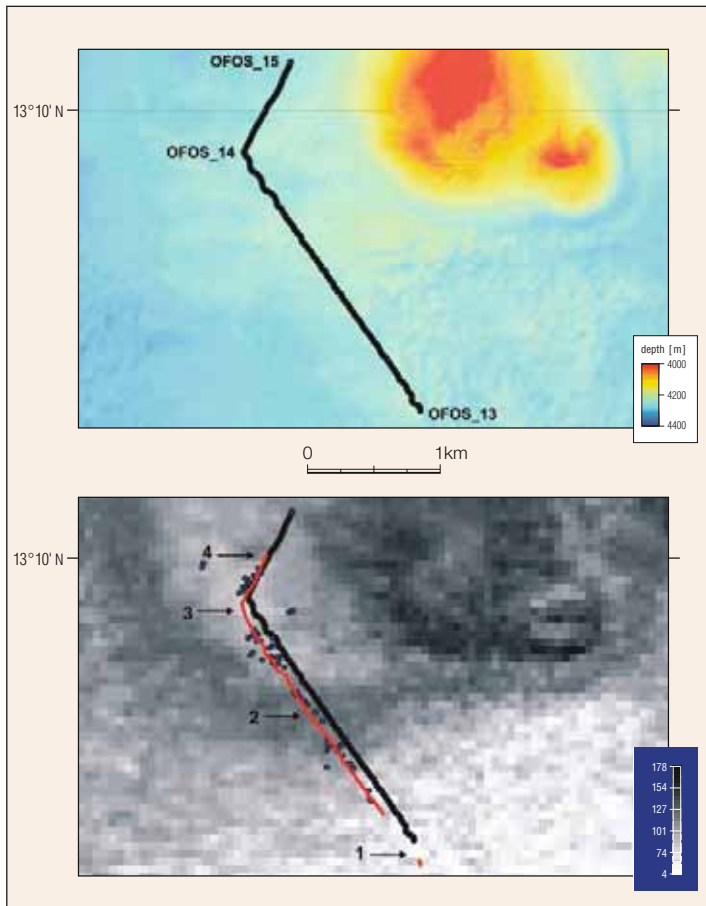
Very little research has been done to date on the biodiversity of the fauna in the extensive fields of nodules which exist in complete darkness, and under extreme conditions of cold and enormous pressure on the deep sea ocean floor. In the new campaign, molecular biological methods were used to investigate the communities on the seafloor and the surfaces of the manganese nodules.

Box corers collecting 50 x 50 centimetre samples of the seafloor are hauled on board to take a snapshot of the larger fauna populating the seabed. Special equipment was also used to extract sediment and water samples from the deep seabed to determine the oxygen and metal concentration of the water.

Other objectives of the expedition are to collect basic data to assess the potential deposits: How big is the deposit? Where are the highest concentrations of nodules? And how economic could the subsequent production of these natural resources be? These important questions have to be answered within the framework of the exploration license. The acoustic backscatter information collected along the detailed survey lines in 2009 were compared with the new videos collected by the photographic sledge to determine the concentration of the manganese nodules on the seafloor in more detail. One of the surprising findings of this analysis was that the acoustic backscatter can be correlated with the average size of the manganese nodules in each area.



*Preparing the deployment of a chain sack dredge on board of the 'Kilo Moana' research ship to extract a manganese nodule sample from a depth of 4,800 metres in the German concession.*



## Seabed topography around station 66-OFOS on the SO-205 research expedition (OFOS = ocean floor observation system).

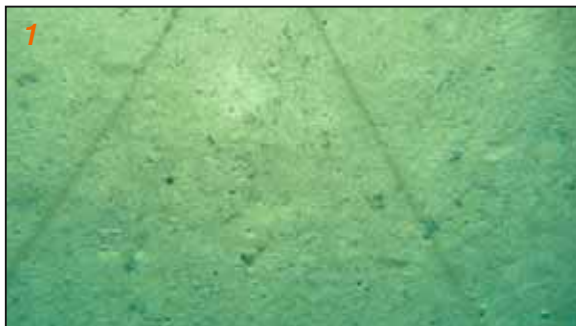
Upper Section of map: the black line shows the route taken by the ship during the video and photo camera survey of the seabed.

Below: this shows the same map section as above but with details of the strength of the reflected acoustic signal highlighted in shades of grey. Dark-grey zones reflect the acoustic signals more strongly than the light-grey zones. The seabed in this area is made up of either hard rock layers or is densely paved with manganese nodules. Light-grey areas are made up of young unconsolidated sediments.

The black line shows the route taken by the ship, the red line shows the profile of the video sledge which is pulled along the seafloor by the ship on the end of a steel cable. The numbers 1 to 4 mark the positions of the photos shown below.

## Photographs of the seabed along profile 66-OFOS on research voyage SO-205.

The positions of the photos are shown in the lower map. The seabed in **photo 1** has almost no manganese nodules, the matching acoustic reflection level (grey value) is 30. **Photo 2** shows a moderate accumulation of mainly large manganese nodules on the seafloor (reflection value 127). **Photo 3** shows a moderate accumulation of mainly small manganese nodules on the seafloor (reflection value 100). The seabed in **photo 4** is characterised by a high concentration of mainly small manganese nodules (reflection value 78). The long edge of the photos correspond to an approx. 2 m long section of the seafloor.



A comparison of the photos and the grey values reveals that there is a correlation between the reflection of the acoustic signal and the concentration of manganese nodules on the seafloor as well as the size range of the nodules.


## BGR-study: Mining can improve the economic situation in Africa

African countries with large mineral occurrences can considerably improve their economic situation. That is the main finding of the BGR study “Government Revenues from the Extractive Sector in Sub-Saharan Africa – A Potential for Funding the United Nations Millennium Development Goals?”

African countries rich in natural resources could use revenues from the mining sector to mobilise additional domestic sources of finance if they improve the taxation system in the natural resources sector and promote sustainable development in this industry. “This also includes the economic-geological training of tax authorities and mining supervision bureaus,” say the authors of this BGR study, Dr. Peter Buchholz, head of unit of mineral economics (BGR), and Martin Stürmer from the Institute for International Economic Policy at the University of Bonn.

In a range of scenarios, the BGR study analyses possible revenues from the mining sector up to 2015. On the basis of assumed world market prices, tax systems, and the development of additional production capacities, four case studies analyse the situation for natural resources such as copper, diamonds, gold and crude oil in Ghana, Namibia, Mozambique and Zambia.

“Government revenues from the natural resources sector are certainly not a source of ‘a fast buck’,” emphasises Martin Stürmer. “They are dependent on a country’s geology, level of geological exploration, the investment conditions, infrastructure, taxation system, including tax revenues, and the tax administration system, as well as world market prices.” The high level of fluctuations in world market prices in particular are a major challenge for all governments:

 [www.bgr.bund.de/government-revenues-2009](http://www.bgr.bund.de/government-revenues-2009) (English)

## Commodity Top News 33 (2010): Are the reserves of high-tech metals limited?

They are called indium, tantalum or germanium: high-tech metals are the raw materials needed by tomorrow’s technologies. From photovoltaic modules and microcondensators, to glass-fibre cables – electronic metals make the development of new innovative products possible in the first place. There is therefore a very strong world-wide growth in demand for these natural resources, whose production is concentrated in only a few countries in some cases. Experts are already raising the alarm about potential supply shortages.

For the first time in the study, BGR shows which industrial sectors use the most important high-tech metals, where they are produced, the size of the known reserves, and how the supply situation could change up to 2030. The high-tech metals indium, tantalum, germanium, gallium, scandium and neodymium are some of the natural resources were analysed in more detail in this study: “Electronic metals – growing future demand with inadequate levels of supply?”:

 [www.bgr.bund.de/CTN-33-elektronikmetalle](http://www.bgr.bund.de/CTN-33-elektronikmetalle) (German)

## BGR presents reports on the natural resources situation in Germany

BGR's annual report with all the important facts and figures on the natural resources situation in the Federal Republic of Germany has now been published for the 30th time. In the first issue of the annual natural resources situation report covering the period from 1979/1980, BGR had already identified the trends in the mineral economics sector at an early stage and analysed the question of natural resource availability in future. The assessment at the time: "If the supply of natural resources was purely dependent on their availability in nature, one could describe the supply situation overall as optimistic."

The interaction of supply and demand is much more complicated today than in the 1970s. Investment decisions in the mining sector are becoming riskier and it is very difficult to foresee the social challenges and environmental impacts of mining which have to be tackled, as well as the accelerating development of technologies controlling the demand for natural resources and the willingness of commodity markets to speculate.

The natural resources industry constantly has to tackle new challenges in the form of the social impact and environmental consequences of mining, as well as the rapid development in technologies which control the demand for natural resources. This situation is exacerbated by price volatilities arising from political uncertainty as well as mergers between mining companies.

The 'Natural resources situation 2008' and 'Natural resources situation 2009' reports contain all of the most important facts and figures on the latest supply situation as it affects the Federal Republic of Germany with respect to mineral resources and energy resources. The information includes figures on natural resource production, foreign trade, and the development in prices and consumption.

They are a core product of the BGR departments "Economic geology of mineral resources" and "Economic geology of energy resources". Experts have observed, analysed and evaluated the global natural resource potential for many years, and the commodities markets for metals, industrial minerals, non-metallic minerals, as well as energy resources like oil, gas, coal and uranium.



**Both of the studies (German) can be ordered from: [www.schweizerbart.de](http://www.schweizerbart.de)  
The study 'Natural resources situation 2009' is also available from: [www.bgr.bund.de](http://www.bgr.bund.de)**



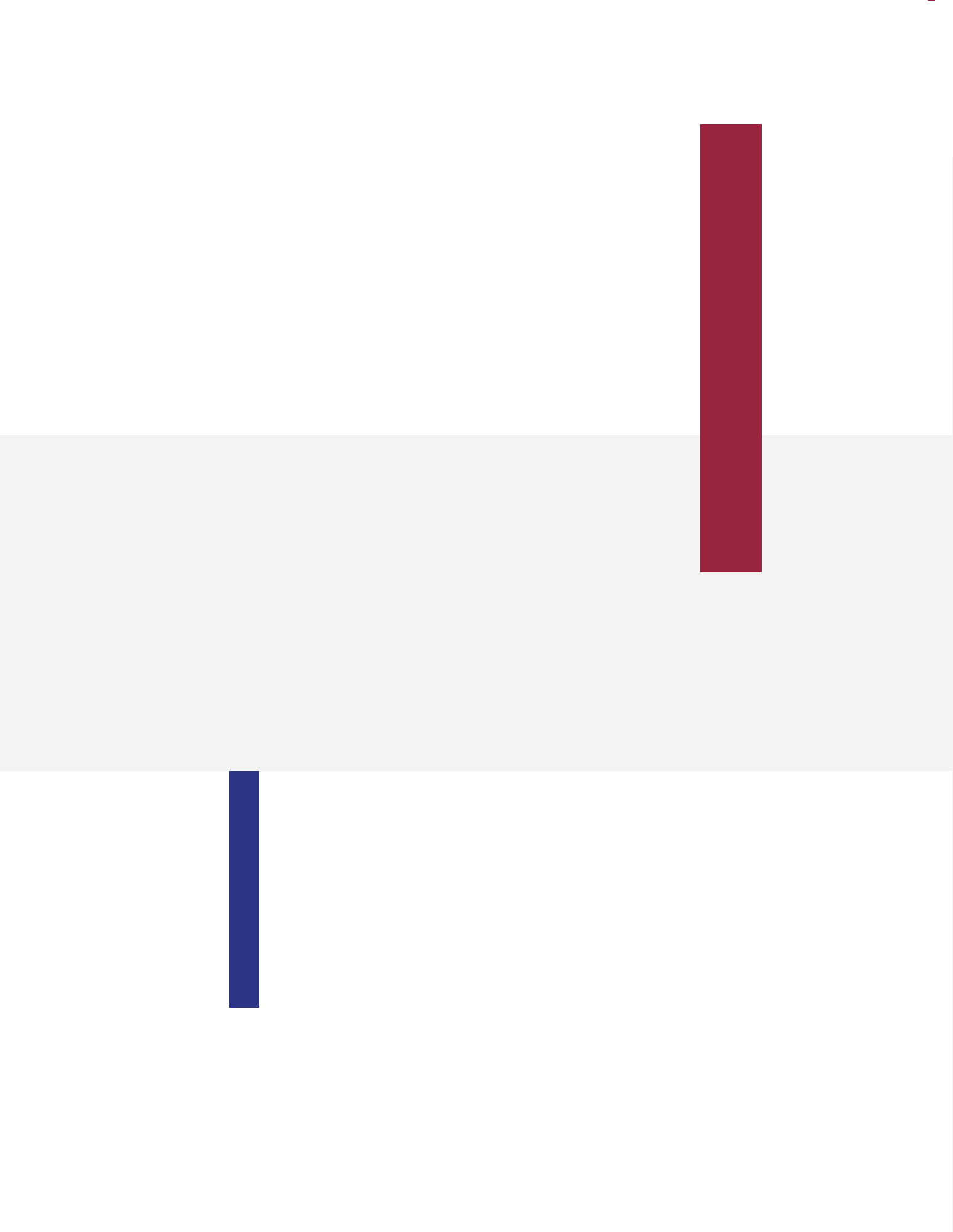
# Outlook

In the interests of safeguarding the continuous supplies of natural resources, the Geological Survey in Germany actively makes available its specific knowledge in the field of natural resources and mining, as well as research into deposits of natural resources from prospecting to production and finally to closure, abandonment and land reclamation.

The tasks and activities involved in analysing the world of mineral resources will be increasingly determined by the turbulence in the commodity markets, the illegal trade in high-tech metals, and exploration of new deposits.

The establishment of the “German Mineral Resources Agency” (DERA) is a major step which will be developed further in the coming years by the close cooperation between industry, politics and science. One of the most important priorities of the German Mineral Resources Agency is to increase market transparency by making available economic analysis, studies and information on the natural resources situation.

A special aspect of cooperation projects with industry and natural resource producing countries is the identification of alternative natural resource potentials and resource efficiency potentials. The BGR’s own mineral deposit research will focus on high-tech metals, the use of mine tailings as secondary sources of raw materials, and verifying the origin of “conflict minerals”. In addition to the work on marine manganese nodules, a new focus in the coming years will be the exploration of polymetallic sulphide deposits on mid-oceanic ridges.



# *Groundwater*



# Introduction

**T**wo thirds of the water supplied as drinking water in Europe is extracted from groundwater. Because of the local climatic conditions, this proportion is often much higher in many developing countries. A large number of natural groundwater resources in developing countries with minor groundwater recharge due to the local climatic conditions, are threatened by over-exploitation or pollution.

Moreover, the use of groundwater resources in arid regions can be reduced, for instance, because they contain unacceptably high concentrations of dissolved salts. In other regions, the natural contamination of the water with heavy metals can also severely restrict the use of groundwater for drinking water.

BGR is a technical consultant at a national and international level for governments, public administrations, industry and social groups, providing advice on all issues involving groundwater utilisation and groundwater protection. BGR assists national and international legislative and development-policy measures to safeguard water as an important resource.

Integrated water resource management is of particular significance for BGR in this context. This also includes the provision of decision making tools which enable mankind's sustainable exploitation of this vital natural resource.

## Syria and Lebanon: Projects for clean groundwater

**A**s part of its international technical cooperation work, BGR has started two new groundwater projects in Syria and Lebanon. Both projects are financed by the German Ministry of Economic Cooperation and Development (BMZ), and are aimed at delineating and implementing groundwater protection zones and the sustainable protection of this valuable resource.

“The significance of sustainable groundwater protection is growing,” says BGR President Prof. Dr. Hans-Joachim Kümpel. “Although this applies world-wide, it is particularly important for developing countries in arid parts of the world. Groundwater is the main source of drinking water in these areas. Increasing pollution is jeopardising water resources and human health. This is why the sustainable protection of groundwater reservoirs is one of the key objectives of development cooperation work, and projects such as those in Syria and Lebanon are important components of this work.”

BGR has been involved in numerous groundwater protection projects all around the world for many years and BGR experts always encounter the same difficulties. Big problems are associated mainly with the inadequate sanitary infrastructure in the inexorably growing megacities around the world. Over 2.4 billion people around the world live without any sanitary infrastructure. Two million people die every year from diseases associated with contaminated drinking water.

Urgent and effective groundwater protection is therefore of major importance – also from an economic point of view. Investments today save costs tomorrow. Usually, extremely expensive measures are necessary to clean up contaminated water resources. The German Toilet Organisation (GTO) for instance runs campaigns to raise awareness of the need for sustainable sanitary facilities.

“The quality of our water resources is increasingly at risk by man-made contamination. This not only jeopardises the ecosystem, but also our further development because groundwater is our most important resource,” says Kümpel. The BGR President therefore considers it all the more important to raise awareness of this key issue with initiatives such as World Water Day, and to promote the implementation of preventative measures to protect water quality.

### New protection areas in Syria and Lebanon

The project in Syria has been established to help safeguard the groundwater supplies to the capital Damascus. The quality of the groundwater around the Fiegh springs is being massively threatened by the infiltration of sewage. This is due to the rapid expansion of housing areas and industrial estates. More and more wastewater is percolating in an uncontrolled manner into

### Syria: Contribution to the protection of the Fiegh spring system

A major proportion (60 – 65 %) of the drinking water supplied to the Syrian capital comes from the Fiegh spring system which lies in the Anti-Lebanon mountains approx. 16 km northwest of central Damascus. The Fiegh springs no longer flow on a purely natural basis during low flow periods but are also pumped between June and February to satisfy the growing demand for water – primarily caused by the rapid growth of the population.

No provision is made for the treatment of domestic wastewater from the major restaurants close to the spring system, so that the wastewater percolates uncontrolled into the highly permeable bedrock or is discharged into the Barada river. Although much of the riverbed has an artificial concrete base, wastewater still penetrates the bedrock here because of leaks in the riverbed.

The groundwater in the karstified limestone aquifer is therefore at severe risk of contamination from infiltrating sewage. This situation is exacerbated by the increased groundwater extraction during summer months which leads to the formation of extremely steep draw-down cones around the springs and wells, which speeds up infiltration of wastewater and the potential contamination of the drinking water.

To safeguard the water supplies in Damascus/Syria, BGR is undertaking a geological-hydrogeological study of the catchment area of the Fiegh spring system to identify and localise the causes of the groundwater contamination, and to assess the recharge-discharge mechanism of the Fiegh spring system more accurately.

the underground rock formations, contaminating the groundwater. Together with their Syrian partners, BGR experts now aim to locate the zones of contamination in the Fiegh spring system and measure more accurately the discharge from the Fiegh aquifer. They also intend to elaborate recommendations on how to redefine the local water protection zones and implement the necessary restrictions on inappropriate land-use.

In Lebanon, BGR is assisting Lebanese Agencies in protecting the Jeita spring. This now suffers from very serious bacteriological contamination because of the intense uncontrolled

expansion of settlements in the catchment area. Together with the KfW Entwicklungsbank, BGR is therefore providing advice to the Lebanese government with the aim of selecting suitable sites for wastewater facilities and to develop a decentralised wastewater treatment concept. They also aim to define protection areas for the Jeita spring. One of the key priorities of the project is to raise the awareness of local population and decision makers of the need for sustainable groundwater protection.

## Lebanon: Protection of the Jeita spring

The main problems in the Lebanese water sector are inadequate management and insufficient protection of the groundwater resources. In the Greater Beirut area, approx. 1.9 million inhabitants depend for their drinking water supplies on the Jeita spring which lies approx. 13 km northeast of the centre of Beirut.

The aquifer in the catchment area of the Jeita spring is threatened by numerous sources of contamination, especially by wastewater. The network of water pipes is also in disrepair and the drinking water treatment plant in Dbaye, approx. 4.5 km west of the Jeita spring is unable to adequately clean up the contamination. Beirut's water supplies are therefore acutely threatened.

A groundwater monitoring system is to be installed in this project with the aim of controlling water treatment and therefore to improve the quality of the water in the pipe network. It will enable the water utility to shift supplies to other sources, or change the treatment technology when major contamination to the water supply is detected. In order to implement the groundwater protection zones, landuse planning needs to integrate aspects of groundwater protection.



*(above right) Spring capture at the Figeih spring (Syria) at its outflow from the rock.*

*(below right) Training the partner agency DAWSSA in snow depth surveying and snow-water equivalent measurements in the Anti-Lebanon mountains near Bloudan.*

*(below left) Discharge measurement at the Naber al Labbane karst spring in Lebanon.*

*(upper left) The Jeita spring supplies drinking water to Beirut and is the largest tourist attraction in Lebanon. This spring is often affected by strong bacteriological contamination because of the absence of wastewater treatment in the catchment area.*

## The thirst of a tiger economy

### Groundwater protection in Vietnam

Vietnam, the so-called “new” tiger economy in Southeast Asia, is in principle richly endowed with water. However, the impressive economic development in recent years, combined with the strong growth of the population over the last two decades, have increased the pressure on this valuable resource. The discharge of untreated sewage, less rainfall, and an increase in extreme weather events, jeopardise the traditional intensive use of surface water. Consequently, groundwater is gaining increasingly in importance in Vietnam’s future water supply strategy. Sustainable groundwater exploitation is crucial for the further development of health, industry and the environment in Vietnam.

Facing this background, the project “Improving groundwater the protection in Vietnam” (IGPVN) was initiated as part of Vietnamese-German technical cooperation. On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), BGR has been advising Vietnamese authorities at national and provincial levels since 2009 on aspects concerning the exploration and monitoring of groundwater resources, as well as their management and protection.

Focus of the cooperation are the consequences of the increasing and uncontrolled overexploitation of groundwater. Namely these are:

- Groundwater drawdown at a regional scale
- Salinization of coastal aquifers
- Groundwater contamination as a result of e.g., percolating industrial and municipal waste water as well as agriculture and aqua farming.

### Overexploitation in Nam Dinh province

Nam Dinh province is located on the South China Sea in the south of the Red River flood plain and has been the pilot working area during the first project phase. As characteristics for delta systems, the local geological structure is dominated by a complex sequence of unconsolidated high and low permeable sediments, including some very productive groundwater bearing strata which are subject of extensive utilisation. The provincial authorities have neither the means nor the expertise to counteract the resulting groundwater drawdown up to 0.4–0.7 m/year and the increasing salinization of the groundwater resources.

The IGPVN project set up a groundwater monitoring network in Nam Dinh allowing the continuous monitoring of groundwater quantity and quality. Based on new as well as archive data, a three-dimensional structural model was

established. After supplementing with hydrogeological and hydrochemical data, the model indicated that a lens of fresh groundwater of high quality was created in unconsolidated sediments of Pleistocene and Miocene time. The evaluation of the complex geology in the southwest of the province showed that this fresh water lens is recharged by a hydraulic connection to an adjacent karst aquifer of high productivity, located in the Triassic limestones of the neighbouring province of Ninh Binh. Since the end of the 1990s, groundwater extraction has exceeded the sideflow of fresh groundwater generated in the catchment area in Ninh Binh. This results in groundwater draw-down and the inflow of high saline groundwater. Therefore, this important local drinking water resource is threatened by depletion and salinisation.

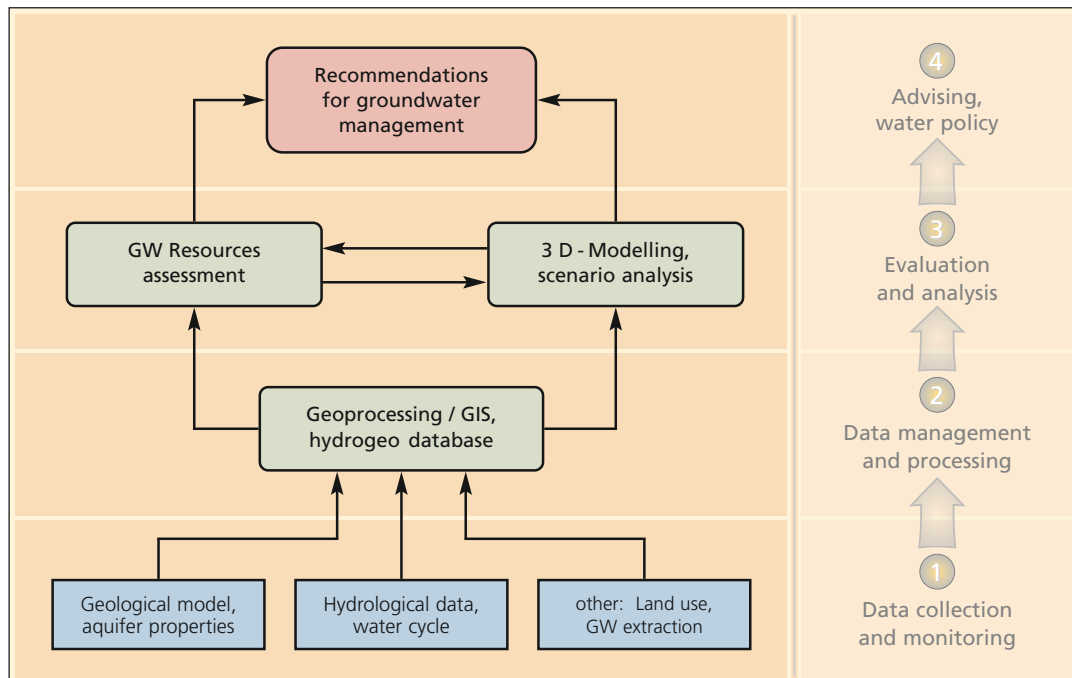
A numerical model simulates these consequences and provides a basis for formulating recommendations for sustainable groundwater management. Furthermore, the project also assists political decision makers in communicating and implementing these recommendations at a national and provincial level. In this context, an improved control of the numerous un-registered extraction wells represents a crucial task.

Thanks to its activities at a range of commitment levels, the IGPVN project ultimately assists the process of implementing Integrated Water Resources Management (IWRM) in Vietnam.





Employees of the National Center for Water Resources Planning and Investigation (CWRPI) are taking groundwater samples.



Areas of action of the IGPVN project comprising data acquisition and processing, evaluation of the results and modelling of utilisation scenarios. The resulting groundwater resources assessment in terms of quantity and quality represents the basis for submitting recommendations for further action.

## Geochemistry of European mineral water

**A**round 1,900 different mineral waters are registered in the EU at a European level. The Geochemistry Expert Group of Europe (EGS) has carried out a European-wide mineral water investigation with the aim of acquiring an initial dataset on the background concentrations and natural variability of the elements in European groundwater from the bottled mineral water sold in supermarkets.

The EuroGeoSurveys project 'Geochemistry of European Bottled Water' was implemented in 2008 and 2009 with the involvement of 39 European countries. 1,785 European mineral waters (of which 908 from Germany) were analysed in BGR laboratories looking at 71 parameters (trace and main elements, anions). The 1,785 mineral waters represent 1,247 springs, wells or horizons at a total of 884 locations.

The evaluation of the mineral water data also included a 150 day leaching test to analyse the influence of the different materials used for the bottles. The results of the analysis of the two different bottle types (glass, PET) revealed a 21-times enrichment in antimony (Sb) median value (0.33 µg Sb/l) in PET bottles compared to the median value in glass bottles (0.016 µg Sb/l).

In contrast, the mineral waters in glass bottles show significant enrichments in the elements lead (Pb, 14 times higher), aluminium (Al, 7 times higher) as well as lanthanum (La), titanium (Ti), hafnium (Hf), thorium (Th, 5 times higher) and praseodymium (Pr), iron (Fe), zinc (Zn), neodymium (Nd), tin (Sn), chromium (Cr) and terbium (Tb, twice as high). The colour of the bottles also influences the trace element concentrations (e.g. chromium, silver, thorium, lanthanum, zirconium, neodymium, cerium) in the bottled waters. Nevertheless, the measured maximum concentrations of the elements still lie well below the limits for drinking water.

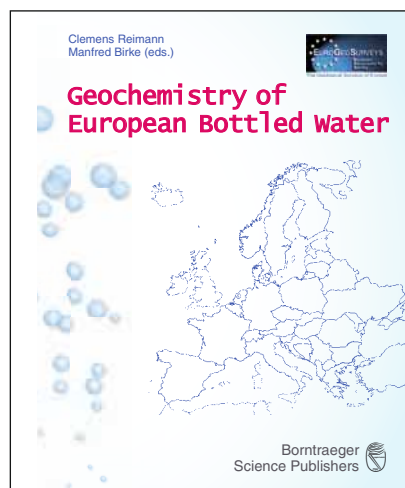
The hydrochemistry of groundwater is influenced by a large range of processes and factors, including precipitation chemistry, climate, vegetation, soil formation processes, rock-water interactions, aquifer chemistry, and contamination. The study found that the geology is the most important influencing factor for most of the elements analysed in the study.

High chromium (Cr) and vanadium (V) concentrations are found for instance in association with ophiolites; while higher and anomalous concentrations in the bottled mineral waters of the elements aluminium (Al), boron (B), beryllium (Be), caesium (Cs), fluorine (F), germanium (Ge), potassium (K), lanthanum (La), lithium (Li), rubidium (Rb), silica (Si), tin (Sn), thorium (Th), titanium (Ti) and zirconium (Zr) mark the presence of Hercynian granite. Raised concentrations of the element associations aluminium (Al), arsenic (As), beryllium

(Be), fluorine (F), potassium (K), manganese (Mn), molybdenum (Mo), phosphorus (P), rubidium (Rb), selenium (Se), silica (Si), thallium (Tl) and vanadium (V) in mineral waters indicates the presence of alkaline volcanites and areas with active volcanism; the distribution of anomalous strontium (Sr) concentrations is associated with the presence of basement structures and fracture zones.

The study overall revealed an enormous natural variation in the concentration of elements in the mineral waters. These range on average from three to four orders of magnitude, and in individual cases (e.g. uranium) even by as much as seven orders of magnitude. A few European bottled mineral waters contain levels of aluminium (Al), arsenic (As), barium (Ba), fluorine (F), manganese (Mn), nickel (Ni), nitrite (NO<sub>2</sub><sup>-</sup>), nitrate (NO<sub>3</sub><sup>-</sup>), selenium (Se) and uranium (U) which exceeded the EU limits and WHO guidelines.

Overall, the project concept to utilise and analyse bottled mineral waters to provide an initial assessment of the groundwater quality throughout Europe was successfully implemented. It confirmed that the natural variation in the concentration of elements in groundwater is much higher than any secondary influences.



*The mineral water atlas 'Geochemistry of European Bottled Water' contains material and evaluations from all European countries.*



Sampled mineral water springs and wells in Europe.

## Blocked wells: An old problem in a new light

**A**pprox. 80 % of drinking water in Germany is groundwater pumped from wells. However, mineral and biomass encrustations in well screens frequently restrict the inflow of water and can even block wells completely in some cases. The associated problems cause cumulative costs of several millions to the water industry in Germany and also abroad, which are passed on to consumers and therefore influence the price of the water.

The most frequent cause of well ageing – particularly in northern Germany – is the deposition of encrustations of solid iron oxides. The oxides form as a result of the mixing of deep iron-rich groundwater with shallow oxygen-rich water. Naturally occurring groundwater bacteria play a major role in this process (“iron bacteria”). Wells provide ideal conditions for these bacteria because they are constantly supplied with their main nutrients iron and oxygen, which they metabolise and excrete as iron oxide.

A survey by the German Technical and Scientific Association for Gas and Water (DVGW) revealed that approx. 1,300 wells a year have to be rehabilitated in Germany alone at great expense. Rehabilitation mainly involves the use of mechanical methods such as brushing, high-pressure flushing, ultrasonics and even explosives. Aggressive chemicals such as hydrochloric acid are used when extremely hard encrustations are involved.

A detailed investigation by BGR scientists and the Oldenburg-East Frisia water supply company (OOWV) has now revealed that the spatial distribution of encrustations in wells is quite different to what was considered in the past. Previously, encrustation was considered as a process which took place uniformly throughout a well. This meant that the whole filter section of the well was dealt with in the same way during rehabilitation.

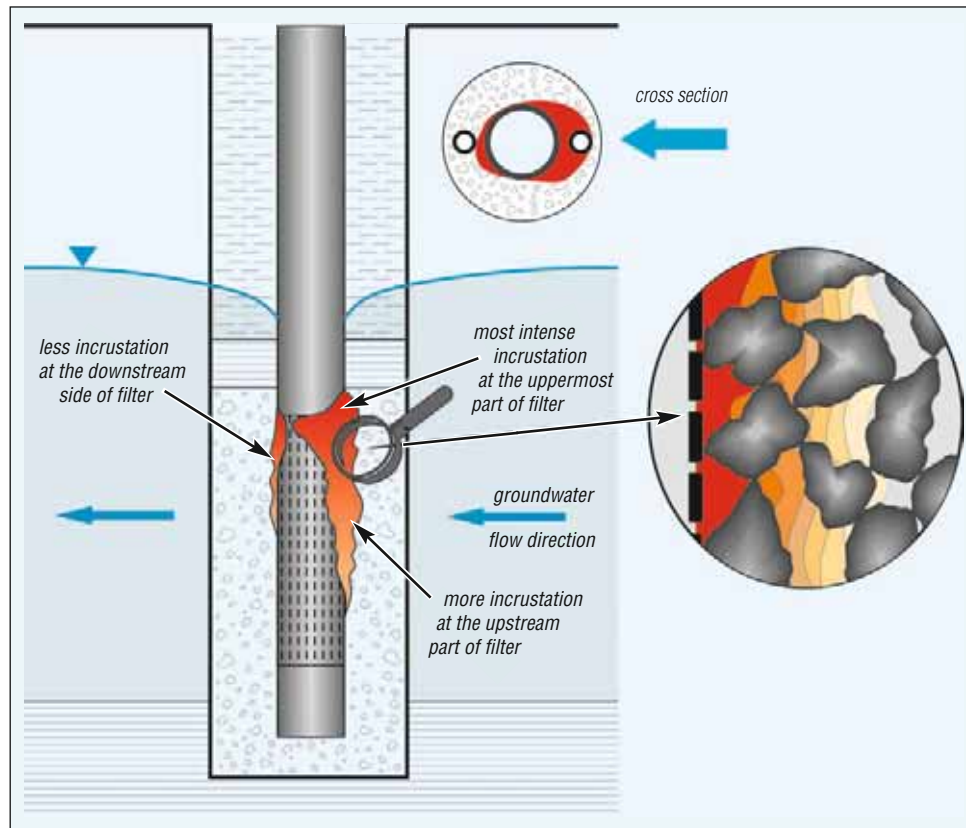
However, a combination of core drillings and numerical modelling has now revealed that the encrustations are often inhomogeneously distributed throughout the screen of the well. Although this appears illogical at first, the encrustations are particularly frequent in zones with very strong flow rates, e.g. often at the upper edge of the screen and on the side facing the natural groundwater flow. This is the place where iron bacteria enjoy particularly favourable living conditions.

Thanks to the research findings, remediation measures can now be conducted in a much more focused way. Intensive treatment now tackles the most strongly affected parts. The use of chemicals in less affected zones can now be limited or even avoided altogether. This saves costs and helps the environment.

For the first time, encrustations were also found in the adjacent aquifer in drill cores from the near-field of a 38 year old well: encrustations were found up to 5 metres from the well itself. These cannot be removed by the usual methods.



*Pipe with encrustations.*



Sketch of the spatial distribution of iron oxide encrustations in a drinking water well.

## BGR publications on the sustainable use of water

There is a very close interaction between present climate conditions and the earth's water cycle. The BGR publication "Groundwater and Climate Change: Challenges and Possibilities" looks at the associated future developments.

For instance, higher temperatures can lead to higher evaporation rates and to reductions in groundwater recharge. Alterations associated with climate change are seen as being particularly serious for future drinking water supplies because a large percentage of the world's population rely on groundwater resources for their potable water.

Climate change also means a rise in sea level. In coastal regions, this can lead to the increased migration of salt water into fresh water aquifers close to the shoreline. Coastal aquifers are already a seriously overexploited source of drinking water because of the population pressure along coasts. This is an additional drain on the quality of the resources.

The dependency on usable groundwater for drinking water and agriculture is particularly high in arid developing countries. These are also places with the least ability to adapt to climate change – which could exacerbate food security and drinking water supply in future.

The sustainable use and management of groundwater resources is therefore very important against this background to guarantee the storage function and maintain a qualitatively and quantitatively viable water supply – even in the face of the predicted consequences of climate change:



[www.bgr.bund.de/groundwater-climate-change](http://www.bgr.bund.de/groundwater-climate-change) (English)

In another publication, BGR groundwater experts and Dutch colleagues use 19 examples from around the world to demonstrate how surface water and groundwater resources can be managed in the face of climate change: "Managing the Water Buffer" describes the successful application of the "3R-concept" (water recharge, retention and reuse). The objective of this integrated resource management is to construct water storages, either by using artificial groundwater storage and recovery or by filling surface storage hyper-structures. All these approaches have in common that they are being replenished during rainy periods and used as reserves during drier periods:



[www.bebuffered.com/downloads/3Rbook\\_2nd\\_edition\\_webversion.pdf](http://www.bebuffered.com/downloads/3Rbook_2nd_edition_webversion.pdf) (English)

## BGR at the 5th World Water Forum 2009 in Istanbul

Groundwater is a vital resource. In the light of climate change and the growth in global population, water supplies will be even more important in future. This is the message sent out by the 5th World Water Forum which took place in Istanbul in March 2009. The international water forum is the largest event on "water" world-wide. BGR took part with presentations and papers.

More than 25,000 experts discussed measures for improved and sustainable water management under the slogan "Bridging divides for water".

World-wide, around 900 million people have no access to clean drinking water. Around 2.6 billion people – more than a third of the human population – have no access to proper sanitation. One of the key goals of the forum organised by the World Water Council is therefore to look at ways to raise awareness at a political level for the importance of water, and discuss concrete approaches to manage water in future in the interests of sustainable economic development. The agenda also dealt for the first time with groundwater resources in aquifers shared by more than one country. The plenary session of the United Nations at the end of 2008 had already recommended internationally binding regulations dealing with this aspect.

"Overall, the World Water Forum achieved its objective of raising awareness of the central significance of water. Groundwater is a strategic resource when properly managed and safeguarded by forward-looking protection. The water needs of a continuously growing global population can only be satisfied when additional groundwater resources are developed and protected from overexploitation and contamination," says Dr. Wilhelm Struckmeier, head of BGR sub-department "Spatial information on groundwater and soil."

However, it also became clear at the World Water Forum that the nations of the world still cannot agree on a joint solution for sustainable water management at global level. The representatives of Germany and other countries unsuccessfully advocated the adoption of a human right to water as well as binding rules for trans-boundary water management.

## Web map service provides information on background values in groundwater

One of the main objectives of the European Water Framework Directive is safeguarding good groundwater quality. Together with the geological services of the German federal states, the BGR has now developed its "Web Map Service" (WMS) which makes available online for the first time to authorities, industry and science all of the most important background value data on the main, ancillary and trace inorganic constituents in groundwater.

"The main advantage of WMS is free access to this statistical data – from every workplace, at any time. All specialists and interested amateurs have access to the necessary information on groundwater quality in Germany and can print out the relevant maps," explains Prof. Dr. Thomas Himmelsbach head of BGR department "Groundwater Resources – Quality and Dynamics".

Viewing the data in the internet requires a WMS-compatible program (e.g. Google Earth or ESRI ArcGIS Explorer), or an internet map application. WMS is accessed via an internet address (URL of the Web Map Service without/with parameters) which has to be entered in the WMS-compatible program.

The new digital map service is compatible with the European Water Framework Directive specifications. Assessing groundwater quality requires the background values of the chemical constituents in the groundwater to be determined and where necessary, limits for dissolved chemical groundwater constituents to be defined.

The individual geological surveys in Germany worked together to elaborate the nationwide aquifer-oriented map showing the main, ancillary and trace inorganic substances in groundwater. This was based on the 1:200,000 hydrogeological base map of Germany (HÜK 200).

Hydrochemical parameters from the groundwater sampling of approx. 1,100 hydrogeological units in the hydrogeological base map were aggregated into so called hydrogeochemical units (HGC) for the statistical evaluation. The analysis took place separately for the ten hydrogeological regions in Germany (information at <http://www.bgr.de/Service/grundwasser/>).

Another step involved compiling over 48,000 hydrochemical analyses from groundwater samples made over the last 20 years and held in the databases of the 16 German states involved in the analysis, and assigning them to the HGC.



**Web map server (WMS):**

**[http://www.bgr.de/Service/grundwasser/huek200/hgc\\_p90/](http://www.bgr.de/Service/grundwasser/huek200/hgc_p90/) (German)**

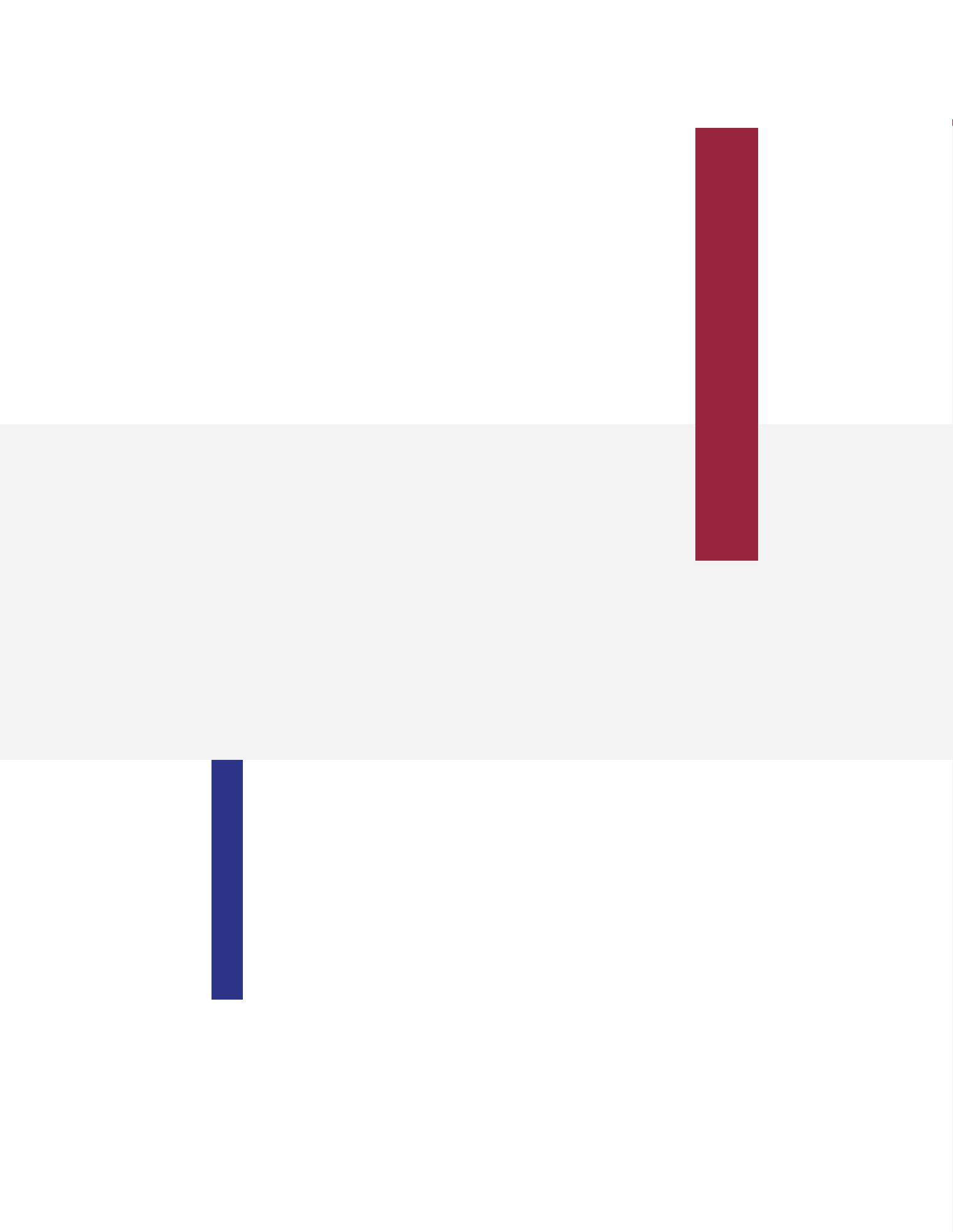


# Outlook

A large proportion of global fresh water reserves is stored in fractured and karst aquifers. They can contain very large quantities of water. However, these aquifers are very sensitive to anthropogenic influences such as toxic infiltration, e.g. from defective sewage pipes or inadequate sewage treatment. The disposal of waste can very quickly contaminate aquifers of this kind and prevent them from being used for very long periods of time. The protective function of the overburden covering an aquifer, especially in karst, is therefore of major importance and creates a strong interdisciplinary link with the natural resource soil.

A well in a karst aquifer usually produces water at a much higher rate than a well in a sandy aquifer. When the groundwater extraction starts in a karst aquifer therefore, it can easily lead to the misleading assumption that an almost inexhaustible groundwater resource is being exploited. Tailor-made concepts for the use and protection of the groundwater resource have to be developed for each individual case, because the level of saturation of a karst aquifer can vary substantially during arid periods.

To boost food production, groundwater pumping will increase around the world in coming decades for the irrigation of farmland with groundwater. BGR develops methods and manages projects for the controlled recharge of groundwater resources by the deliberate infiltration of rain water which would otherwise flow away unused in streams. To achieve these aims, BGR makes basic information, methods and decision making tools available which can be universally used and only need to be adapted to each specific region. This provision ensures that strategies can be developed for the sustainable use of water and soil.



# Soil



# Introduction

Soils are part of our habitat and the source of our food. This finite resource faces severe competition including crops of energy plants and space for infrastructure.

Soil erosion by water and wind, soil degradation and soil depletion from the loss of humus as a result of inappropriate practices are further threats. At the same time the growing global population demands more food to be produced from the arable land.

Soils also play a very important role in the water cycle. They filter the rain water and protect groundwater from contaminants from natural and anthropogenic sources.

Soil scientists at BGR investigate and evaluate natural and anthropogenically modified soils. The interaction between soils and percolating water, the effects of degradation processes and natural background values of elements and chemical compounds are top rank topics. The results of our research are made available on a regional, national and EU scale as well as internationally. In projects of technical cooperation sustainable land management for food security and climate change resilience are promoted by BGR.

## National soil base map sets new standards

**B**GR has been working for many years together with the geological surveys of the German states on the soil base map 1:200,000 (BÜK 200). This high resolution national map is designed to satisfy the significantly increased demands for up-to-date soil information required by government, industry and research, in this new age of remote exploration and digital data processing.

The BÜK 200 is essentially based on the regional soil information collected by the German states over many decades. "This data can vary considerably from state to state in terms of its spatial resolution and the accuracy of its content," says Dietmar Krug, BÜK 200 project manager. "BGR's job is to standardise this data for the BÜK 200 and make it available in this form to users across the country."

The differences in the database for the BÜK 200 arose from the use of different regional mapping techniques and variances in the ambitions and objectives to be achieved by the state maps. In addition, historical mapping results are often not available in digital form but only in print, and in some cases, some areas have not even been mapped at all.

By using new inference techniques and the effective use of the existing information, BGR aims to further improve the quality of this technical data and to fill in the remaining "white spaces" in the "pedological landscape." "Modern geographic information systems help utilise the data from already mapped areas. This enables predictions to be made for areas with no mapping data but similar site conditions," says Ulrich Stegger, project manager "Technical information system soil".

Complex topographical parameters can be automatically derived today from digital terrain analysis on the basis of digital topographic models. In combination with geological and soil information, these enable predictions to be made on the distribution of soils at the defined scale of 1:200,000. In addition to allowing basic data to be better assessed, this also makes it possible to fill in gaps where there is missing data.

A crucial prerequisite for the use of new digital mapping techniques is the geomorphological map of Germany 1:1,000,000 (GMK 1000) constructed on behalf of BGR, and which forms a critical database for the standardisation and delimitation of soil units in BÜK 200 – especially in the German Mittelgebirge (highlands). GMK 1000 was created with the idea of uniformly deriving relief units for the mapping of soil across Germany from the various digital topographic models.

The range of uses of GMK 1000 was recently expanded as part of a project "Soil inference and mapping" (SIAM) on a test map at a scale of 1:200,000 in close cooperation with the Geological Survey of North Rhine-Westphalia (Krefeld). This succeeded in inferring pedological mapping units on the basis of a digital relief model and the incorporation of geological information and statistical methods. This technique enables the soil units sketched in earlier by the mappers to be delimited and described more uniformly and more transparently.

Using this technique, and incorporating the regional expertise of experienced mappers, it is possible to develop a soil landscape model that is also valid for those areas within a major soil landscape which had not yet been mapped. "This enables us to extrapolate the distribution of soils from well mapped areas to regions with older or non-existent mapping," says Jan Willer, geologist and scientific member of staff in the SIAM project.

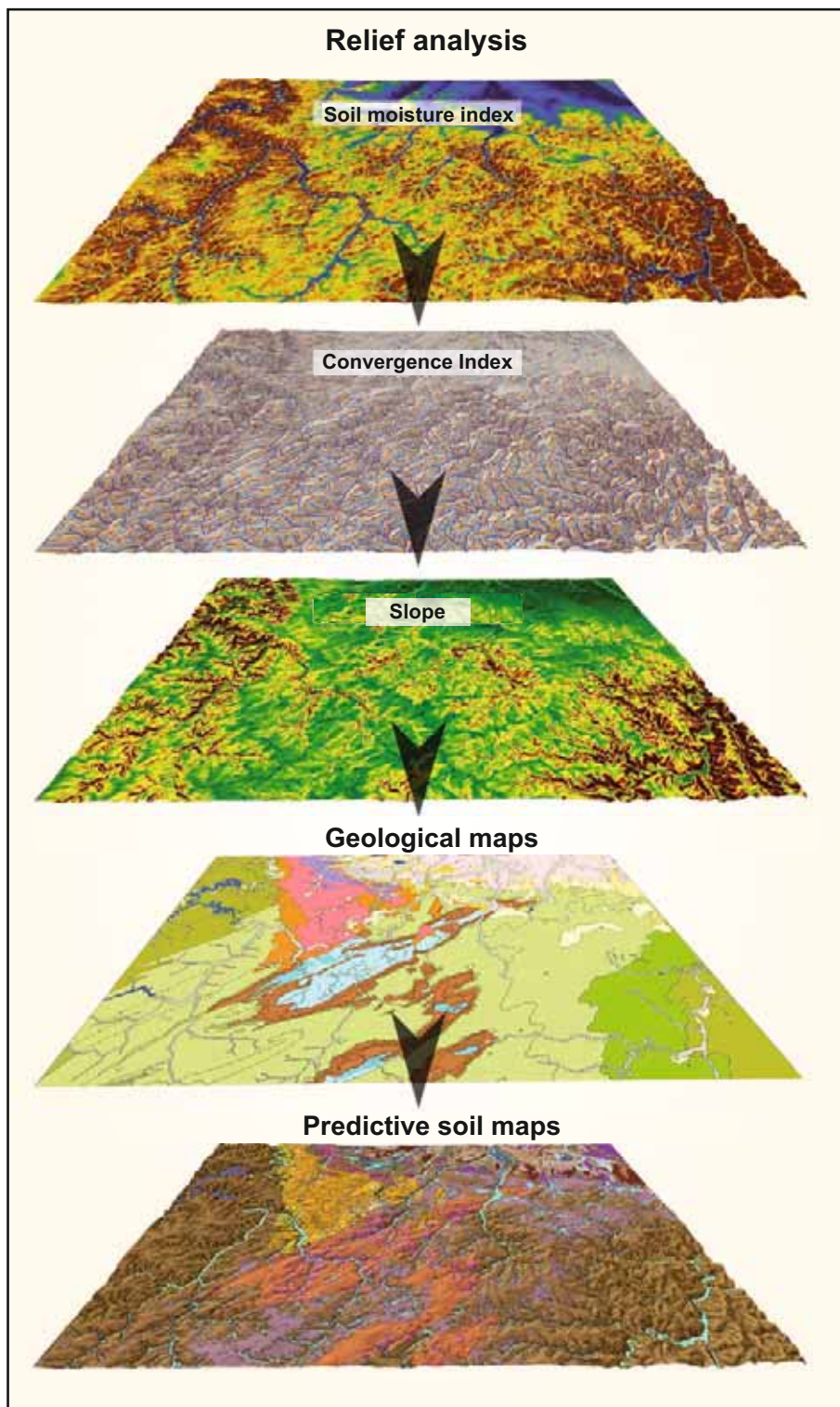
The methodological work involved in the SIAM project is being extended in cooperation with the State Institute for Environment, Agriculture and Geology in Sachsen, and other project partners working on the Chemnitz sheet at a scale of 1:250,000 as part of the "eSOTER" EU project (Regional pilot platform as the EU contribution to a Global Soil Observing System). This mapping project also makes use of radiometric and satellite data in other pilot regions (arid climate zones with a general lack of vegetation). The aim of this approach is to map the soil properties (texture, rock, humus content, and bedrock indirectly from the vegetation indicators). BGR focuses here particularly on the improved mapping of the bedrock whose boundaries in soil maps often deviate from those in geological maps – because of weathering and redeposition processes.

The findings flow into the GEOSS project (Global Soil Data). This project works on a global "soil information system" which makes interoperable soil data from various sources available as a web service. A major part here is played by raster maps with soil properties at a resolution of 90 metres developed on the basis of the globally available SRTM topographic model (Shuttle Radar Topography Mission) as well as point measurements and estimates extrapolated in the landscape (e.g. carbon content, pH).

"These new methodological approaches are the platform for the more intense involvement of BGR soil scientists in project regions in future with an acute shortage of pedological data," emphasises Rainer Baritz, department manager "Technical information systems, harmonisation and quality assurance

of regional data". "By combining conventional mapping and digital methods, we are able to improve the quantification of gaps in the soil database for application-oriented modelling, e.g. to model the consequences of climate change on land use," says Baritz.

The atlas "Soil base map of the German Federal Republic 1:200,000 (BÜK 200)" can be ordered from the Geoshop Hannover: [www.geoshop-hannover.de](http://www.geoshop-hannover.de)



*Different information levels are used to create a soil concept map in the soil landscape model:*

*First block: Three topographic parameters derived from the digital topographic model.*

*Second block: Geological maps at various scales.*

*Third block: Concept map results for BÜK 200.*

## Inorganic trace elements can contaminate groundwater

Pollutants can be leached into groundwater more easily from acid soils. The result: because of the high proportion of acid sandy soils in Northern Germany, the background concentrations of inorganic trace elements frequently exceed the German insignificance thresholds for groundwater. By contrast, the concentrations of selected organic pollutants are very low. This is the finding of a study conducted by BGR on behalf of the German Environment Agency.

“The BGR study aimed at evaluating soil contamination and its consequences on groundwater with the help of a standardised dataset in compliance with the Federal Soil Protection and Contaminated Site Ordinance,” explains BGR soil expert Prof. Dr. Wilhelmus Duijnsveld. To this end, the background concentrations of inorganic trace elements in percolating water, e.g. cadmium, cobalt, nickel, vanadium and zinc, were determined at various locations.

Samples are derived from three spatially-dominant soil parent material groups: sand, glacial loam, and loess. Further differentiation was made within these groups depending on the type of use: whether the soils were in cropland areas, grassland areas or forests. Measurements of the background concentrations of organic pollutants e.g. polycyclic aromatic hydrocarbons, polychlorinated biphenyls, were also made at some selected sites.

A suction probe was used to extract samples of the percolating water from the transition zone between the unsaturated and the saturated zone directly above the groundwater table. The soil horizons were characterised by taking various soil samples using ram coring, as well as soil samples from the transition zone between the unsaturated and saturated zone.

To be able to estimate any potential uncertainties due to the sampling strategy, the BGR soil experts analysed the spatial and temporal variability in the measured concentrations. The variations in the measured values over time at the sampled localities may be attributable to various effects including weather, crop rotation and the use of fertilisers. The spatial variability in the trace element concentrations tends to be more dependent on the element and less on the specific locality.

One of the main aspects looked at by the investigations was “how mobile” the trace elements are. pH and the concentration of dissolved organic carbon are important factors in answering this question. “As expected, the lowest pH values were in sandy soils, and the higher pH values were in glacial loam and loess. With respect to the land use factor, the localities on sandy soils used for forestry had the lowest pH values,” says BGR soil expert Duijnsveld. “This acidification mobilises the trace elements and can therefore result in higher concentration levels in the groundwater.”



*Preparing a borehole to extract a soil percolation water sample.*

*Extracting soil samples from the unsaturated soil zone down to the groundwater.*



German insignificance thresholds derived for groundwater are based on human and eco-toxicological parameters and used to define good groundwater quality. The background concentrations of trace elements in percolating water were therefore compared with the German insignificance thresholds for groundwater. "The trace element concentrations in percolation water from glacial loam and loess soils are much lower than these thresholds. Thus, if the levels in the percolation water from these soils are exceeded, it is therefore most probably a consequence of soil contamination due to higher trace element immissions," says Duijnsveld.

In sandy soils, however, which intrinsically bind trace elements much less strongly, several of the measured trace

element concentrations already exceed the German insignificance thresholds. This is particularly true for the elements cadmium, cobalt, nickel, vanadium and zinc, whose levels lie up to 10 to 50 per cent above the values for the insignificance thresholds for groundwater. This applied particularly to the percolation water samples from acidified sandy soils in the vicinity of industrial centres. In these soils, very high trace element concentrations were determined because of the enhanced mobilisation of the trace elements due to the very low pH of the soil.

"The concentrations of the analysed organic pollutants in the sampled sandy soils are, however, below the detection limits for each substance," emphasises Duijnsveld.



*Ready for installation: the tips of percolation water suction probes.*



*Preparing soil percolation water samples on site.*



## Brief field manual simplifies the work of soil protection experts

Soil protection can now be implemented even more effectively. A new concise field instruction set for soil protection experts simplifies the work of the responsible staff. BGR prepared the manual "Instructions to describe soil for preventative and sustainable soil protection measures" together with the Ad Hoc Working Group Soil of the state geological surveys and soil protection experts.

The manual is based on the German standard soil mapping guide (KA 5). The "KA 5" ensures that soil scientists describe and map soil properties in a standardised manner across Germany. Criteria include mineral composition, humus content, and aquifers and aquicludes. The soils are also evaluated according to their properties, functions and identifiable soil damage. The mapping instructions provide authorities and experts with a binding basis for implementing measures pursuant to the German Soil Protection Act.

"Unfortunately, KA 5 is too detailed for many every day aspects. The new concise field instructions will considerably simplify the work of our colleagues," says Dr. Wolf Eckelmann, departmental manager at BGR and chairman of the Ad Hoc Working Group Soil.

The new instructions include all of the parameters necessary for soil protection issues, strictly applying the same descriptions, abbreviations and symbols as in KA 5.

"Soils are one of our life support systems. Erosion, contamination and soil sealing in particular still continue to threaten this important geo resource. We therefore need thoroughly researched planning principles to protect soils. Mapping instructions and practical assistance, now provide soil scientists with the tools they need," emphasises Eckelmann.



**The German standard soil mapping guide (KA 5) and the new concise manual "Instructions to describe soil for preventative and sustainable soil protection measures" (German) are available from: [www.schweizerbart.de](http://www.schweizerbart.de)**

## Soil data for climate change research

In the 2008 "German Adaptation Strategy to Climate Change" (DAS), soil is mentioned as one of the fourteen areas of action. It is recognized that climate change has an impact on the properties and the functioning of soils, as well as on their development, and that this feeds back into areas such as food security and the water cycle. The German government's "Adaptation Action Plan" can be seen as the next step to further specify and to implement the DAS. Regarding soils it is said there that more accurate knowledge about the physical properties of soils and more reliable data about the changing condition and functioning of soils over time is needed. Soil monitoring and soil surveys about the condition of soils provide such information. In the context of climate change, the availability of such data would allow the investigation of the long-term effects of environmental change on soil processes. Such knowledge is crucial to plan and control the sustainable use of soils.

Against this background, BGR participated in a special workshop on "Soil data in climate change and adaptation research", held at the German Environment Agency, 29 to 30 September 2009. At that event, BGR presented information and data on its soil research including an interactive presentation "Marketplace for soil data". "The soil ecosystem plays an even more important role in the debate on climate change," explains BGR soil expert Dr. Olaf Düwel. "There is a very close set of interactions between soils and the climate. Changes in temperature and precipitation have an impact on the central processes taking place in soils and on their functions. Decisions about the use of soils are affected as well, and vice versa: land use also affects the responsiveness of soils to climate change. As a soil science information centre, BGR provides data which is required to improve the forecasting of climate change effects on the environment; such data is needed to plan and implement the necessary adaptation measures."

Active research is conducted in the project "Application of soil data in climate research" (BOKLIM), which has been initiated and funded by the German Environment Agency and the German Ministry of the Environment, Nature Conservation and Nuclear Safety. The project covers aspects such as knowledge demands arising from increasingly intensified land management as well as climate change, and how this affects soil functions; it also analyses the availability of soil data and its suitability to investigate the identified knowledge gaps. With the results, existing soil monitoring and surveying systems can be further modified and improved. "Every forecast about changes of important soil functions can only be made on the basis of very careful investigations about the sensitivity and response behaviour of soils. This requires monitoring and inventory programmes which need to be more intensely interlinked and evaluated in an interdisciplinary way," explains the BGR soil expert Dr. Jens Utermann.

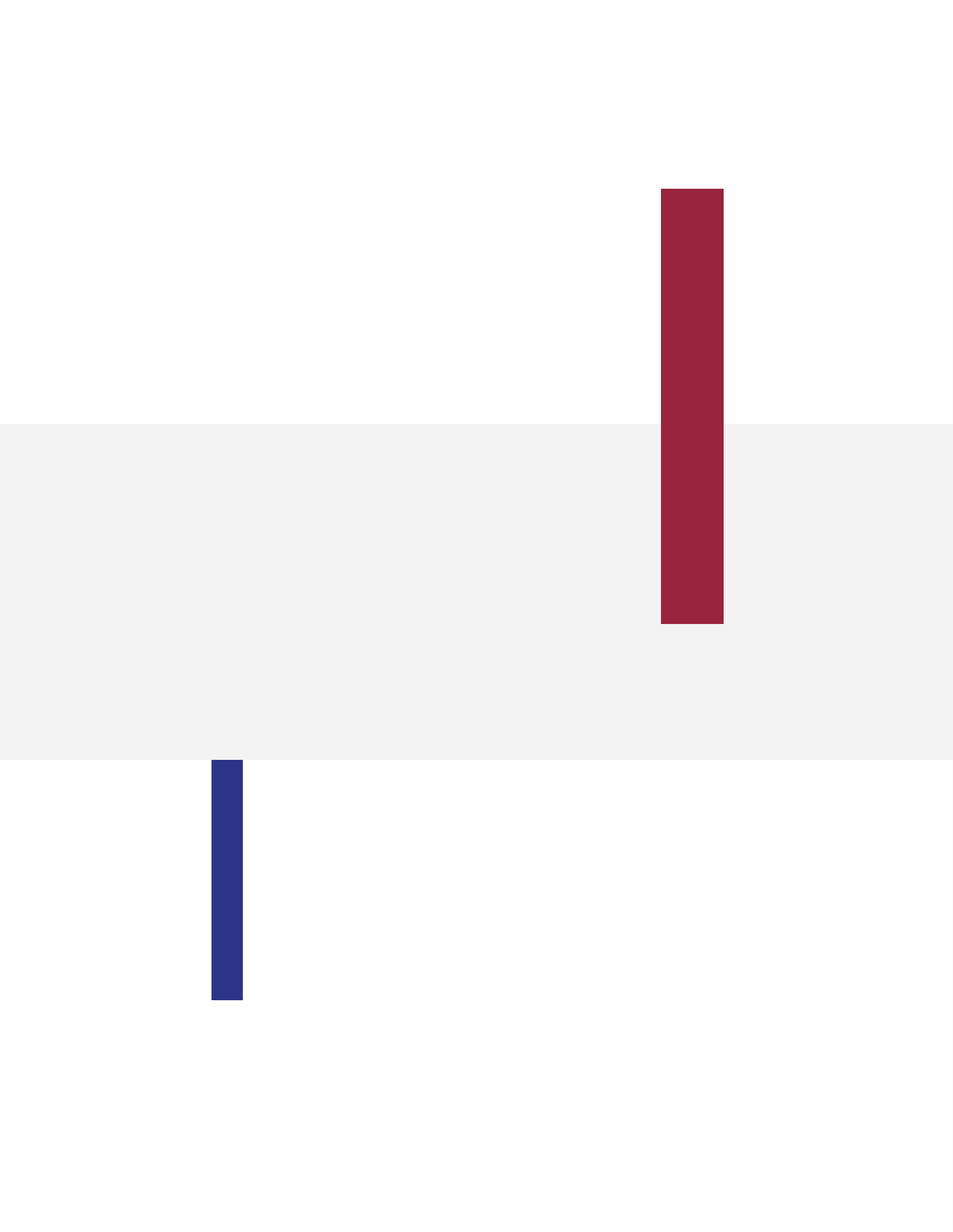
However, the BOKLIM project has detected that a large amount of existing and needed data is not available. "Therefore, it became a long-term objective of the BOKLIM project to create a soil information portal which enables the link between data providers and the interested users of soil data. On the basis of available, well-described metadata, access to soil data can be simplified," adds BGR soil expert Dr. Rainer Baritz. The final steps of the BOKLIM project have concentrated on the design of an information exchange network and platform. Solutions build on the involvement of the main data providers at the national level. Improved communication and data sharing has already begun.

# Outlook

**N**ot only is soil a finite resource, it is even subjected to degradation due to natural and anthropogenic reasons. Soil degradation results in a partial or total loss of productivity, either quantitatively, qualitatively, or both. It is essential to investigate and understand typical material compositions and properties of soils and relevant processes which effect soils and percolating water.

The data on soils collected and evaluated by BGR are vital decision support instruments for soil use, soil protection and sustainable land management. Interaction between soils and the water cycle are essential as well as effects of climate change and extreme weather events. Natural processes in soils may be effected by climate change and, thus, their use and productivity. One important question for example is whether carbon can be permanently stored in soils, or if the reverse is true because organic matter is decomposed and leads to a higher release of carbon.

Our responsibility is to develop decision support systems for sustainable management of soils. Soil protection requires further improvements in our understanding the distribution and properties of soils.



# *Final Disposal of Radioactive Waste*



# Introduction

**R**adioactive substances are valuable resources for energy production, medicine, measuring technology, and other industrial applications. However, the use of radioactive substances also gives rise to radioactive waste whose emitted radiation can be hazardous to people and the environment. To protect people and the environment from such radiation, waste has to be permanently and safely isolated from the biosphere. Scientists agree that this long-term safe protection can only be guaranteed by final disposal in geological formations.

The Federal Government is responsible for the final disposal of radioactive waste in Germany. As an affiliated federal institute assigned to the Federal Ministry of Economics and Technology

(BMWi), BGR works on the geoscientific and geotechnical aspects involved in the basic research undertaken in geologic repository projects. In particular, investigations are carried out on site selection, geological site exploration, the characterisation of geologic repository host rocks, and analysis of future scenarios for long-term safety.



*Example of a subglacial melt water outflow at a glacier.*

## The significance of subglacial channel systems for geological repository sites in north Germany

**T**he strategy of disposing of radioactive waste permanently in geological formations depends on the ability of the geological barrier to safeguard the long-term integrity of the geologic repository, and to do so without any subsequent human involvement to maintain the integrity of the repository system. Long-term safety analysis is carried out to verify whether the geologic repository has any radiological impact on the biosphere during the next one million years. Their understanding of the geological history of the earth gives geoscientists the expertise required to forecast geological processes that may take place in the future. In the long-term safety analysis undertaken by BGR, the scientists investigate all of the processes involved and draw conclusions from the findings on which processes can take place in future at a geologic repository site and about the mutual dependencies. They need to assess processes such as those which could be associated with future climatic events.

Part of long-term safety analysis for potential geologic repositories harbouring high-level radioactive, heat-generating waste (HAW), is estimating changes taking place in the cover rock overlying host rock formations in north Germany, which could be made up of either salt or claystone. The long-term safety analysis includes an evaluation of geological and climate related processes which could give rise to fundamental changes

in the properties of the cover rock during an isolation period of one million years, and which therefore enable conclusions to be drawn on the impact of such processes on the isolation potential of the host rock.

The melt waters flowing at the base of inland glaciers have a crucial influence on the structure of the cover rocks overlying host rocks. This is because their enormous erosional effects can result in deep channels being cut into the underlying rock. The channel systems formed in this way in north Germany during the Elsterian ice age approx. 400,000 years ago, reached average depths of approx. 200 – 300 metres and maximum depths of around 500 metres (e.g. Hagenow channel: 584 metres).

This was the background against which BGR used information from the climate history to develop a perspective for the climate evolution in the next one million years and to then estimate the chance of deep subglacial channel systems forming again in north Germany during future ice ages.

It is estimated that up to ten more ice ages could occur during the next one million years, and that at least one of them could have the same potential as the past Elsterian ice age which e.g. led to the formation of the subglacial channel in the cover rock above the Gorleben salt dome. Because it is not

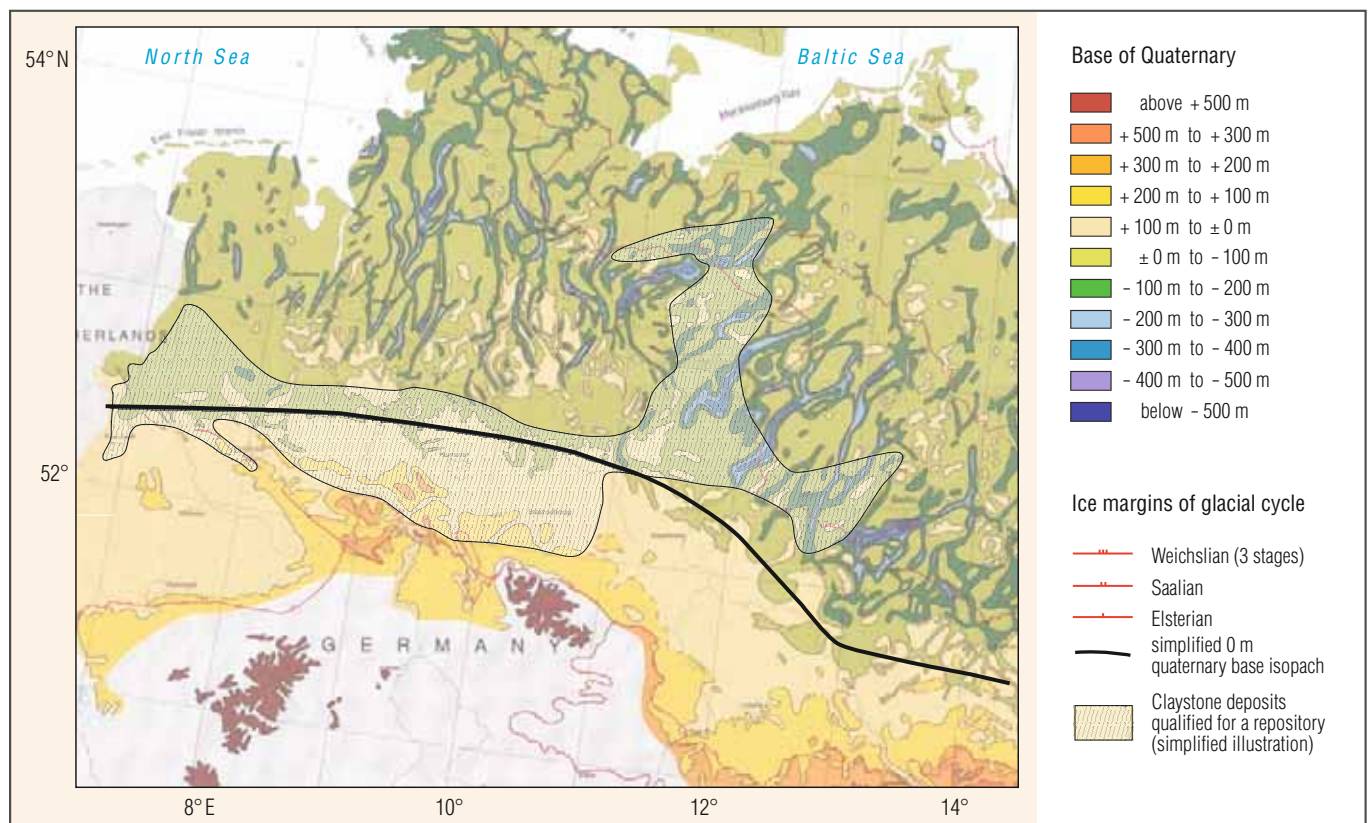
possible to predict the specific locations where subglacial channels might develop in future, the cover rock conditions above the Gorleben salt dome can also be seen as a model for alternative locations in rock salt or claystone in north Germany. This means that the cover rock above a geological repository host rock in north Germany in future can be exposed to continuous change associated with future ice ages. The current composition of shallow rocks and their structures change significantly, particularly when a continental glacier crosses a potential geological repository site.

Because of the large thicknesses of rock salt accumulated within salt domes, waste disposal is planned at depths of between 800 to 1,000 metres to exclude any negative consequences of channel development on a geological repository in future. The consequences of any future channel formation are also limited by the hardness of the rock salt because this is an important parameter controlling the formation of subglacial channels in the first place.

Geological repository sites in claystones worthy of further investigations have already been restricted to depths exceeding 300 metres. And the zones of most interest also lie at depths of between 300 to 400 metres for petrophysical, engineering and economic reasons. The barrier function of these relatively

shallow and soft claystone formations would be directly at risk from the formation of subglacial channels down to maximum erosion depths of approx. 500 metres – and particularly because of the absence of hard, calcareous and low permeability Upper Cretaceous rocks.

The evaluation of the changes in the cover rock above potential geological repository sites facilitates a direct comparison between the potential host rocks claystone and rock salt in north Germany. When considering the potential host rocks claystone or rock salt in north Germany, the conclusions drawn from such a comparison reveal that claystones are less suitable for the final disposal of high-level radioactive and heat-generating waste than rock salt in salt domes unaffected by salt mining or other activities. This applies especially to locations in north Germany where claystone formations worthy of further investigation lie at depths between 300 and 500 metres.



Distribution of Elsterian ice age subglacial channel systems shown on the Base Quaternary depth map (STACKEBRANDT et al. 2001) and claystone deposits (simplified after Hoth et al. 2007).



## Clay stones as host rocks for geological repositories for radioactive waste

In addition to salt, BGR also investigates clay as a potential host rock for the final disposal of radioactive waste. BGR therefore participates in international research projects in underground laboratories. Argillaceous rock formations are being considered and investigated in numerous countries for their use as host rocks and/or barrier rocks for the final disposal of radioactive waste. The frequently low to very low permeability of clay stones, their typical plasticity in parts, their chemical buffering properties, and their ability to retain toxins and radionuclides, are the main characteristics making clay stones favourable barrier rocks.

Comprehensive investigations are therefore being carried out to characterise the location-specific clay stone formations and to analyse their suitability as host rocks for geological repositories. The aim of these investigations is to determine their thermal, hydraulic, mechanical and chemical properties, and the interaction of these properties. BGR uses its knowledge and experience in in-situ geotechnical and geophysical investigations acquired as a result of its many years of research in rock salt, and expands its know-how to include clay stone host rocks through its involvement in international research projects. In this way, BGR makes fundamental basic scientific findings available for the comparative evaluation of potential host rocks, as well as enabling the application of new and further developed technical methods at an international level. In this way, BGR also considerably assists its project partners in their search for potential locations. At the same time, BGR participates at an international level in the findings and developments, and their potential extrapolation to applications in Germany.

BGR has carried out geotechnical in-situ investigations in the Mont Terri Rock Laboratory in Switzerland since the end of the 1990s. Research here aims to determine the mechanical and hydraulic properties of the Opalinus Clay and the stress states within the rock formation.

### Rock stresses

The evaluation of numerous findings has revealed that the properties of the rock formations bordering the Opalinus Clay, and the rock stresses existing in these formations, must not be ignored. BGR has therefore carried out investigations to determine their stress state. Research results reveal a strong dependence of the stress magnitude on the direction (stress anisotropy) in the investigated zone, which is ultimately attributable to the bedding conditions in the sedimentary layers. The measured stresses revealed that a portion is due to recent residual stresses arising from the mountain building or tectonics affecting the area in which the rock laboratory is located. Both the magnitude and the direction of the measured rock stresses, correspond very well with the results of tests carried out by other international institutions involved in the

project. The results are used as input parameters for large-scale numerical calculations which enable the more precise interpretation of other investigation results, and the prognosis on the long-term behaviour of the Opalinus Clay as a host rock.

### Deformation behaviour of Opalinus Clay

In addition to rock-mechanical laboratory tests on core material, it is also essential to conduct in-situ investigations because these also take into consideration discontinuities, bedding, underground caverns, and local anomalies, and therefore also enable the determination of the rock mass properties. Several boreholes were drilled in different directions relative to the bedding of the Opalinus Clay to investigate its mechanical behaviour. The changes in the diameter of these boreholes over time were then recorded in follow-up measurements.

The results of these tests revealed the significant influence of anisotropic rock mass stresses on the deformation behaviour of the rock mass. Characteristic spalling of the wall of the boreholes occurred in association with cherry-stone-like deformations. This also provided a clear indication of the orientation of the directionally-dependent formation stresses. A very surprising finding was the observation of localised inflows of moisture of various kinds into these boreholes, which in some cases had an impact on the walls of the boreholes, and even caused the complete collapse of some boreholes.

These investigations showed that local inflows of formation water with different volumes can be expected in the Opalinus Clay, which in some cases have a considerable impact on the mechanical behaviour of the host rock. This finding confirmed



*Stress measurements in the Mont Terri Rock Laboratory.*

the need to carry out in-situ investigations to hydraulically characterise the clay stone.

## Geophysical investigations

Mechanical, hydraulic, thermal and chemical processes associated with the drifting and servicing of underground cavities give rise to changes in the formation properties. Geophysical parameters react to changes of this kind. In-situ investigations using ultrasonic, seismic and borehole geoelectric surveys can be used to determine numerous parameters suitable for characterising the rocks surrounding underground workings, and to detect changes.

For this purpose, BGR develops numerous ultrasonic and seismic in-situ measuring techniques used in boreholes or on tunnel walls. The parameters determined in this way can be used for the very high resolution characterisation of the rock. A geoelectric borehole logging tool developed by BGR is also used to specifically characterise the zones surrounding the walls of the borehole. In addition, videos and photos are also made of the borehole and the walls. In the Swiss Mont Terri Rock Laboratory (Opalinus Clay) and in the French Meuse/Haute-Marne Rock Laboratory (Callovian-Oxfordian), BGR uses these geophysical in-situ methods to make a major contribution to the following aspects of the investigations: determining dynamic-elastic in-situ rock parameters, detecting disturbed borehole wall zones, the degree and extent of excavation disturbed zones, seismic anisotropies, the detection of local stress orientations, detecting fractures and faults, characterising small-scale rock heterogeneities, and long-term seismic monitoring.

## Excavation disturbed zones

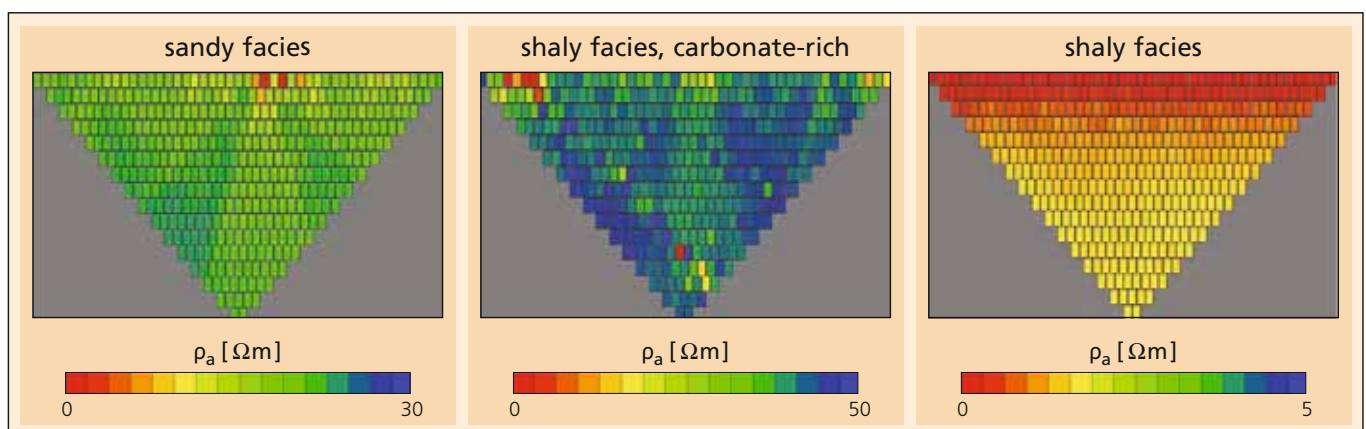
The excavation disturbed zones around underground workings are the inevitable results of tunnelling. Because they can potentially give rise to migration paths for toxins, and can also

have an impact on the stability of underground workings, research into the excavation disturbed zones is an important part of repository investigation programmes. The size and the extent of these zones is dependent on numerous parameters including the type of drifting technique used to construct the tunnel, the geometry, and local stress relationships.

In a horizontal large-scale borehole in the French Meuse/Haute-Marne Rock Laboratory, seismic surveys were conducted in 2010 to seismically characterise the excavation disturbed zone around the tunnel and the excavation disturbed zone around the borehole. The large borehole with a diameter of 740 millimetres could be logged to a depth of eight metres using a modified 10-channel borehole logging tool normally used in boreholes with diameters of up to 130 millimetres. The first results show a seismically characterised excavation disturbed zone (influence of the tunnel) extending a few metres into the rock mass, and that the disturbed zone in the borehole wall decreases with increasing borehole depth.

## Geoelectric borehole logs

Geophysical surveys to characterise the short-term changes affecting borehole walls were carried out in autumn 2010 in the Swiss Mont Terri Rock Laboratory in a zone in which boreholes penetrated three different Opalinus Clay facies (shaly, sandy, and shaly carbonate-rich facies). The logging programme involved ultrasonic and geoelectric borehole logs. Clear differentiation was seen between the different facies on the basis of the specific electrical resistivities. In addition, the only 1.5 centimetre distances between the 50 measuring electrodes enabled high radial resolution. These investigations were carried out to detect any inflows of moisture which may be present, and to record the changes in these inflows over time.



Apparent electrical resistivities of the three facies of the Opalinus Clay.

## BGR scientist Enste acts as a consultant for the Swiss repository site selection programme

The BGR scientist Gerhard Enste was appointed to the "Expert group Swiss geological repository" (ESchT) in January 2009. The committee of nine chaired by Dr. Wilhelm Hund from the Federal Office for Radiation Protection is the German representative working on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety monitoring the search for a geologic repository for radioactive waste in Switzerland.

The collaboration is based on the "Deep Geological Repositories" sectoral plan in Switzerland which was elaborated with the involvement of neighbouring countries. This plan, submitted by the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra) in autumn 2008, includes recommendations for geological sites chosen on the basis of technical safety and geological criteria.

Some of the proposed sites lie in direct proximity to the border with Germany because the Opalinus Clay Formation occurring in north Switzerland is considered to have properties which are particularly good for the construction of a geologic repository. Another important task of the German expert group is therefore providing advice to the affected regional and local authorities, and interested associations on the German side, who are provided with a platform by the Swiss Monitoring Commission (BeKo-Switzerland). "The ultimate aim of the expert group is to provide independent technical advice via BeKo-Switzerland to the affected inhabitants in border regions," says Enste.

Enste is a graduate geologist and has been head of the BGR "Geological-geotechnical exploration" sub-department since 2009. This department works on issues concerning the geology of barriers and host rocks, in situ rock-mechanical and rock hydraulic investigations, as well as geophysical near field investigation.



*BGR scientist  
Gerhard Enste.*

## BGR has new improved 3D geological models

Since the middle of the 1990s, 3D geological models have formed the basis for work including the exploration and evaluation of deposits, as well as the planning of mines and caverns. In recent years, BGR scientists and industrial partners have developed a new software package which enables the production and more targeted use of even more detailed 3D models for geological exploration and numerical simulation.

A key tool for elaborating the 3D models and the model-supported evaluation of exploration results is the 'openGEO/GEOravis' program package. This software, which was specially customised for very complex structures, and the frequent very wide range of input data used in geological projects, is based on precursor programs which have been used by BGR for ten years.

"Unlike other programs, the 'openGEO' software provides more detailed opportunities for producing geo-referenced 3D geological models of complicated geological structures in a very accurate way. This not only saves time and money, it also enables the exploration of deposits in a much more focused way which more accurately matches the specific geological conditions," explains BGR scientist Dr. Jörg Hammer.

The program functions available in 'openGEO' are the only ones which allow the clear modelling of structures in which one location coordinate can have several height coordinates, e.g. salt diapirs with very tight flow folding, and very closely spaced overturned and strongly varying formation thicknesses and bedding conditions. "Conventional programs are either incapable of displaying such conditions, or can only do so with the input of a great deal of time and effort," says Hammer.

The 3D models elaborated by the BGR salt geologists are used as the basis for e.g. mine planning or geomechanical calculations, e.g. to verify the barrier integrity of host rocks and the stability of underground workings. They are also used for transport modelling which is important for long-term safety analysis. The 3D models prepared with the help of 'openGEO/GEOravis' also enable the visualisation or interpretation directly within the 3D model of the results of complex database searches (e.g. on the geochemical and mineralogical composition of rocks) in connection with the identified or forecast geology. The database linkage supported by 'GEOravis' enables the direct interactive use of the 3D models as data stores of knowledge.

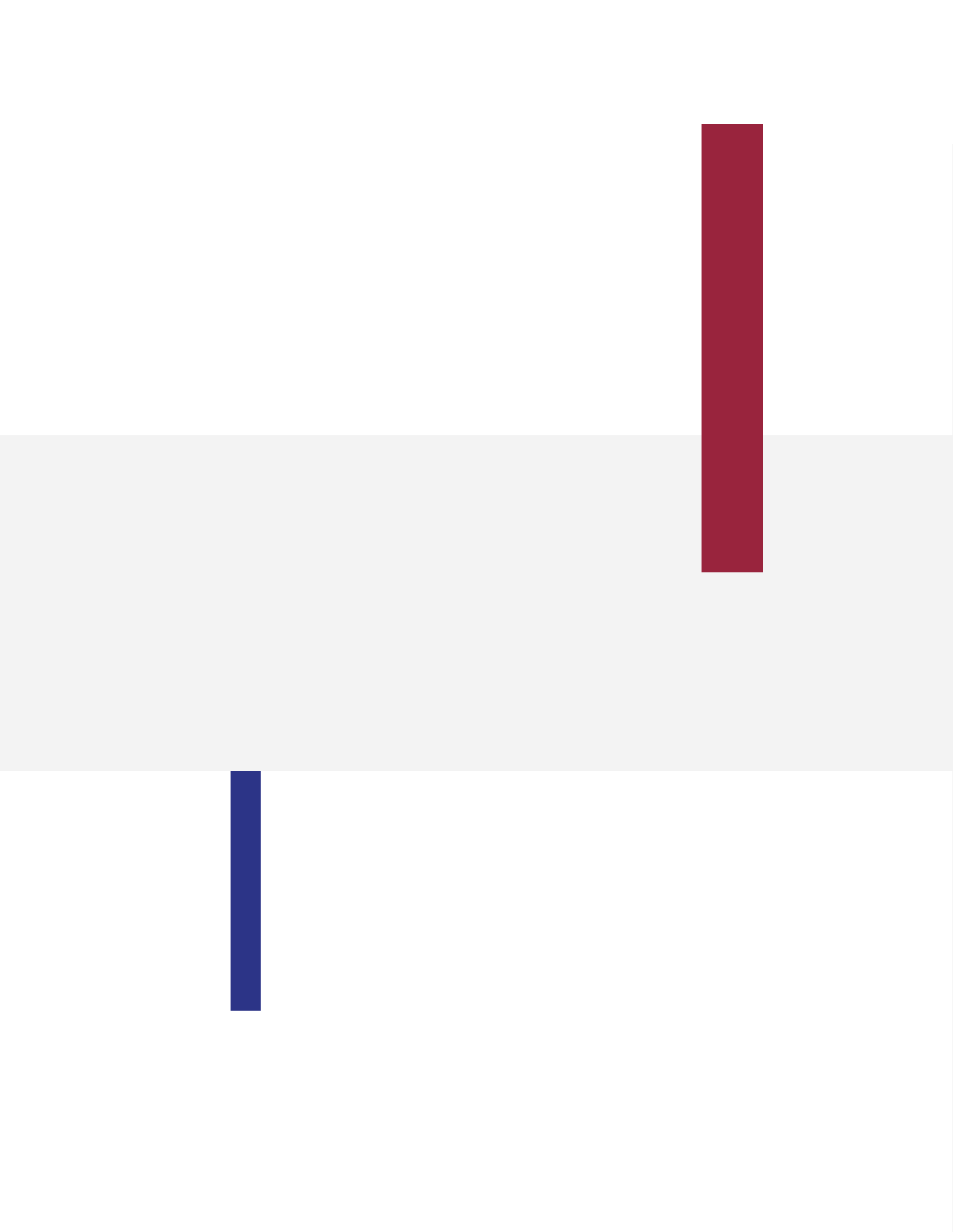
The integrated evaluation of borehole and mapping results with the help of 'openGEO' in recent years, and the integration of a wide range of geophysical data (e.g. seismic data or borehole and helicopter geophysical logging results) has made it possible to elaborate numerous geological site models (e.g. Gorleben, Morsleben, Etzel and Staßfurt). In addition to geological exploration and the evaluation of geologic repository sites, the geological models can also be used for the precise positioning of gas/oil storage caverns, and the planning of solution mining processes in salt structures with complicated internal structures.

# Outlook

**T**he geology in Germany provides the prerequisite conditions for the long-term isolation of radioactive waste in a repository constructed in deep geological formations. Final disposal in a geological repository should be maintenance-free, of unlimited duration, and not include any planned retrievability.

BGR scientists do their own research work to actively assist the development of the state-of-the-art science and engineering which needs to be taken into consideration when disposing

of radioactive waste in geological repositories. This research is often done within the framework of extensive cooperation activities with international partners and in association with other research institutions. The main priority of this work is focused on the development of techniques and equipment, as well as transferring expertise. With its geoscientific site investigations and application-oriented research activity, BGR makes a significant contribution to the efforts involved in the safe permanent disposal of radioactive waste.



# *Geological Storage of CO<sub>2</sub>*



# Introduction

Carbon dioxide dominates the debate on the influence of human activity on climate change. Options to reduce the emissions of this small molecule into the atmosphere include improved energy efficiency, reducing energy consumption, the fastest possible replacement of fossil fuels by renewables – as well as the development and application of the Carbon Dioxide Capture and Storage (CCS) technology.

Putting this technology into effect means establishing viable CO<sub>2</sub> capture and transport technologies, and optimising their costs; as well as identifying and making available an adequately large volume of permanently safe storages.

BGR experts are involved in this endeavour by elaborating – usually together with partners – the necessary knowledge to evaluate the geological storage possibilities in Germany, and to make these findings available for politicians, industry and the general public. In more detail, BGR is actively involved in a number of research projects looking at various aspects of the permanent and safe storage of CO<sub>2</sub>. The COORAL project, for instance, deals with geological and geotechnical issues concerned with the tolerance of reservoir and barrier rocks to the effects of flue gas variations (CO<sub>2</sub> and associated substances), simulating in-situ conditions of deep geological formations in autoclaves.



## The CO<sub>2</sub>-storage potential of deep underground rock formations

**B**GR scientists investigate potential reservoir and barrier rocks in Germany and regularly update the calculations of the potential storage capacities. In Germany only depleted natural gas fields and deep saline aquifers have considerable CO<sub>2</sub> storage potential. The CO<sub>2</sub> storage capacity in gas fields is estimated at 2.75 billion tonnes CO<sub>2</sub>, based on published production data and known reserves, remained almost unchanged for years. In contrast, regional studies carried out during the last years have resulted in a step-wise improvement of our understanding of the storage capacity in saline aquifers.

An important prerequisite for the implementation of the geological CO<sub>2</sub> storage technology is the availability of adequate storage capacities in deep underground rock formations. BGR has conducted numerous studies in the last ten years focusing on CO<sub>2</sub> storage potentials in deep saline aquifers (at depths below 800 metres). Regional studies in northeast and southwest Germany enabled BGR in 2005 to estimate the potential volumetric storage capacity in German onshore areas at 12 to 28 billion tonnes CO<sub>2</sub>.

Including the most recent studies, by now around 75 per cent of the area of the three largest German sedimentary basins – North German Basin, Upper Rhine Graben and Molasse Basin (Alpine Foreland Basin; Figure, p. 91) – have been considered. The new investigations also include the German North Sea sector (without the so-called “duck’s beak”). Within the investigated areas potential storage structures (traps) were evaluated on the basis of existing maps (e.g. ‘Geotectonic atlas of Northwestern Germany’). The analyses also took into consideration site-specific reservoir properties, where known

and available. On this basis the CO<sub>2</sub> storage capacities have been recalculated in a standardised way using Monte-Carlo simulations. This method enables consideration of site-specific parameter variations and thus allows further refining of the potential storage capacity estimate. Accordingly, the storage capacity of deep saline aquifers in the investigated areas (North German Basin, Upper Rhine Graben, Molasse Basin) is currently estimated at 6.3 to 12.8 billion tonnes CO<sub>2</sub>.

In addition to the volumetric storage capacity, other geological factors play a very important role in determining the usable storage capacity. These factors include the regional distribution, thickness and hydraulic conductivity of the reservoir rocks, the structural setting, and especially relevant information on the barrier rocks. BGR and the state geological surveys have moved an important step in this direction with a project co-financed by the German Ministry of Economics and Technology (BMW) and Industry: “Informationssystem Speichergesteine für den Standort Deutschland – eine Grundlage zur klimafreundlichen geotechnischen und energetischen Nutzung des tieferen Untergrundes (Storage Catalogue of Germany)”.

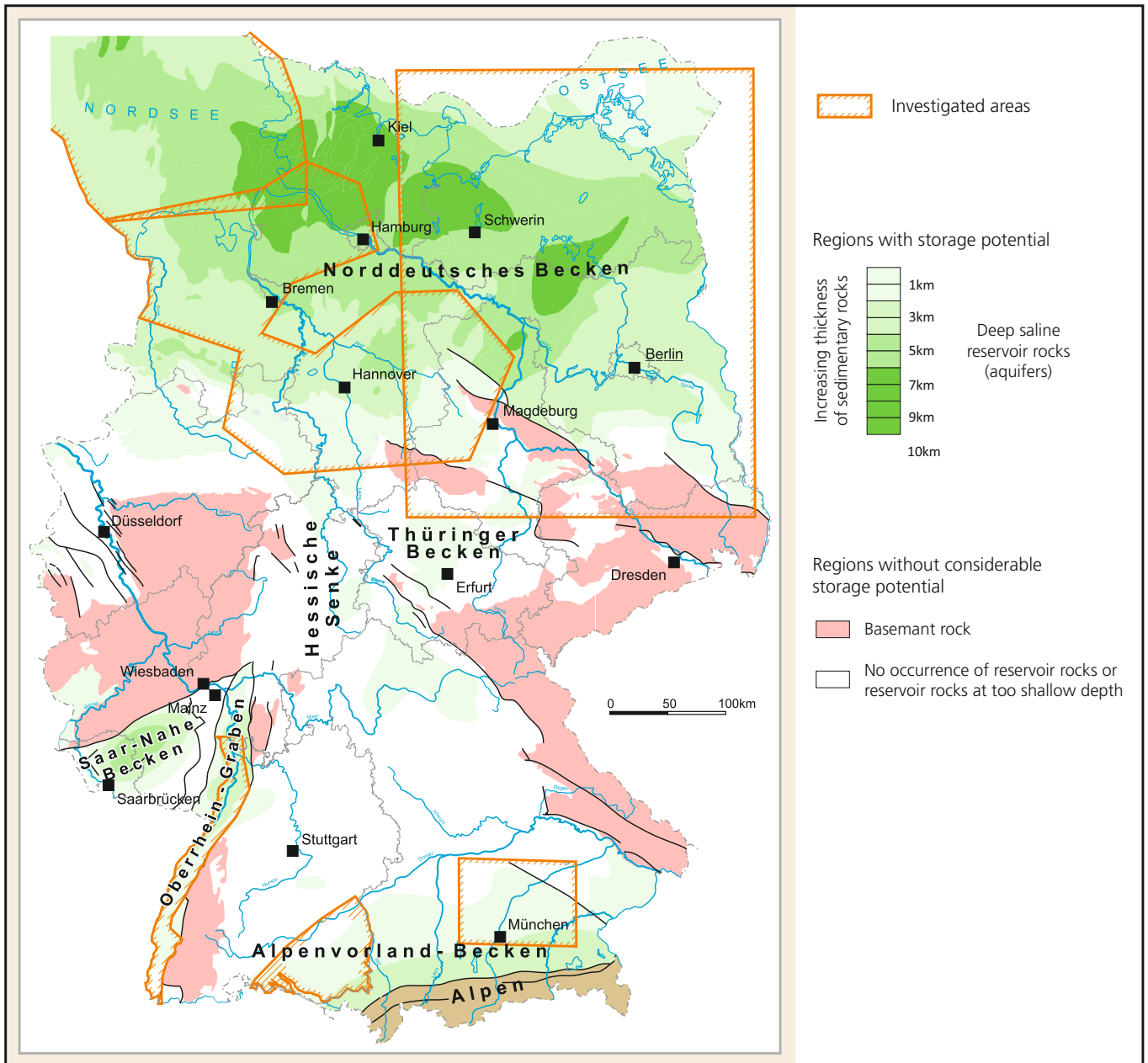
The objective of this project is to provide a first systematic nation-wide compilation and evaluation of information on potential reservoir and barrier rocks in deep geological formations. The project partners have been elaborating maps and information on properties of reservoir and barrier rocks since 2008. An important aim of this project is to provide qualified advice to politicians, the general public and industry. The results at the end of the project in 2011 are to be published as report, publications, and also made available in a GIS application.

Potential reservoir and barrier rocks in Germany, occurring at various depth levels, are found in deep sedimentary basins, e.g. the North German Basin. In the project Storage Catalogue of Germany the preparation of maps on storage potential, delineating areas identified for further investigations, is done on the basis of stratigraphically defined units, the so-called reservoir and barrier rock units, beginning from the stratigraphically oldest or deepest reservoir rock unit in the Permo-Carboniferous up to the stratigraphically youngest and highest barrier rock unit in the Cretaceous.

Internationally recognised criteria for defining minimum depth and thickness were used to categorise the reservoir and barrier rock units and thus identify regions for further investigations. Reservoir rock units identified for further investigations, e.g. potentially suitable for the permanent geological storage of CO<sub>2</sub>, must satisfy a minimum depth of 800 metres at the top of the reservoir rock unit and a cumulative thickness of reservoir rocks of at least 10 metres. Other reservoir properties, including porosity and permeability, are taken into consideration when available. The state geological surveys often have additional information at their hands which are also taken into consideration, e.g. on local and regional post depositional (diagenetic) processes, or on facies variations within the reservoir rocks.

The project Storage Catalogue of Germany is the first step to create a nationwide database and to identify areas for further investigations based on geological criteria. A large amount of additional data and information not considered within this project, such as borehole logs, is currently only available in analogue form and needs to be compiled and evaluated in the future as part of a subsequent and much more comprehensive analysis of the storage potential in deep saline aquifers.

In addition to geological factors influencing the suitability of reservoir and barrier rocks, economic aspects, potential conflicts of use, and especially the acceptance of the general public play an important role. Therefore, the suitability of a specific location can only be determined by detailed site-specific exploration and evaluation.



The areas highlighted in green mark sedimentary basins which are deep enough to make them suitable in principle for the permanent geologic storage of CO<sub>2</sub>. BGR has carried out regional studies in the areas highlighted in orange.

## COORAL: Safety first – from power plants to geological storage

The CO<sub>2</sub> captured at power plants may contain varying concentrations of sulfur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), hydrogen sulfide (H<sub>2</sub>S), carbon monoxide (CO), oxygen (O<sub>2</sub>), dust, and solvents etc. depending on the processes and capture technology involved.

These substances may trigger corrosion of facility plant components, pipelines or borehole cements. They also alter the phase characteristics of CO<sub>2</sub> and thus properties that are important for transport and injection. Furthermore, little is known about the impact of these incidental substances on the fluid behaviour and geochemical reactions in the storage complex.

In consequence, the COORAL project (CO<sub>2</sub> purity for capture and storage) aims at finding the optimal proportions of CO<sub>2</sub> and incidental substances in the flue gases generated by different power plant types, to ensure long-term safe geological storage of CO<sub>2</sub>. The goal is to prevent corrosion of equipment and pipelines, and to keep the costs of the carbon capture and storage (CCS) technology economically acceptable. The 3.5 year project started in April 2009 and is funded by the German Federal Ministry of Economics and Technology.

In the COORAL project scientists of the following institutions cooperate: BGR, BAM Federal Institute for Materials Research and Testing, the Universities of Hamburg-Harburg and Halle, as well as DBI-Gas- und Umwelttechnik GmbH from Leipzig. BGR coordinates the project and investigates potential geochemical fluid-rock interactions in CO<sub>2</sub> storage reservoirs.

To understand the geochemical reactions between CO<sub>2</sub>-rich fluids, formation water and host rocks under in situ conditions, BGR is experimentally determining data on reaction kinetics and the thermodynamic stability of various minerals. For this, mineral separates 'typical' for various potential storage and barrier rocks are exposed to binary fluid mixtures (CO<sub>2</sub> and incidental substances) and artificial formation water in inert reaction vessels. The pressure and temperature conditions in the reaction apparatus simulate reservoir conditions. Compositions of solids and fluids are analysed before and after the experiments to observe the geochemical reactions.

Numerical simulations are performed to optimise experimental parameters, e.g. time scales. Experimentally determined data are in turn used to check the simulation results and to improve the database for geochemical simulations. This way, it will be also possible to predict geochemical reactions with very low reaction rates.



*Natural rock alteration caused by CO<sub>2</sub>.*

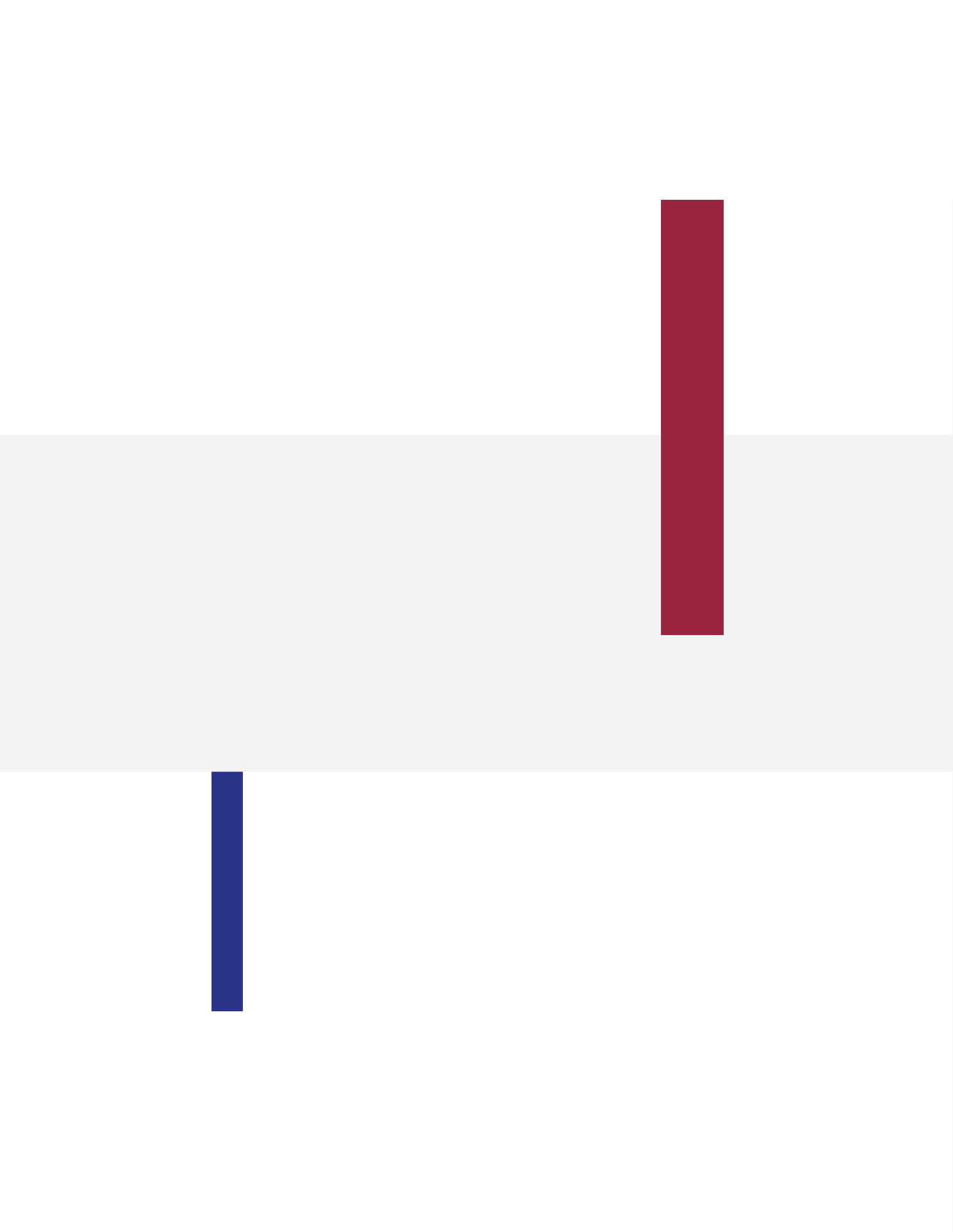


*Reaction vessel for geochemical experiments.*

# Outlook

**T**he storage of CO<sub>2</sub> in geological formations requires a lot of subsurface space and will influence the pressure conditions around the storage site as well. Because of the underground storage space, all potential interests in this room have to be given fair consideration. There is already competing interest between, for instance, the conventional mining activities for energy resources and salt, the storage of oil and gas, and the disposal of toxic and radioactive waste. In future times, there will be even more competition from mining of deep geothermal energy, and most likely the storage of renewable energies (e.g. hydrogen, methane, compressed air).

To be able to offer geoscientifically competent solutions to these challenges, BGR for instance carries out – together with LIAG – the project “Geothermal Atlas” to identify potential conflicts of interest between CCS and mining of geothermal energy. Likewise, potential conflicts of interest in the use of underground storage space are explicitly addressed in the draft German act on the permanent storage of carbon dioxide – to be taken into consideration by BGR in future activities regarding the nation-wide evaluation of storage potentials.



# *Geoscientific Information and Principles*

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# Introduction

The base for work in geoscientific disciplines such as the development of new economic zones to exploration of natural resources, and the analysis and estimation of the risks of geohazards, is the availability of geoscientific data and information. New methods and technologies make the collection of data increasingly more effective, comprehensive and faster – the knock-on effect of which is an enormous increase in the volume of data and information available. At the same time the exchange and utilisation of geodata from various sources is gaining in importance. This data flows into specific technical geoinformation systems for further processing, e.g. into the German North Sea Geopotential Project (GPDN). Because the input data is usually tailored to the conditions and working processes of the source generating the data, further processing by third parties often involves a considerable amount of work to transform the data to match their own formats.

This hindrance to the use of geodata was identified some years ago and led to national and international programmes on the

interoperabilisation or standardisation. BGR actively contributes its expertise and experience in the further processing of data in geoinformation systems into the development of the relevant standards within the context of several projects, e.g. INSPIRE (Infrastructure for Spatial Information in Europe) and GDI-DE (Geodata infrastructure Germany). In addition, BGR enters into cooperation agreements for the mutual use of geodata, e.g. with the German Army Geoinformation Bureau. Agreeing on standards and the associated improvement in the ability to use the data generates synergies in processing and enhanced product quality. It also ensures faster reaction times when responding to requests from industry or government.

Another important aspect is the integration of countries from outside Europe. African countries for instance have enormous geopotential which can be exploited better by cooperation within international projects, such as the GIRAF project (Geoscience Information in Africa). Information on georesources and georisks can be evaluated more specifically by the initiation of a pan-African network.



## Geoinformation system assists sustainable development of the North Sea

The German North Sea is to be systematically developed as an economic zone. Geoinformation provides an important basis for implementing this strategy. Important scientific principles for this purpose are being supplied by the joint project "Geo-scientific Potential of the German North Sea" (GPDN), which BGR is currently working on together with the State Authority for Mining, Energy and Geology (LBEG) and the Federal Maritime and Hydrographic Agency (BSH).

The results of the ongoing geoscientific investigations are input into the 'Geoinformation system North Sea', whose products will be made available on an internet platform in 2013 to companies, research institutions, authorities and interested members of the public. "The project provides access to basic geoinformation on the genesis and structure of the North Sea," explains BGR project co-ordinator Dr. Lutz Reinhardt. "In this way, we create the necessary information essential for the sustainable development of the North Sea as an economic zone, and to protect nature."

The scientific findings of the project are an important platform for the further expansion of offshore wind farms as well as planning pipeline and marine cable routes. The information also assists the exploration of oil and gas fields, and sand and gravel deposits, as well as estimating the potential for future energy storages or potential storage capacities in deep geological formations.

The project is financed by the Federal Ministry of Economics and Technology as well as the Ministry of Economics, Labour and Transport of Lower-Saxony. The project is also supported by industrial, research and public administration partners. The GPDN team works in six interlinked project modules in which geological data is collected and processed. This also includes data searches in archives and cooperation with companies, research institutions and authorities. This enables all of the available data to be bundled and used to set up a new geoinformation system.

Seismic and other surveys of the seafloor of the North Sea have been undertaken on four marine expeditions so far. The results of the surveys and the analysed sediment samples help scientists fill gaps in their data and map the distribution of sediments across the whole seabed. This information flows into dynamic 3D models for a digital 'Geotectonic atlas' which enables an even more accurate and comprehensive visualisation of the geology beneath the North Sea, and which will also be part of the North Sea geoinformation system. "3D models help improve the analysis of deep geological structures. They simplify future offshore planning and thus help improve harmonisation between the many different uses, and overlaps with the objectives of environmental and nature conservation", explains BGR project co-ordinator Reinhardt.



'Vibro-corer' to extract up to 6 metre long cores from the seafloor.



Box corer sample to determine the distribution of sediments on the seabed.

## 'Airborne Laser Scanning' as part of technical cooperation with Bangladesh

Life for the people living in Bangladesh is made difficult by repeated flooding during the monsoon season: the consequences of flooding include famine, epidemics, and the loss of housing and jobs. The capital Dhaka is also affected by flooding. Around 12 million people are squeezed into an area covering approx. 150 square kilometres in Dhaka. Whereas the slightly higher lying areas, which are not affected by flooding were originally settled, the city has been expanding very rapidly since 1970, largely without any central planning, so that the built-up area has now spread onto the flood plains of the large rivers Brahmaputra, Padma (Ganges) and Meghna. These rivers transport almost all of the melt water and rain water from the Himalayan mountains bordering India through Bangladesh to the Gulf of Bengal.

Parts of the low-lying areas, which are regularly flooded during the monsoon season are often filled with debris and waste, and houses are often built without necessary preparation of the building ground. This is done without any regard to the considerable but avoidable hazards and risks (including damage to buildings, flooding, and soil and water contamination). Because of the inadequate preparation of the building ground and the settling in lagoonal areas, which have now been filled and built on, a risk to multi-storey buildings (collapse) and infrastructure (breaking water and gas pipes) arises. Moreover, this land reclamation practice has been leading to the reduction of the flood plain further and therefore exacerbates associated risks and hazards.

High-resolution relief maps are a vital prerequisite for improving disaster prediction and mitigating the catastrophic consequences of the devastating floods, which occur every year in the Dhaka area. This data can be used to very accurately model areas with hazards of flooding. When combined with aerial photographs, they can also reveal former lagoons, which have now been filled with debris and waste. Buildings and infrastructure in these areas are exposed to risks because of resulting land subsidence. Precise delineation of these hazardous areas is important for town planning and designation of new development areas.

The provision of such data was one of the goals of the project 'High resolution terrain modelling for hazard assessment of developed and planned areas in Greater Dhaka City, Bangladesh', implemented jointly with the Geological Survey of Bangladesh (GSB). This involved conducting a laser scanning survey in parts of Greater Dhaka City in combination with the recording of high resolution digital aerial photographs. The project required almost two years of planning and preparation. 'Airborne Laser Scanning' – also known as LiDAR – is a standard topographic surveying technique today. However, this method has previously never been used in Bangladesh. A great deal of public education work was therefore required, primarily to dispel fears of any danger from the laser operating

in the infrared spectrum. In addition, discussions with the participating authorities were also necessary to coordinate the in situ work for georeferencing activities, and to regulate the handling of the data, which is made available in digital form, exclusively.

The scanner installed in an aircraft or helicopter scans the ground surface with a laser beam in very tight grid. In Dhaka, an average scan rate of 7 points per square metre was used. The height of the terrain at each of these points is determined with high accuracy by measuring the time the laser beam needs to travel from the scanner to the ground surface and back. Complex technology for geo-referencing is required. This has been achieved by linking the laser scanner and the aerial camera with an inertial measurement unit as well as a system of GPS stations. Because the laser beam is not only reflected by the ground, but also by branches, leaves, roofs and other objects, the survey produces clouds of points of which only the ground points are used to derive the digital terrain model.

The data flights have been conducted in February 2009 by Hansa Luftbild on behalf of BGR, using an Mi-17 helicopter provided by the Bangladesh Air Force. Around 700 million laser ground points and 3750 digital orthophotos were recorded at the same time. This generated more than 2000 GB of data.

After processing the raw data, Hansa Luftbild supplied digital terrain models with a 25-centimetre grid, and digital orthophotos with a pixel resolution of 10 centimetres. This formed the primary dataset, which was further processed and evaluated with ENVI and ArcGIS in cooperation with the project partners from Bangladesh. The final result are maps of flood hazards, improved topographic maps for planning purposes to mitigate risks, as well as important information on potential building foundation problems.

Airborne laser scanning was used for the first time in Bangladesh as part of this project. It was therefore a milestone towards the implementation of state-of-the-art geomonitoring methods in Bangladesh. The project was financed by the German Ministry of Economic Cooperation and Development (BMZ).



◀ Oblique aerial view looking upstream along the Meghna River to the east of Dhaka. The area covered by the photo is shown as an angle in the satellite picture.

▶ The Landsat 5 satellite image recorded during the normal rainy season (26 October 2009), shows Dhaka's exposed position on the flood plain of three major rivers, the Brahmaputra, Padma (Ganges) and Meghna.



▼ Index map showing the position of the area represented in the satellite image.



## Ground penetrating radar measurements from an airship

**B**GR has successfully used an airship to carry out ground penetrating radar (GPR) surveys exploring the subsurface in 2009 and 2010, to our knowledge first-time worldwide. Airborne GPR was previously performed by airplanes or helicopters. The advantage of the new platform is that airship GPR measurements provide better data quality for the exploration of shallow geological structures.

The maiden survey was done by the hot air airship AS105GD, equipped for GPR measurements by GEFA-FLUG GmbH (Aachen) on behalf of BGR, for the profiling of peat deposits in Northern Germany. Filled with 3000 cubic metres of hot air and powered by a 65 HP two-stroke engine driving a four-blade propeller, the 41-m-long airship cruised along profile lines in an area near Bremerhaven for three days.

With a crew of two persons, speeds of up to 20 kilometres per hour at a height of around 40 metres, a large directive antenna suspended below the gondola transmitted and received electromagnetic pulses which the BGR scientists used to explore the underground georesources. Additional airship surveys were undertaken in 2010 over the Colbitz-Letzlinger Heide using the 5000 cubic metre version of type AS105GD/6.

The aim of the aero georadar surveys is the remote sensing of shallow geological structures, thus helping to safeguard the sustainable use of resources like minerals, soil and water. Up to the 1990s, airborne GPR was exclusively used to explore polar glaciers. BGR developed systems for geological applications since 2004. Such systems have to satisfy two important criteria: high resolution combined with sufficient penetration depth.

Two radar techniques are currently being used. BGR and RST (Radar System-Technik GmbH, Salem) developed a helicopter-borne stepped frequency radar (SFR). This SFR-GPR benefits from a selectable frequency range for optimum performance, presently 20 to 250 MHz. The powerful BGR-P30 pulse system operates as a classical time domain GPR in the lower frequency range (30 MHz). Penetration depths of this system range from tens of meters in sandy sediments to almost one kilometre in temperate glacier ice.

BGR's airborne GPR systems have been applied successfully from airplanes and helicopters. Besides the use for mapping polar ice the method produced good results in exploring a salt deposit in the Atacama Desert in Chile, mapping groundwater horizons in glacial deposits in Northern Germany, and surveying temperate glaciers in the Alps and Patagonia.

GPR from an airship has a major advantage compared to other airborne GPR surveys: The low speed allows for an increase of the along-track data density and thus improves the quality of the results for the mapping of geological structures.

Using a hot air airship may be also favourable from an economic point of view. The envelope made of high quality synthetic fabric and the gondola for up to six persons can be easily transported to the survey location in a car trailer. It takes just 30 minutes to get the hot air airship ready for take-off. However, GPR from an airship is feasible only at times of the day with little thermals and generally low winds.



*Airship with stepped frequency radar.*

## Analysis of micro-seismic activity for deep geothermal energy purposes

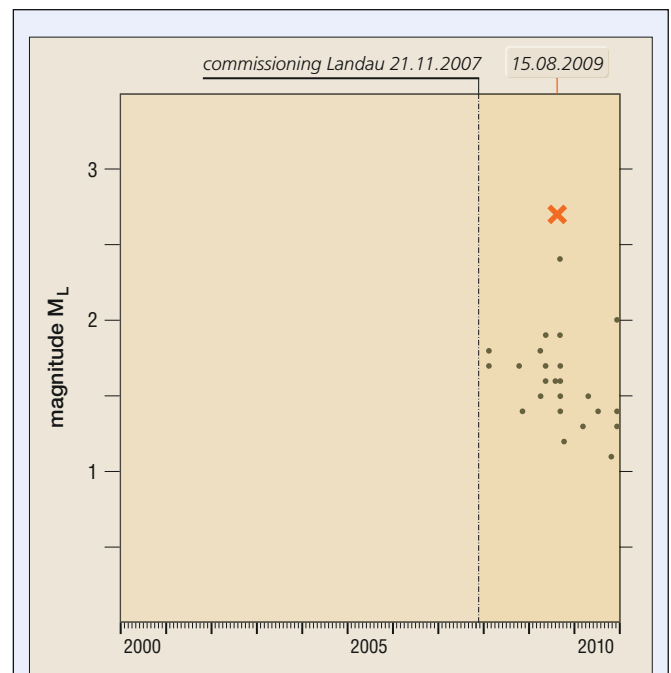
**S**afety aspects are of key significance for the public acceptance of energy generated using deep geothermal sources. BGR experts are now working together with scientists from German universities to jointly develop methods to limit micro-seismic events generated during the construction and operation of geothermal power plants.

Concepts to limit micro-seismic activity when exploiting deep underground geothermal systems to produce energy were developed as part of the joint project "Micro-seismic activity of geothermal systems" (MAGS). This involves measuring as accurately as possible and classifying the seismicity at German deep geothermal energy extraction sites. The second part of the project is calculating the seismic hazard. The hazard is then compared with the hazard potential of natural earthquakes at the same site. In addition, strategies are developed to avoid detectable seismicity during the hydraulic stimulation and permanent operation of geothermal power plants. The joint project also ultimately aims to improve the understanding of the processes involved in the generation of fluid-induced earthquakes. "One of the objectives of MAGS is to make data and methods available to the competent mining authorities, that helps them assess the potential hazard more accurately," explains Dr. Ulrich Wegler, BGR's co-ordinator for the joint project.

The MAGS project, financed for three years by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU), involves BGR, the Karlsruhe Institute of Technology, the Ludwig-Maximilian University in Munich, the Free University in Berlin, and the Technical University in Clausthal.

The growth in global energy demand is primarily satisfied today by fossil fuels. This is increasing the percentage of CO<sub>2</sub> in the earth's atmosphere with potential consequences for climate warming. Exploiting deep geothermal sources of energy is to make an important contribution in future to climate protection and reliable future energy supplies. The further expansion of this technique is jeopardised, however, by the occurrence of earthquakes in the vicinity of geothermal plants.

A local geothermal project was abandoned after it induced an earthquake in Basel (Switzerland). And detectable earthquakes which worried local inhabitants occurred in Germany in various places, including in the vicinity of the Landau geothermal plant in Rheinland-Palatinate. "An honest scientific assessment of whether this seismicity will always be in the form of micro-quakes or whether the seismic events could cause injury or damage to people and property is vital for the acceptance of deep geothermal energy exploitation projects," emphasises BGR physicist Ulrich Wegler.



Seismicity observed by the national earthquake observatories in Germany in the Landau area (01.01.2000 – 31.12.2010). The position of a point marks the time of each earthquake and the associated local magnitude  $M_L$  as a measure of its strength. The time the Landau geothermal power plant was commissioned on 21.11.2007 is also marked. The strongest of the earthquakes shown here occurred on 15.08.2009. The earthquake cluster is classified overall as induced by BÖNNEMANN et al. (2010).

From WEGLER (2011), modified after BÖNNEMANN et al. (2010)

## Airborne geophysical surveys along the German North Sea coast

**A**irborne geophysical surveys along the German North Sea coast were carried out between 2008 and 2010 by BGR as part of the "D-AERO" project. This project focused on saltwater and freshwater issues and was jointly conducted with the Leibniz Institute for Applied Geophysics (LIAG).

The problem of groundwater salinization is becoming more important in northern Germany within the context of groundwater extraction and treatment, and is a latent risk for the sustainable use of aquifers.

The intrusion of seawater is a natural source of coastal salinization. Onshore salinization is attributable to the leaching of salt domes close to the earth's surface, and the upwelling of deep saline water. These natural sources are exacerbated by man-made hydraulic activities such as groundwater extraction and drainage systems.

Other aspects are climate change and coastal protection. The North Sea islands, the Wadden Sea and the polder areas face further risks by the long-term rise in sea level and storm floods. These events will also have an impact on the distribution of saltwater in the subsurface and can also jeopardise aquifers used to produce potable water.

To survey the actual large-scale subsurface saltwater and freshwater distribution and to create a platform for future monitoring, the BGR helicopter was used equipped with an airborne sensor containing an electromagnetic transmitter and receiver system.

The measurements collected by the helicopter-borne electromagnetic (HEM) surveys reveal the electrical conductivity of the sediments down to depths of the upper hundred metres. This data is very important for hydro-geological interpretation as the electrical conductivity reveals the distribution of sandy and clayey sediments as well as salinization zones and freshwater occurrences. The conductivity models derived are displayed as resistivity maps at several depths and vertical cross-sections along the flight-lines.

In addition to the electromagnetic measurements, the earth's magnetic field and the natural radiation of the earth's surface (gamma radiation) are simultaneously recorded. These measurements can be used to interpret the structure of the earth's crust and the mineral composition of the shallowest soil layers, respectively.

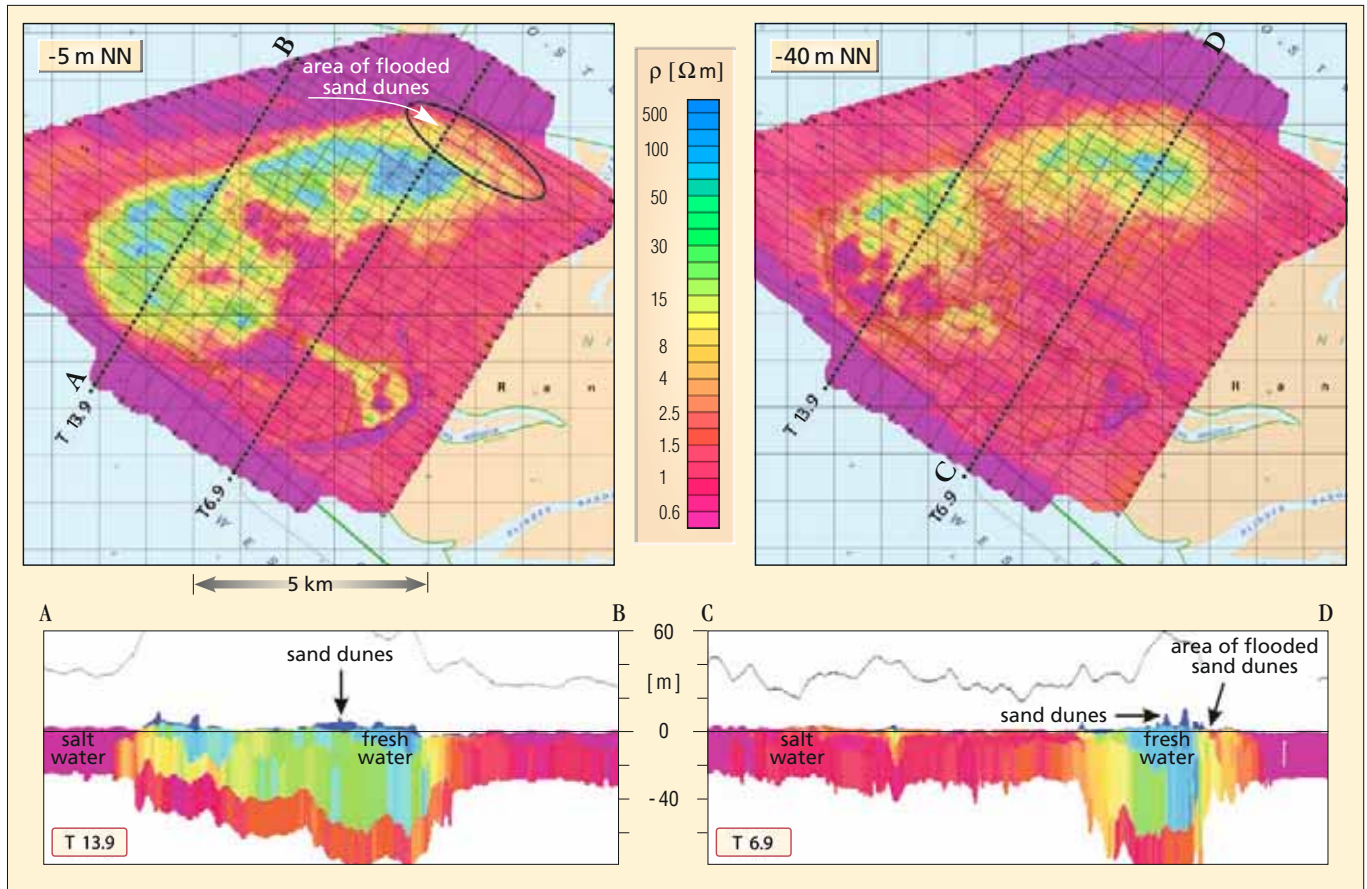
The joint interpretation of this data supports three-dimensional modelling of the subsurface and is also used as basis for planning and activities in many environmental and economic disciplines, e.g. for regional planning, development of water

utilisation and water protection concepts. The airborne data sets will be accessible via LIAG's geophysics information system ([www.geophysics-database.de](http://www.geophysics-database.de)).



*BGR helicopter towing an electromagnetic sensor over the North Sea.*

## Investigation of the freshwater lenses of the North Sea island of Borkum



Resistivity maps at 5 metres below sea level and 40 metres below sea level, and vertical resistivity sections along flight-lines T13.9 and T6.9. The first layer represents the rather dry dune sands above the groundwater table (dark blue) and the lowest layer represents saltwater-saturated sediments (red) below the freshwater lens (blue-green).

## Maiden voyage of a new marine electromagnetic surveying system

**D**uring a cruise on 'RV Poseidon' in the Black Sea in December 2010, the BGR working group 'Marine Electromagnetics' tested a new controlled source electromagnetic system (CSEM) to explore the electrical resistivity of shallow marine sediments. The surveying system was developed by BGR over the last two years as part of the German project SUGAR (Submarine gas hydrate deposits: exploration, exploitation and transport).

Gas hydrates are solid, frozen compounds consisting of methane and water, which are formed under high pressure and low temperatures in the seafloor along most continental margins, in permafrost and in deep sea regions. They store enormous quantities of methane gas and could be utilized in future as a major global source of energy. CSEM methods are particularly good at confirming the presence of significant gas hydrate deposits on the basis of their electrical properties. Gas hydrates are poor electrical conductors, especially when compared to the highly conductive saline pore water. CSEM has proven to be useful for reservoir characterisation in offshore oil and gas exploration complementing seismic methods.

HYDRA, the new BGR CSEM system is particularly designed to resolve the gas hydrate stability zone which stretches from the seafloor to a few hundred metres below. It consists of an electrical transmitter dipole and several receiver dipoles modularly connected with an one kilometre data cable. The whole system is towed along profiles on the seabed behind the research ship.

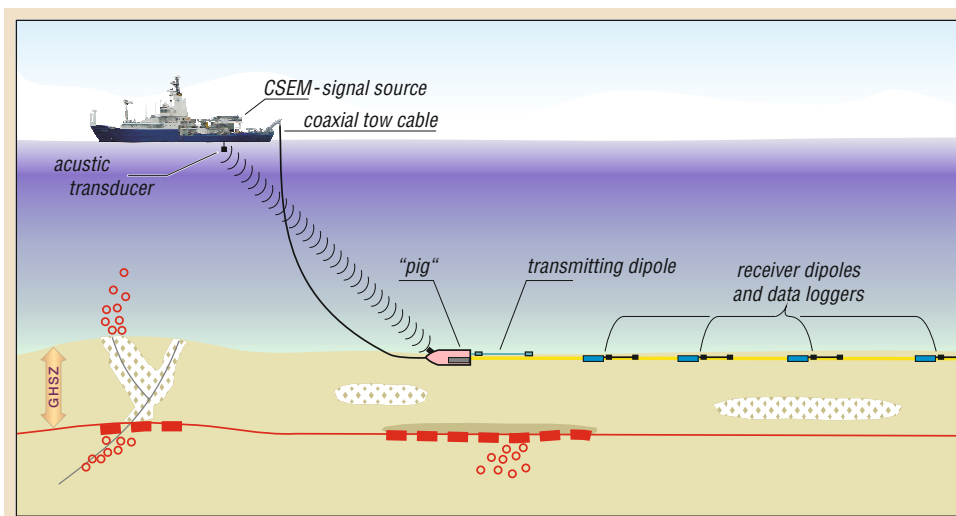
The data cable is used for synchronisation and communication. The seafloor system is connected to the ship via the coaxial deep tow cable and is towed along the seafloor along the surveying lines. The rectangular transmitter signal is generated on board with a CSEM signal source, and sent via the coaxial tow cable to the transmitter dipole on the seafloor. Electromagnetic fields propagate by diffusion in the sediment structure and are picked up by the receiver dipoles. The travel times and the shape of the received signals resolve the conductivity structure of the seafloor.



In December 2010, the complete system was first time tested during a one-week expedition supervised by IfM-Geomar (Kiel) on 'RV Poseidon' over gas hydrate deposits in the Danube delta offshore Romania. The system was safely deployed and recovered along three profiles, all components of the system recorded data and worked reliably. However, a first quality control of the data showed the data are distorted by inductive noise generated by the transmitter dipole which propagates along the data cable to the following receivers. This problem could not be detected during previous laboratory tests and needs to be addressed by improved shielding and filtering.





Deploying the CSEM system on the 'RV Poseidon' in the Black Sea. The receiver dipoles are attached to pressure cylinders housing the analogue electronics and the data loggers to record the signals.





 gas hydrate  
 free gas

 BSR – bottom simulating reflector  
 GHSZ – gas hydrate stability zone

The configuration of **HYDRA**, a new CSEM logging system developed by BGR for submarine gas hydrate exploration. The seafloor array consists of the 'pig', a heavy plough that carries sensors for seawater conductivity and acoustic ranging, the transmitter dipole and four receiver dipoles. The synchronisation and communication is handled by the data cable. The seafloor array is connected to the ship via the coaxial tow cable and is towed along the seafloor along the surveying lines. A rectangular transmitter signal is generated on board and sent via the coaxial tow cable to the transmitter dipole. Electromagnetic fields propagate away in the seafloor and are picked up by the receiver dipoles. The travel times and the shape of the received signals resolve the conductivity structure of the seafloor.

## BGR harnesses synergies with the German Army Geoinformation Bureau

BGR develops surveying technologies and verification methods to explore for georesources, e.g. groundwater deposits, and to monitor georisks. The success of the German army's foreign operations significantly depends on the effectivity and operability of such methods and the quality of detailed knowledge about the natural resources available in the area. The most frequently required information concerns drinking water deposits, the availability of natural construction materials, as well as the structural safety and ability to drive on ground surfaces. Modern exploration methods such as remote sensing are used for this purpose, or the relevant information is sought in the comprehensive archives of BGR and the German Army Geoinformation Bureau (AGeoBw).

To benefit better from synergies in future when implementing new techniques or procuring information on operations zones, BGR President Prof. Dr. Hans-Joachim Kuempel and Brigadier General Walter Schmidt-Bleker, head of the Geoinformation Service and director of the German Army Geoinformation Bureau, signed a new cooperation agreement at the first meeting of the AGeoBw's scientific committee. The main focus of the agreement is the broader thematically organised provision of geoinformation. This will assist the work of both institutions when tasks such as engineering-geological site investigations, groundwater issues, and avalanche risks in poorly accessible regions are involved.

Cooperation agreements are important elements for both research institutions for the scientific analysis of urgent problems.

In the case of BGR, this concerns aspects such as mineral and energy georesources, drinking water supplies, and risk analysis. Cooperating and making use of synergies when advising German ministries, and undertaking long-term project work to support and satisfy contractual obligations (such as monitoring the nuclear test ban treaty), enables the available expertise to be optimally used, and results to be made available faster and more cost-effectively.



*Brigadier General Walter Schmidt-Bleker (left), head of the Geoinformation Service and director of the German Army Geoinformation Bureau, and Prof. Dr. Hans-Joachim Kuempel, President of the BGR, signing the cooperation agreement.*

## BGR granted patent for a new type of vector gradient magnetometer

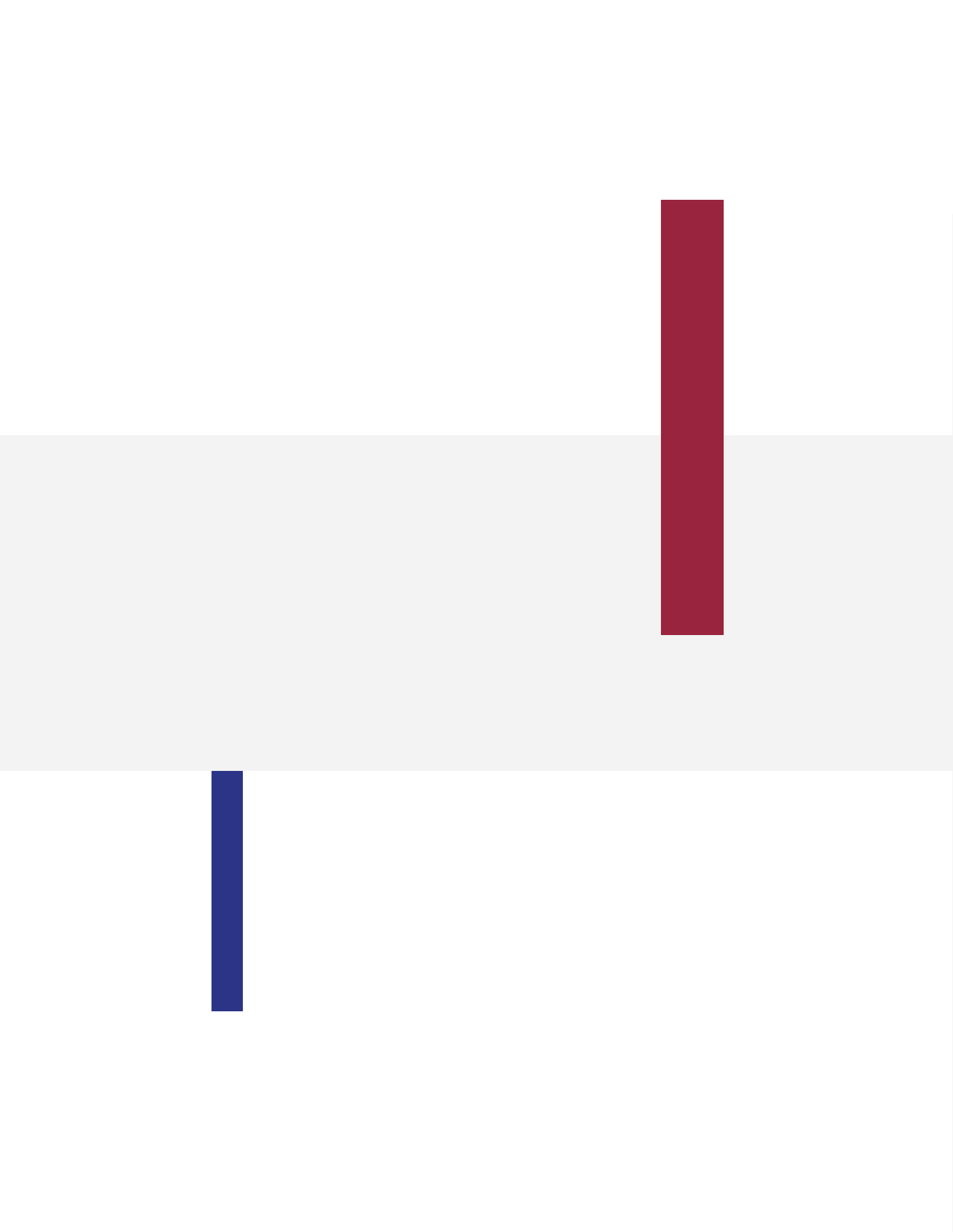
BGR developed and patented a new method for logging spatial changes in the earth's magnetic field. Unlike previous instruments, the new marine-compatible 'vector gradient magnetometer' developed by BGR is also able to measure the direction of the earth's magnetic field. The BGR invention registered at the German patent and trademark office in Munich under number 10 2006 059 204 opens up completely new possibilities for geomagnetic surveying.

How does the new vector gradient magnetometer function at sea? The vector magnetometer instruments are lowered into the water from a research vessel at the end of a surveying cable. To ensure that the magnetic field measurements are not affected by the research ship's own field caused by its steel hull, the magnetometer has to be towed 850 metres behind the vessel. The steel cable also supplies power to the tools and transmits the data back to the ship. The vector gradient magnetometer can operate at slow surveying speeds in parallel to seismic surveys, as well as at faster speeds when the ship is carrying out low resolution water depth measurements.

# Outlook

**T**he large volume of available geodata, and the willingness to make it available to a larger extent to third parties in future, are important prerequisites for national and international cooperation. BGR will therefore continue to work intensively on the standardisation and inter-operabilisation of the existing geodata; centrally archive all GIS data, e.g. covering geology, pedology, hydrogeology and natural resources; and make selected products available to the general public.

In the case of the digital map data, the technical and disciplinary adaptation will be implemented according to the specifications defined by INSPIRE and/or the Geodata Accessibility Act (GeoZG). The needs of different user groups in industry, science and administration will be taken into consideration in the product configuration.



# *Comprehensive Nuclear Test Ban Treaty; Risk Analysis*



# Introduction

**M**ore than 2000 nuclear weapon tests have been carried out around the world since 1945. The Federal government is committed to the global ban on such tests. Germany therefore became a signatory back in 1996 to the Comprehensive Test Ban Treaty (CTBT) and ratified it in 1998. To monitor compliance with the CTBT, a global monitoring system is used to collect measurement data derived from seismological, infrasound, hydro-acoustic and radionuclide monitoring systems, which is all gathered by the CTBT organisation in Vienna. BGR plays a key role in satisfying Germany's technical and scientific obligations associated with the CTBT. BGR operates seismological and infrasound stations in Germany and the Antarctic, runs the national CTBT data centre and advises the Federal government on all scientific issues concerning the CTBT, also including incidents such as the nuclear weapons tests conducted by North Korea in 2006 and 2009.

BGR operates the seismological central observatory to monitor global earthquake activity and satisfy its responsibilities as a national earthquake service. This network includes ultra-modern earthquake monitoring stations distributed throughout Germany, and a data centre operated in close cooperation with the earthquake services of the Federal states. The general public can therefore be provided with rapid and detailed information whenever an earthquake occurs. The large database built up by BGR in this way, combined with the historical earthquake catalogues, enables BGR to estimate the seismic risks at national and international locations.

## Mining damage investigations in Staßfurt

**A**s part of the responsibilities bundled in the department "Underground storages and economic zones – The safety of underground cavities", BGR was involved from 2006 to 2010 in the joint research project "Dynamics of drowned or flooded salt mines and their overburden" financed by the German Ministry of Education and Research (BMBF).

Hundreds of industrial buildings and houses were demolished in the last 110 years as a result of the mine damage caused by potash mining in Staßfurt (Sachsen-Anhalt). 40 years ago, the district council in Magdeburg responsible for Staßfurt classified large parts of the town as "zones of latent collapse risk". This made investments in building projects impossible until this day. The city was therefore scarred for a long time by old unrenovated buildings and large abandoned industrial sites. The results of the research project are aimed at sustainably assisting the development of Staßfurt as a location for housing and industry, and to provide a future perspective for towns suffering from similar mining damage.

For this purpose, the research association has carried out research on those processes in particular which led to the subsidence or cave-ins around the former salt mines on the Staßfurt anticline and those which can also influence the stability of the subsurface in future. The research methods required to investigate these processes had to be adapted and further developed. In line with BGR's scientific specialisation, its work concentrated on the geological, salt-geology, mining and geophysical aspects.

BGR's job was also to co-ordinate the research association project which involved ten partners. These included the Leibniz Institute for Applied Geophysics Hannover (LIAG), the Technical University Clausthal, the Brandenburg University at Cottbus (BTU), the Helmholtz Centre Dresden-Rossendorf (HZDR) Research Institute in Leipzig, the Johannes-Gutenberg University in Mainz, IHU Geologie und Analytik GmbH Stendal, DHI-WASY GmbH, Berlin, and K-UTEC Salt Technologies AG, Sondershausen. The Sachsen-Anhalt State Office for Mining and Geology (LAGB) is an associate member of the research association.

### Geology and mining: 3D models, boreholes, geophysics

The key elements required for implementing the project included the 3D models prepared by BGR on the mine shafts and underground workings, and the geology of the northeast and south-western flank of the Staßfurt salt anticline. The models are particularly helpful in understanding and analysing the complex mine structures and the geological situation in Staßfurt. This involved creating 3D models using the digitised

mine plans of the Staßfurt mines provided by LAGB, and researched archive data. In addition, three deep boreholes were drilled, and numerous old boreholes were reviewed. This data and the data from shallow boreholes drilled for hydrogeological exploration purposes, LIAG's reflection seismic surveys, and BGR's aero and ground geophysics, were also input into the models (Figure 1).

BGR makes a major contribution to exploring and evaluating hydrogeological, hydraulic and geomechanical properties by using very modern aero and ground geophysical methods.

Old and new seismic stations installed throughout the urban part of Staßfurt were set up on the surface to detect the seismic signals generated within the underground workings, even though the signals only differ very slightly from the background noise in the city. Nano-seismic monitoring is therefore implemented in cooperation with the University of Stuttgart to improve the results of the seismic detection. This now makes it possible to determine the order of magnitude of the small signals. And thanks to the 3-component geophone systems installed in the new deep boreholes, the detection sensitivity has been considerably improved so that even the smallest signals generated by collapse processes within the underground workings can now be reliably detected.

Monitoring the changes in the gravity field over the last 30 years is now possible by combining the gravimetric measurements recorded from 1977 to 1981 over the underground workings in the Staßfurt subsidence zone, with numerous new measurement points. The new map reveals gravimetrically "compacted" areas within the subsidence zone which are therefore no longer considered to be at risk of caving in (Fig. 2). The "unconsolidated" zones marked in red indicate areas where the subsidence processes within the cover rock have not yet finished. Karst in the cap rock of the Staßfurt salt anticline was confirmed in the south of Staßfurt by a combination of gravimetry and high resolution geoelectric surveys.

Anomalies etc. can be investigated in detail using ground geophysical surveys and high-resolution geoelectrics and transient electromagnetics (TEM) to reveal hidden structures and groundwater upwelling zones.

### Aerogeophysical methods

Full-coverage helicopter electromagnetics (HEM) over the whole Staßfurt-Egeln salt anticline makes it possible to describe the groundwater properties and the geology in detail over the survey area measuring approx. 470 km<sup>2</sup>. When enough data is available, detailed geological cross-sections can be generated when the aforementioned information is combined with the 3D models of the geology and the underground workings (Fig. 3).

The airborne laser measurements of the earth's surface (LIDAR) were used to derive a terrain model to interpret geomorphological phenomena such as subsidence and lineations. The LIDAR interpretations are much richer in detail than the vertical photographs and reveal the structure of the subsurface in a way which is largely hidden from surveys using the visible spectrum.

## Project findings

Mining in Staßfurt has seriously held back the development of the city. The research association has investigated and analysed the current status of the mines within the urban area using geological, geophysical, geochemical, and hydrogeological methods and models. The results of this analysis reveal no signs of any continuing collapse processes in the deep-lying parts of the underground workings, and also no indications of any risk of a cave in at the surface. In the higher parts of the

underground workings, however, the highly dynamic hydraulic system continues to have the potential to flow through the workings and dissolve evaporite rocks in the Leine and Staßfurt Series. This is the cause of the continuing subsidence in the former mine subsidence zone. Another finding is that the deep boreholes did not encounter any open underground cavities.

The competent state institution now has the arguments it requires to reduce the size of the "zones of latent collapse risk" and open up the derelict industrial sites and the damaged parts of the inner city for redevelopment. The suite of instruments tested in Staßfurt can now also be used in other regions suffering from similar mine damage.

The results of the work of all of the project partners was presented and published from 18 to 20 November 2010 at the final conference "Staßfurt 2010 – Detection, analysis, evaluation and forecasts for the future development of the post-mining damages".

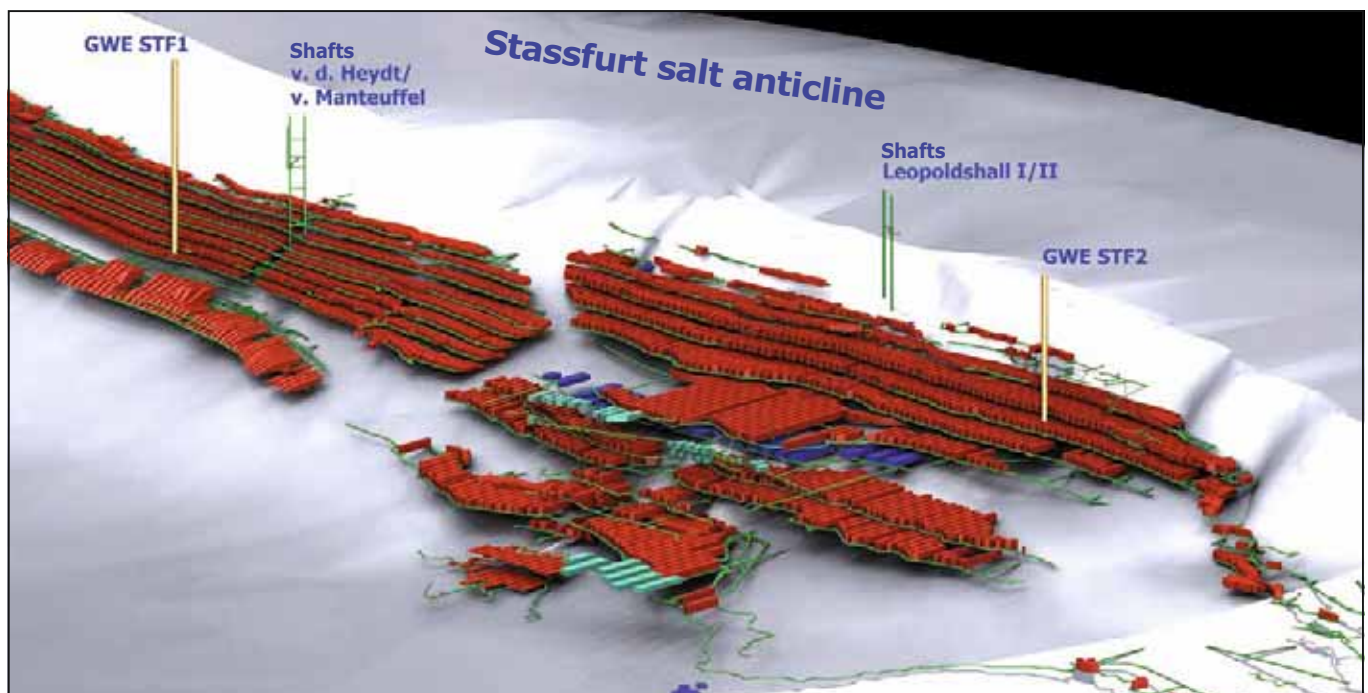


Fig. 1: 3D map of the underground workings "v.d.Heydt/v. Manteuffel" and "Leopoldshall III" showing their shafts and drifts (green), the extraction chambers in the potash deposit (red) and in the Leine rock salt (turquoise), as well as the so-called waste raises in the Zechstein rock salt (dark blue).

(Source: BGR/GGL)



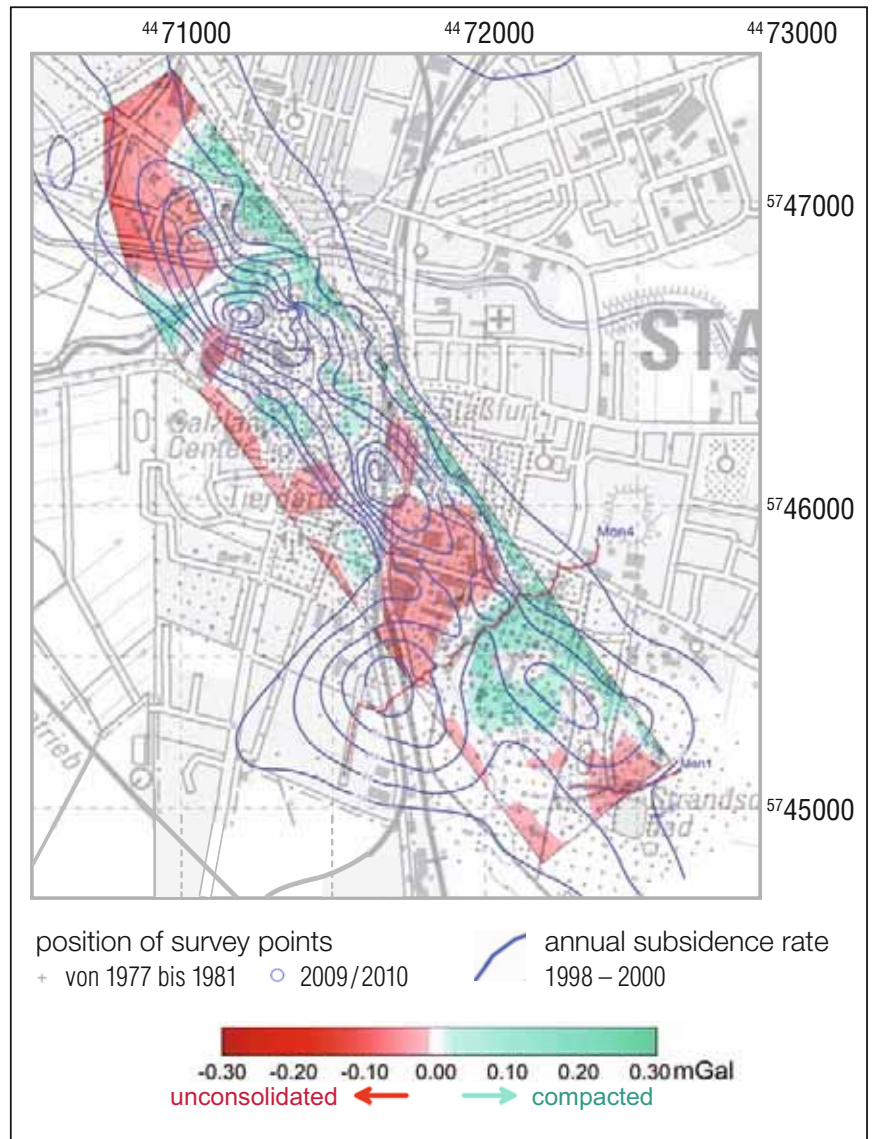


Fig. 2: Map of the difference in gravity (new vs. old surveys). Green areas are considered to be gravimetrically "compacted", red areas are still considered to be "unconsolidated".  
 (Source: BGR/GGL)

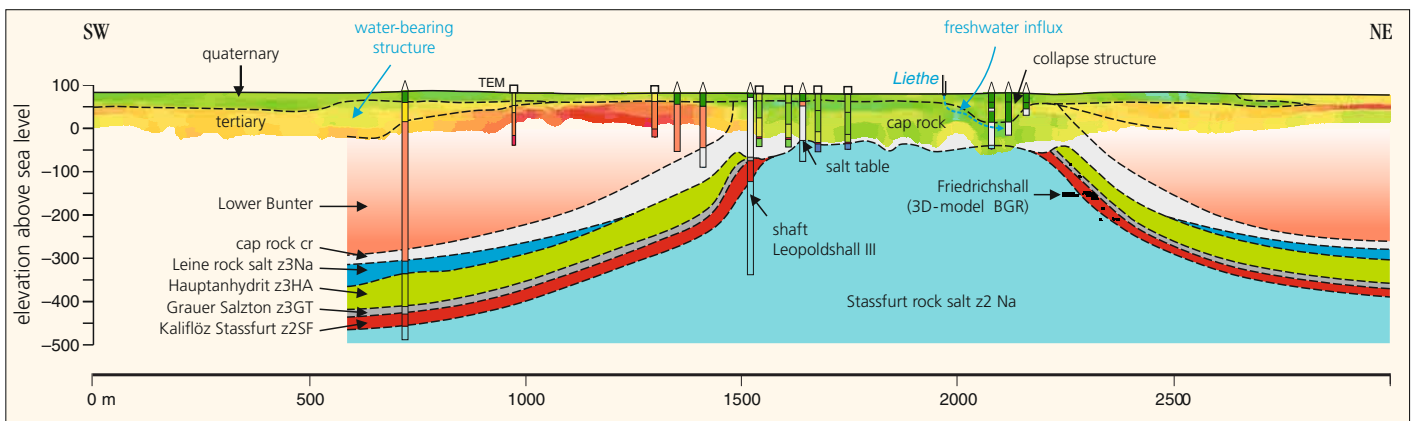


Fig. 3: cross-section in the southern part of the Staßfurt-Egeln-Saltartictline. Sketch derives from the data produced by the helicopter and transient electromagnetic surveys, the boreholes, as well as the Staßfurt 3D geological and underground workings models.

(Source: BGR)

## Evaluation of risk exposure to natural hazards in Central America

Central America is one of the most disaster prone regions of the world and frequently affected by catastrophes triggered by earthquakes, volcanic eruptions and the periodically returning floods and landslides during the hurricane season. Besides the direct consequences for the existence of the affected population these natural events pose an enormous threat to the regional economic development of the countries and the struggle for poverty reduction. In general, increasing disaster risk is a global trend due to the growing exposure of population and assets in high risk areas. Therefore, a 'more effective integration of disaster risk consideration into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction' (UNISDR 2008) has been fixed in the Hyogo framework for action as a strategic goal for the future, in order to achieve a 'substantial reduction of disaster losses, in lives and in the social, economic and environmental assets'.

In the scope of international development cooperation, the demand for effective integration of risk sensitive spatial planning as a key activity for disaster risk reduction (DRR) has decisive impact as it requires holistic and interdisciplinary operation methods. From the geoscientific point of view the activities comprise not only scientific and technical consulting like hazard or vulnerability analysis, but include also advisory services in the application and implementation of the results in the disaster risk management. In this context, it is essential that the geoscientific contribution to spatial planning is based on validated and reproducible datasets and methods which preferably cover the spatial distribution of all kinds of risks which might affect a certain region. In doing so, the interdisciplinary discussion with spatial planners and civil protection agencies implies a comprehensive and understandable presentation of the information.

As a result, the interdisciplinary assessment and discussion of risks provides the local authorities, decision makers and politicians with the necessary elements and tools for a sustainable spatial planning in local or regional scale and ultimately may lead to the implementation of standard guidelines or legal regulations.

### Analysis of Georisk-Exposition

In the framework of the regional technical cooperation project 'Mitigation of Georisks in Central America' (2002-2010), the BGR assisted the mandated Federal agencies of the project countries Nicaragua, El Salvador, Guatemala and Honduras in the recording, assessment and monitoring of geological hazards and the realization of respective georisk analyses. The project fostered social and political awareness rising

regarding disaster risk and aimed at the integration of georisk assessments into the regional spatial planning and disaster prevention.

The regional perspective had been considered as the natural disasters affecting Central America like volcanic eruptions, destructive earthquakes or hurricanes are regional phenomena which often affect several countries or the whole region. Therefore, these events require regional and transnational planning tools and mitigation strategies which should be based on respective regional datasets.

In this context the project performed comprehensive nationwide and regional georisk exposition analyses for the four countries which were based on a uniform methodology and comparable, harmonized data sets. The main focus was placed on the development of a practicable and reproducible standard methodology which enables the elaboration of comparable georisk information and their implementation in spatial planning procedures and for disaster prevention. A regional comparability was ensured by using solely scientific based official datasets and the risk mapping was based on the administrative unit 'Municipio'. For that purpose a special application called 'Central American Risk Analysis (CARA) – GIS' was developed, whose methodology was based on a similar BGR application, previously applied in Indonesia.

The CARA-GIS tool enables the analysis, mapping and visualization of the risk exposition for the four hazards/susceptibilities earthquakes, volcanic eruptions (ash fall), landslides and flooding in the national and regional scale. As indicators of vulnerability, the exposed population, exposed infrastructure and the exposed economic potential were investigated. Due to the open architecture of the application, additional hazards easily may be integrated and the working scale is unlimited, i.e. solely depends on the scale of the input data.

Following the well known correlation  $Risk = Hazard \times V$  vulnerability, the spatial distribution of the respective hazard zones and the regarded elements at risk were related to each other and the resulting risk exposition was determined. The system offers the analysis of single hazards as much as multi-hazard analysis, i.e. different scenarios of possible and contemporaneously occurring events like landslides and flooding triggered by intense rainfall can be analyzed. Only this spatial relation between hazard and vulnerability and the incorporation of multi-risk analysis creates a powerful instrument for a preventive spatial planning and risk reduction.

### Results

The development and implementation of CARA-GIS performed a regional standard for the analysis of risk exposition,

which may also be applied in the neighbouring countries of the project area. For this the definition of regionally applicable methods for hazard analysis and the GIS-based processing of available datasets (including metadata) was a basic requirement.

By now there exists a qualified dataset of the existing information of baseline, hazard and vulnerability data for each of the four counterpart countries which are directly comparable due to a fixed architecture of the respective spatial and attributive databases. Updating of datasets or incorporation of new information may be performed separately by each country.

As a result of the comprehensive risk exposure assessment for Central America using CARA-GIS a set of representative samples of thematic risk exposure maps and accompanying statistics have been elaborated representing both single and multi-hazard risk exposure scenarios in the context of disaster risk management.

Of outstanding importance are analyses of probable losses and damages in case of a future destructive natural event, which have been deduced from land use data and economic statistics (Economic Commission for Latin America and the Caribbean, ECLAC) for different production sectors (agriculture, wholesale and retail sale, construction etc.). This information allows for pre-investment studies and is of major importance for the insurance business.

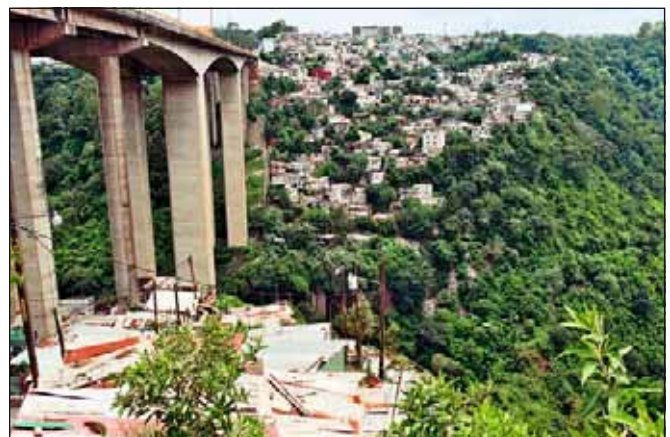
Comparative mapping of risk exposition on the scale of Municipios allows a nation- and regionwide comparison of the considered administrative units. This kind of presentation permits a quick overview of the general situation, highlights the hot spots which require further investigation and therefore supports a fair, transparent and demand-oriented allocation of resources for mitigation measures in highly vulnerable zones.

The methodological framework and the risk exposure assessment results for Central America including the used baseline information (e.g. administrative divisions maps, land use maps, infrastructure maps), hazard/susceptibility maps and vulnerability/capacity considerations have been published in a 'Guidebook for Assessing Risk Exposure to Natural Hazards in Central America: El Salvador, Guatemala, Honduras and Nicaragua' (BALZER et al., 2010) focusing on the Disaster Risk Management context. The guidebook is available in Spanish and English as well.

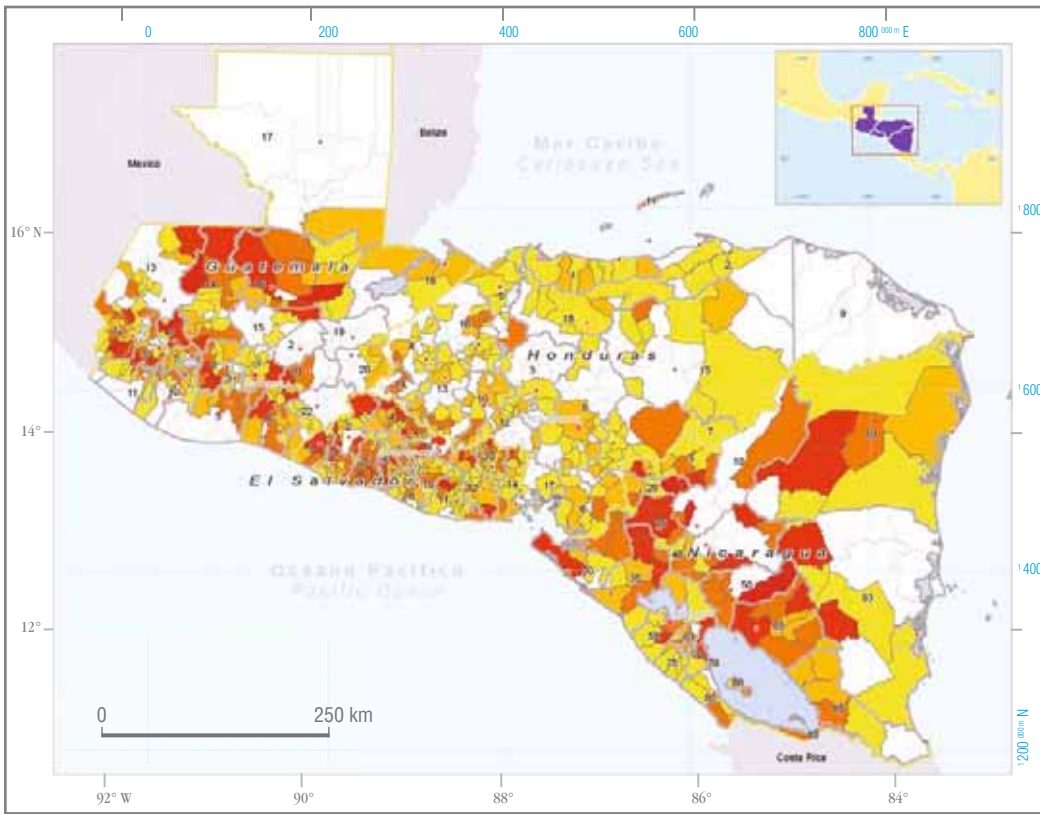
The CARA-GIS application and the accompanying products have been handed over to the project partners. Counterpart personnel, composed of GIS experts and planning officers, have been trained. The maps and statistics are therefore available for the different scientific-technical agencies, the land use planning authorities and the civil protection organisations; in addition the project homepage offers the data for the public.



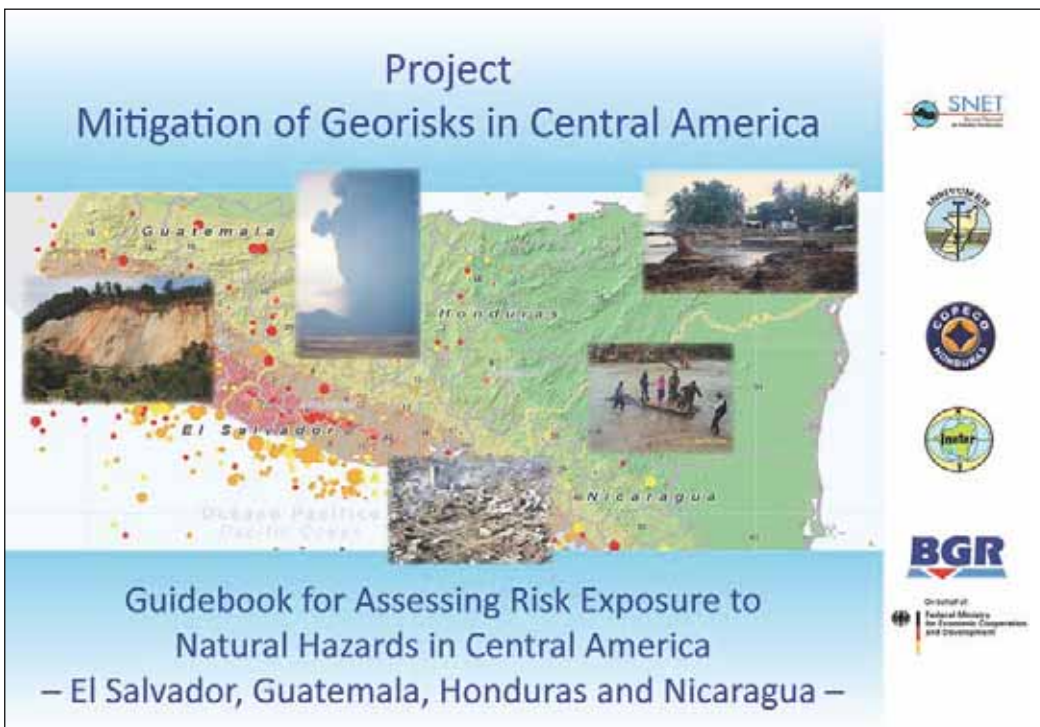
*Active volcanism in Nicaragua: periodic eruptions of Concepción volcano (Island of Ometepe) require risk-sensitive planning strategies.*



*Guatemala City: unplanned housing estates without construction standards on landslide-prone slopes represent high risk zones.*



Example of a risk map for Central America: The map displays the exposure of road length per municipio (in km) with respect to a high or very high hazard potential of mass movements (landslides); the colour-coding highlights the exposed road length (from yellow < 5 km to dark red > 50 km; white areas mean either no exposed roads or no threat in the regarded municipality).



Front page of the "Guide book for Assessing Risk Exposure to Natural Hazards in Central America – El Salvador, Guatemala, Honduras and Nicaragua".

## BGR infrasound station in the Antarctic restarts its nuclear test monitoring activities

BGR has been monitoring compliance with the Comprehensive Test Ban Treaty (CTBT) on behalf of the Federal Republic of Germany since 1996. In addition to its stations in the Bavarian Forest, BGR also satisfies its treaty obligations by operating monitoring systems in the Antarctic. At the beginning of 2009, the polar infrasound station had to relocate to another site. It is now back on duty in the international CTBT monitoring network.

The Antarctic monitoring station had to move location because of the construction of the new Neumayer III research station. When Neumayer II was abandoned, BGR was no longer able to operate infrasound station IS27 at its original location. It originally began monitoring operations here in 2003 as an integral part of the international monitoring system, and registered atmospheric pressure waves around the clock with a reliability of more than 99 per cent.

The Neumayer III Antarctic research station operated throughout the year by the Alfred-Wegener Institute (AWI) was officially commissioned around 6 kilometres south of Neumayer II on 20 February 2009. Before the opening ceremony, the two staff members of BGR department "CTBT, seismological central observatory" who travelled to the Antarctic especially for the purpose, had a great deal of work to do to move IS27 to the new research station.

The field stations now upgraded with WLAN equipment for data transmission were re-erected around 2.5 kilometres to the southwest of Neumayer III. 10 kilometres of cable had to be re-laid to supply power to the monitoring points which cover an area with a diameter of 1 kilometre. The central data recording system moved into the new computing centre at Neumayer III. The central data acquisition unit has to collect the continually registered data from all nine field stations, totalling around 20 values per second, and to guarantee complete data transmission of all of this data to the international data centre of the CTBT organisation in Vienna, as well as to BGR.

Stormy weather delayed the outdoor work by almost two weeks. This means that there was less than six weeks between the topping out ceremony and completion of the new station building. The new observatories were installed by each of the scientific departments in parallel to the construction staff working under great time pressure to complete the interior furnishings of the building. All of the work on IS27 was completed on time thanks to the good cooperation with the logistics team and the AWI geophysics staff.

The day then finally arrived on 11 September 2009: the CTBT organisation certification group officially confirmed the successful revalidation. Since then, IS27 has again been one of the three monitoring stations operated by BGR and forms a reliable component in the international monitoring system.



*BGR President Prof. Dr. Hans-Joachim Kuempel at the official commissioning*

## Viennese diplomats visit the monitoring station in the Bavarian Forest

On 27 and 28 May 2010, around 40 ambassadors and representatives from permanent national representatives at the international organisations in Vienna visited the stations monitoring the international Comprehensive Test Ban Treaty, and operated by BGR in the Bavarian Forest.

The CTBTO (Preparatory Commission for the Nuclear Test Ban Treaty Bureau) facilities near Freyung, consist of a seismological station (GERES) and one infrasound station. Both are part of the network of 337 monitoring stations currently being constructed as part of the commission's duty to monitor compliance with the Comprehensive Test Ban Treaty in future. The seismic station operated by BGR is one of the CTBTO installations which registered the nuclear tests conducted by North Korea in 2006 and 2009.

GERES is one of the first seismological stations in Europe to monitor the Comprehensive Test Ban Treaty. It lies adjacent to the infrasound station also operated by BGR, which is used to detect extremely low frequency sound waves in the atmosphere.

When Germany became a signatory to the Comprehensive Test Ban Treaty in 1996, BGR was officially given the task of running a national data centre (NDC) within the international monitoring system. In addition to the representatives of the permanent representatives at the United Nations in Vienna, the media also used the opportunity to send staff to participate in the tour.

## Global earthquake data 2009 and 2010

Date	Time	Strength [magnitude]	Location	Comments
25 May 2009	02:54 (CEST)	4.7	North Korea	2nd underground nuclear weapon test
05 May 2009	03:39 (CEST) 01:39 (UTC)	4.5	Black Forest	<b>Earthquake</b> The epicentre lay 5 km east of Kandern and 5 km northwest of Schopfheim near the village of Tegernau (Baden-Württemberg).
29 September 2009	19:48 (CEST) 17:48 (UTC)	8.2	Samoa	<b>Earthquake in the Pacific near the Samoa islands</b> This subsea earthquake generated a tsunami which led to destruction and numerous fatalities on the Samoan islands according to the initial press reports.
30 September 2009	12:16 (CEST) 10:16 (UTC)	7.9	Sumatra	<b>Earthquake in the Indian Ocean directly off the west coast of Sumatra</b> According to the first press reports, there were over 100 fatalities, and numerous houses collapsed, especially in the coastal town of Padang. It was assumed that the ultimate number of fatalities would actually be considerably higher.
12 January 2010	22:53 (CET) 21:53 (UTC)	7.1	Haiti	<b>Earthquake in the Caribbean on Haiti near the capital Port-au-Prince</b> According to the first press reports, this caused a large number of fatalities and injuries, and the collapse of numerous buildings. It is assumed that the figures for the number of victims will rise considerably in the following days.
27 January 2010	07:34 (CET) 06:34 (UTC)	8.8	Chile	<b>Earthquake offshore around 10 kilometres from the Chilean coast</b> The epicentre lay around 300 kilometres southwest of the capital Santiago. Earthquakes of this magnitude can cause tsunamis. Considerable damage was expected in the towns along the coast.
08 March 2010	03:32 (CET) 02:32 (UTC)	5.9	Turkey	<b>Earthquake in eastern Turkey</b> The epicentre was around 40 km to the west of Bingöl. The hypocentre of the earthquake was only a few kilometres under the surface. This means that considerable damage is expected in the vicinity of the epicentre.
13 April 2010	07:49 (local time) 23:49 (UTC)	6.9	Tibet	<b>Earthquake on the Tibetan plateau to the south of the province of Qinghai</b> According to the first press reports, there were more than 400 fatalities and numerous houses collapsed. It can be expected that there will be a considerable rise in the figures for the number of victims.

# Outlook

The second nuclear weapons test conducted by North Korea in May 2009 was a good test of the global system to monitor compliance with the Comprehensive Test Ban Treaty – the test was passed with flying colours. The German CTBT data centre managed by BGR was able to reliably inform the German government and the general public only a few hours after the test that the sensors had not picked up an earthquake but an explosion equivalent to around 10,000 tonnes of TNT.

The construction of the new German Neumayer station in the Antarctic also meant that the infrasound station operated by BGR as part of the CTBT network needed to be relocated. Within the remarkably short time of 54 days, BGR experts completed the relocation, including re-certification by the international CTBT authority in Vienna.

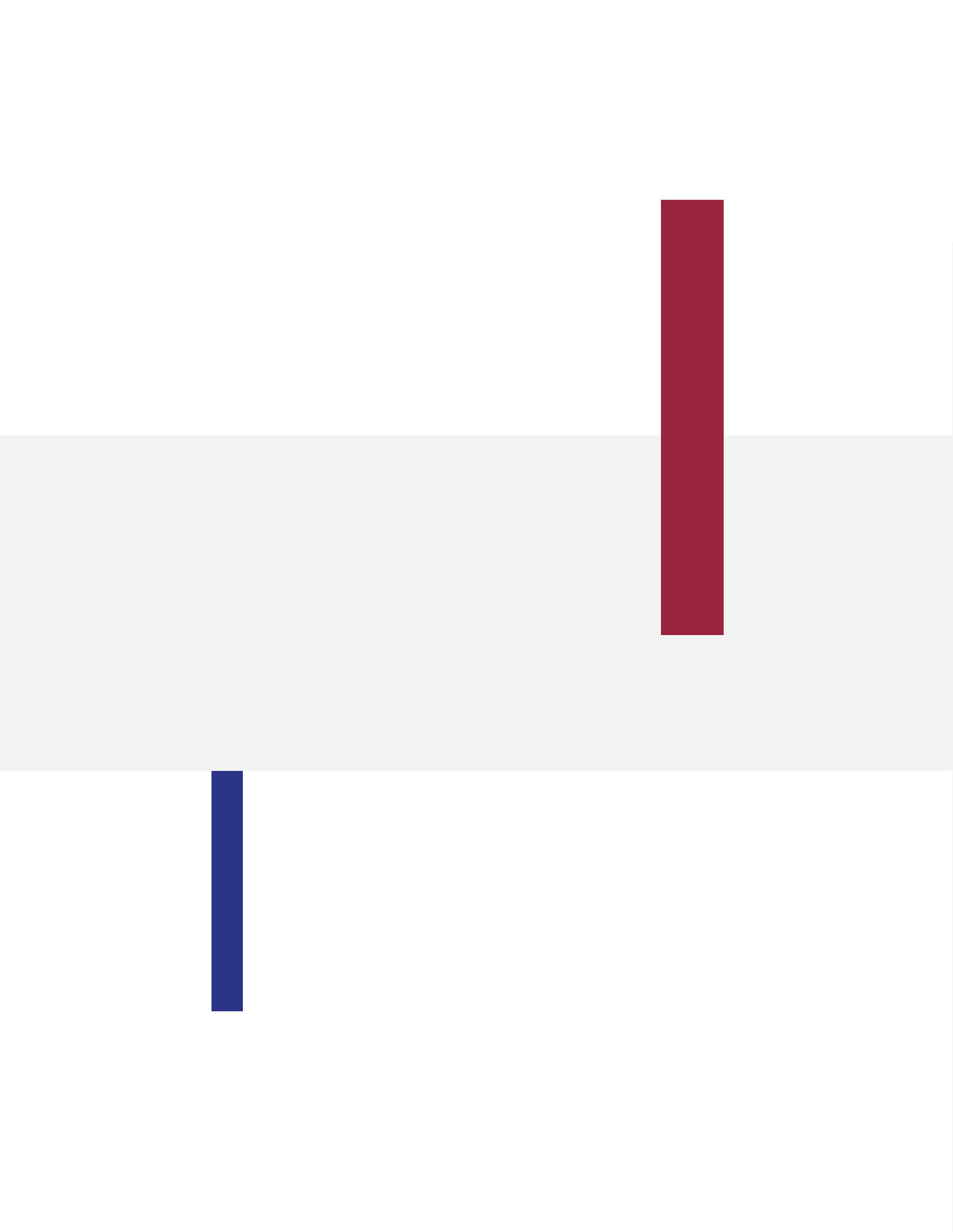
The CTBT stations operated by BGR in the Bavarian Forest are a popular destination for diplomats because of their proximity to Vienna. BGR welcomed a particularly senior dignitary there in May 2010. At the invitation of the German government, a visit by numerous ambassadors was also accompanied by Tibor Tóth, executive secretary of the CTBT organisation. They all came along to see for themselves how a seismological and infrasound station operates in practice. Tibor Tóth also said that Germany was a role model because of the very reliable operation of its stations.

BGR informed the public about numerous earthquakes, one of which also occurred in Germany. In the first quarter of 2010,

there was a succession of three large damaging earthquakes: on Haiti, in Chile and in Turkey. The BGR experts were able to rule out the commonly asked question of whether there was a shared origin for these large quakes. The apparent increase in the number of earthquakes in recent years assumed by the general public can be shown on the basis of earthquake statistics to only be an increase in the damage caused by earthquakes as a consequence of the increasing population densities in regions susceptible to earthquakes.

Risk sensitive regional and development planning is gaining increasingly in importance within the context of development cooperation because there is no end to the global trend of increasing vulnerability attributable to the steady growth in population and a concentration of economic activity and critical infrastructure in conurbations and megacities. Climate change will also have an impact on georisk exposure in an as yet unforeseeable way. Improved georisk management is therefore prudent to minimise the risk of natural disasters.

The large demand for reliable georisk information and the increasing need for professional advice to assist sustainable regional planning and disaster mitigation will also stimulate the further development of BGR's own risk analysis methods to enable them to be used as standard BGR applications in future development cooperation projects.





# ***National/International Geoscientific Cooperation***

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# Introduction

**G**eoresources such as mineral resources, energy resources, water and soil are crucial parts of the livelihood of present and future generations. Overexploitation or the improper use of these resources in many countries are not only responsible for inadequate access to these resources by the poorest sections of the community, but also for shortages in overall supply, and therefore a cause of many social and environmental problems. Hence, BGR supports measures safeguarding the sustainable use of georesources, and makes important contributions to alleviating poverty, improving economic development, environmental and resource protection, and sustainable resource management, and therefore ultimately to boosting social justice and preventing conflicts.

Based on its broad scientific expertise and the findings of its research and development activities, BGR analyses integrated development-policy problems at a geological level. BGR therefore boasts a unique selling point. In addition, thanks to its broader international cooperation (e.g. EuroGeoSurveys, scientific-technical cooperation) BGR is also able to incorporate geo-issues early on in EU directives, and exchange up-to-date geo-expertise and geodata through its scientific-technical cooperation work at an international level.

BGR has been involved in geoscientific and mining projects for the Federal Ministry for Economic Cooperation and Development (BMZ) since 1958. BGR advises BMZ and executes geo-

resource management projects in around 30 partner countries around the world. The main scientific focus is on groundwater, environmental geology, mining, georisks, energy/geothermy, mineral georesources, and other scientific sectors mainly reflecting the political priorities necessary to reach the development-policy, stability-policy and economic goals.

There is not only a huge difference in the level of development of the partner countries, there is also enormous variance in the advisory instruments used to pursue the aforementioned objectives. Many of our partner countries are (still) at a very early development stage. On the other hand, BGR also advises countries which already have emerging economy character. These societies in each of our cooperation partner countries expect answers to questions which affect them today and which could become even more urgent in future. Experience has shown that the challenges facing our partners generally come in the same order: geological exploration, resource evaluation, resource projection, regional planning, participation and good governance. As development progresses, the activities move increasingly towards assisting decision making at a regional and socio-political level. BGR therefore also makes contributions to these issues as well.

## BGR supports geo-network in Africa

**B**GR assists the establishment of an African network for geoscientific information: 'Geoscience Information in Africa (GIRAF)'. The aim of this project is to integrate the continent in all global activities of the international geoscientific community.

At the 'GIRAF 2009' International Workshop, organised jointly by BGR and the 'Geological Survey of Namibia (GSN)' in March 2009 in the Namibian capital Windhoek, leading scientists and experts from 26 African countries and four European countries, adopted a strategy paper with recommendations for future cooperation and project work.

"This paper highlights strategies for evaluating important information on georesources and georisks in a more targeted way. It involves methods aimed at improving information management in Africa using the whole of the geological data available around the world," says Dr. Kristine Asch, BGR expert for geological information and the organiser of the workshop.

The specific goals pursued by the project include bringing together the staff of African authorities, national experts and representatives of stakeholders active in the geoscientific information field. In future, all of the relevant authorities and national experts in Africa should be represented in the GIRAF project. Another objective is to initiate a pan-African network for the exchange and joint utilisation of geoscientific information and proven techniques. The African authorities and experts are to be incorporated within global geoinformation projects. And finally, a strategic 15 point plan has been developed to define concrete steps for the geoscientific information field in Africa.

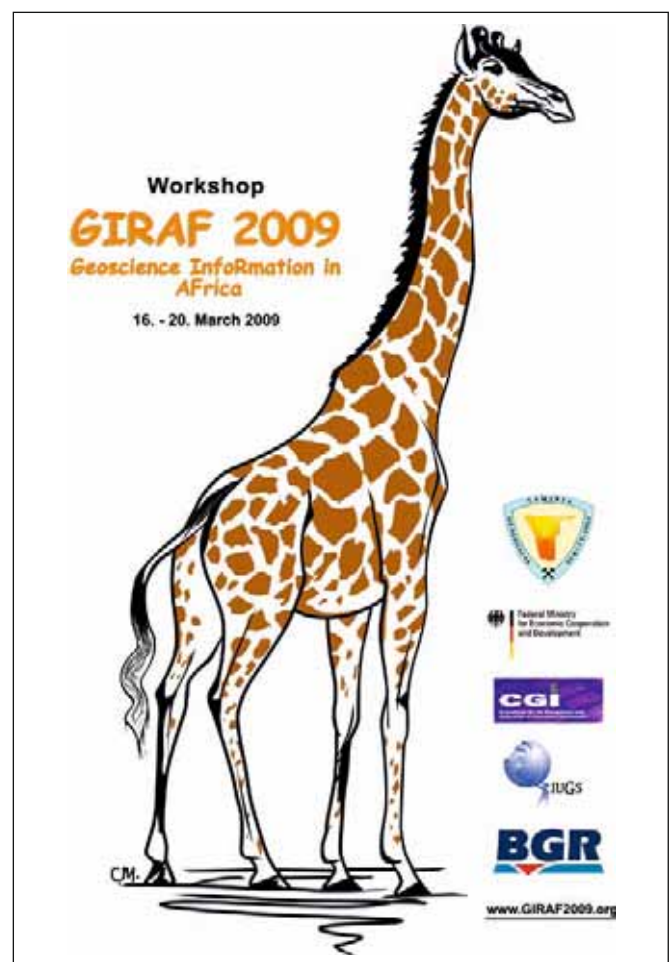
The workshop was financed by the Federal Ministry for Economic Cooperation and Development (BMZ). It was also supported by the IUGS Commission for the Management and Application of Geoscience Information (CGI). About 100 scientists and international experts – including UNESCO representatives – took part at a 5-day meeting at the Namibian Ministry of Mines and Energy (MME).

The workshop participants were welcomed by the Namibian Minister of Mining and Energy, Erkki Nghimtina, the German ambassador to Namibia, Egon Kochanke and GSN Director Dr. Gabi Schneider. The workshop included discussion forums and presentations at which the representatives of the geological surveys described geoscience information projects and issues in their home countries.

"The African continent is full of riches – people and georesources – and boasts a rich cultural heritage and beautiful countryside. But there are also major problems: poverty, inadequate water supplies and underdeveloped health services. The workshop was focused on the role geoscientific information can play in maximising opportunities and minimising risks,"

says BGR organiser Dr. Kristine Asch. "We hope that the GIRAF Workshop 2009 marks the start of a fruitful and sustainable pan-African network on Geoscience information."

The GIRAF network has been running since 2009, and four other organisations have joined as associate members: the Geological Society of Africa (GSAF), the African Association of Women Geologists (AAWG), the UNESCO-funded Commission of the Geological Map of the World (CGMW) and the One-Geology initiative (OneG). A second GIRAF workshop is planned to take place in Daressalaam/Tanzania in December 2011. The agenda includes a debate on the successful integration of African partners in international projects, and the presentation of current projects by GIRAF members. (Registration at: [www.GIRAF2011.org](http://www.GIRAF2011.org)). The workshop is again being organised by BGR and CGI, hosted by SEAMIC (the Southern and Eastern African Mineral Centre) and supported by the UNSECO. Several short training courses are planned.



# BGR assists developing countries with the extension of their maritime sovereignty rights

**O**n behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), BGR has successfully assisted developing countries since 2007 in defining the outer limits of their continental shelves in accordance with the United Nations Convention on the Law of the Sea. The project contributes to creating the legal framework for the subsequent exclusive use of the seabed resources in the extended areas by the countries. Germany thus makes an important contribution to the future economic development of these countries.

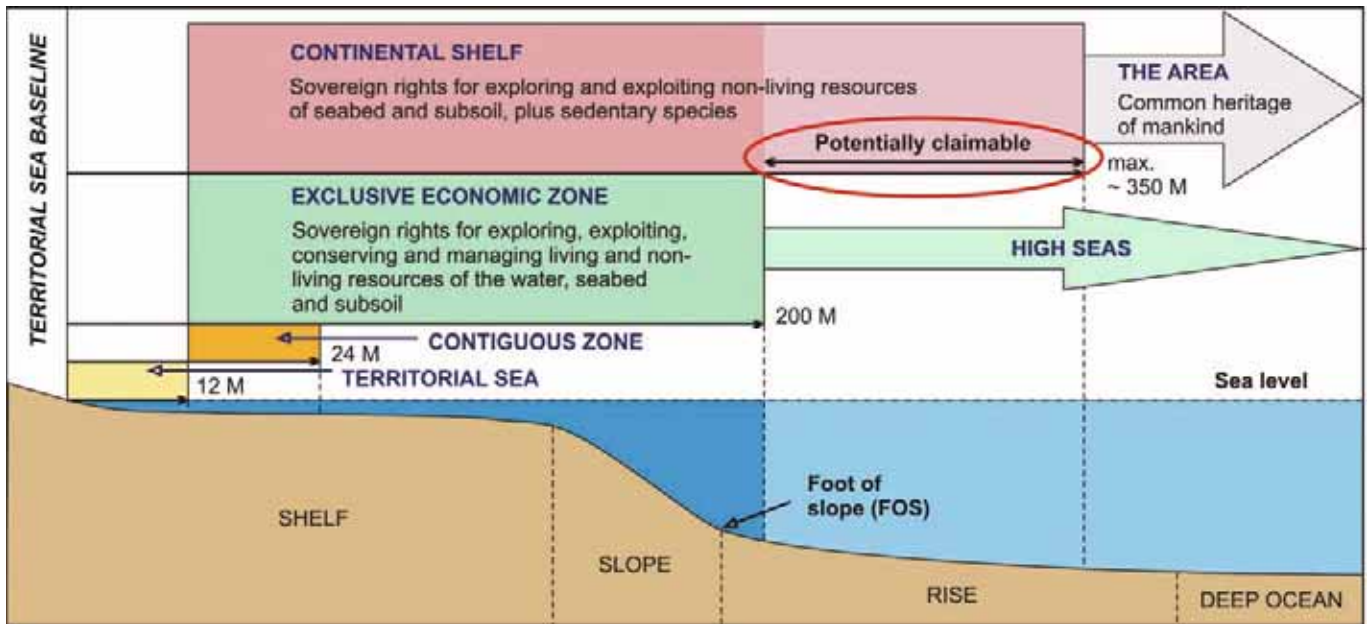
The United Nations Convention on the Law of the Sea (UNCLOS) defines inter alia various maritime zones with graduated rights of use and sovereignty. Pursuant to Article 76, coastal States have an entitlement to an extended continental shelf beyond the 200 nautical mile boundary under certain geological conditions. "To verify its entitlement, the coastal State in question must submit comprehensive documentation on the geology and geophysics of its continental margin, including detailed marine geoscientific data on water depth and the thickness of the sedimentary layers, to the competent expert commission for examination" explains BGR project co-ordinator Dr. Snježana Žarić. "Only when consensus has been reached, can the respective State establish the outer limits of these extended maritime areas as final and binding under international law," emphasises the geologist Žarić.

"However, due to a lack of financial and technical resources, and relevant expertise, many developing countries are not able to elaborate the submissions to the commission on their own," says the BGR project co-ordinator. 12 countries have therefore made use of the advice and assistance offered by BGR within the framework of the project "Implementing the United Nations Convention on the Law of the Sea (UNCLOS)". These countries are Guyana, Mozambique, Ghana, Angola, Côte d'Ivoire, Tanzania, Philippines, Bangladesh, Cape Verde, Viet Nam, Chile and Comoros.

The nature and the scope of the assistance provided by BGR are governed by the specific needs for advice of each country. The partners are the respective competent ministries and specialised institutions such as national oil companies. The measures range from providing advice on scientific and technical issues, to assisting with the compilation, acquisition and interpretation of relevant data, and carrying out specialised training courses, as well as assisting in the preparation of the documents to be submitted to the commission. Here, BGR makes use of its over forty years of marine science expertise gained in the investigation of continental margins and the acquisition and interpretation of marine geophysical data.

In addition, this project supported training courses of its cooperation partners, the UN Division for Ocean Affairs and the Law of the Sea (DOALOS), and the UNEP Shelf Programme (GRID-Arendal, Norway) by providing funding and staff. Altogether, around 150 participants from 35 developing countries taking part in 5 sub-regional training courses (southern and western Africa, south-east Asia and the Caribbean) were comprehensively informed about the legal and scientific-technical requirements as well as the special tasks relevant for the elaboration of the submission documents.

BMZ recently extended the term of the project to the end of 2013. "In the coming years, BGR will therefore continue to contribute to a just implementation of the UN Convention on the Law of the Sea, and thus to enhancing the equality between countries," says BGR project co-ordinator Žarić.



Schematic cross-section from the shelf to the deep ocean floor. The different colours show the different maritime zones defined by the UN Convention on the Law of the Sea.

Source: after Symonds et al., 1998



BGR expert Michael Schauer analysing data with Ghanaian counterparts.

## BGR and Paraguay: 20 years of geoscientific partnership

BGR and Paraguay celebrated the 20th anniversary of their technical cooperation. One hundred representatives of politics, administration, science and society were invited to the celebration event in Paraguay's capital Asunción. The successful geoscientific cooperation was praised in speeches by the Paraguayan Environment Minister Oscar Rivas, the German ambassador Dietmar Blaas and BGR President Prof. Dr. Hans-Joachim Kuempel.

Environment Minister Rivas explained that the lengthy cooperation between BGR geoscientists and Paraguayan experts is a groundbreaking example of modern partnership between two countries. BGR President Kuempel highlighted the aims of development cooperation in his speech: "We aim to support our partner countries in their economic and social development by assisting them with technical expertise and modern equipment. This has been implemented very successfully in Paraguay over the last 20 years."

Many former participants of technical cooperation projects undertaken during the last 20 years also attended the celebrations. BGR scientists have been working in Paraguay since 1990 on technical cooperation projects on behalf of the German Ministry of Economic Cooperation and Development.

They mainly supported their Paraguayan colleagues in the geological mapping of the country, exploring for natural resources, and dealing with environmental-geological issues. BGR experts are currently involved in water protection and regional planning projects. Working together with the competent water agencies in Chaco in Paraguay, the scientists taking part in these projects carried out groundwater protection investigations, also with the aim of improving drinking water supplies, particularly for the indigenous Indian population. They advised their South American project partners in the construction of small water reservoirs known as "Tajamare", the building of cisterns, and water pipeline laying in arid regions.

The current projects being carried out together with the Paraguayan Environment Ministry focus on environmentally-compatible regional planning, as well as sustainable resource protection. The cooperation is targeted at improving water, soil and landscape protection. The three BGR experts currently working in Paraguay are involved here in identifying locations for landfills, and assisting their South American partners in elaborating the necessary approval and operating procedures. This project runs to the end of 2011 and involves the Paraguayan cities of Coronel Oviedo, Caaguazú, Villarrica and Areguá as well as the two regional governments in Guariá and Caaguazú.



*Anniversary celebration in Paraguay's capital Asunción.*



**The recently published CD-ROM "Paraguay – Germany: Technical cooperation in the geosector" (in two languages: German, Spanish) is available free of charge from Franca Schwarz, departmental manager "International Cooperation": [Franca.schwarz@bgr.de](mailto:Franca.schwarz@bgr.de)**

## Study on the georesource situation in Russia

At the 2nd German-Russian georesources conference on 27 and 28 March 2009 in St. Petersburg, BGR presented a concise study 'The georesources industry in the Russian Federation'. The study analyses the georesources potential, mining industry, commodities trading, and their development. Mineral georesources and energy georesources are key economic sectors in Russia.

BGR experts have been working together with Russian geologists in georesource deposit research since the beginning of the 1990s. Projects included scientists from both countries taking part in several expeditions in the Laptev Sea and the surrounding Eastern Siberian regions to study the geological history, and to use this information to assess the potential for processes which could have given rise to the formation of deposits, particularly oil and gas fields. The study is available in German:



[www.bgr.bund.de/rohstoffindustrie-russ-foederation](http://www.bgr.bund.de/rohstoffindustrie-russ-foederation)

## BGR and Jordan: 50 years of geoscientific cooperation

BGR and the Hashemite Kingdom of Jordan celebrated the 50th anniversary of their international cooperation work in 2009. A ceremony took place on 11 May 2009 in the Jordanian capital Amman to celebrate the event, and brought together around 100 representatives from politics, science, society and international cooperation organisations. His Majesty Prince Faisal of Jordan welcomed the guests.

In addition to the BGR President, Prof. Dr. Hans-Joachim Kuempel, the ceremony was also attended by the Jordanian Minister of Water and Irrigation, Raed Abu Soud, and the German ambassador in Jordan, Dr. Joachim Heidorn.

"This anniversary marks an important milestone in the history of international cooperation covering georesource research and applied consulting. Georesource work in Jordan was the first project in this discipline undertaken on behalf of the German government by the then only recently established Federal Institute for Geosciences and Natural Resources. This led to a long standing partnership which has become a real success," says BGR President Kuempel. This was highlighted during the anniversary events in Amman by the signing of a new project agreement on 12 May 2009 which continues the German-Jordanian cooperation. As was the case with most of the previous projects, this new agreement was financed by the German Ministry of Economic Cooperation and Development (BMZ).

"The cooperation between BGR and Jordan is also an example of how international cooperation activity involving BGR has evolved over the last 50 years," says Kuempel. "In the early days, the priority was mainly to secure Germany's supplies of industrial georesources." Together with their Jordanian colleagues, BGR experts set up the Jordan Natural Resource Authority (NRA) in the first two decades of their partnership. During the geological mapping of the country, significant phosphate deposits were explored, amongst other resources. Jordan still exports phosphates and other fertilisers to Germany today.

The nature of the cooperation changed as Jordan built up its scientific expertise. BGR today mainly assists the country with advisory services. But there are now also priority objectives for the geoscientific project activities: groundwater exploration, groundwater protection and efficient groundwater resource management are the key aspects of cooperation between BGR and the Jordanian Ministry of Water and Irrigation (MWI) established in 1992.

## 'OneGeology' project: European geology has a common language

Another important milestone for 'OneGeology', the first geological world map in the internet: together with 20 national geological surveys, BGR elaborated a common "language" to describe the geology of the digital European map at a scale of 1:1,000,000.

"Geology knows no political boundaries. The common language ensures that we use the same terms everywhere in Europe – quasi-Esperanto for geologists," explains Dr. Kristine Asch, BGR expert for geological information and cartography, and head of the standardisation process of the 'OneGeology-Europe' project (1G-E).

The vocabulary of 1G-E helps avoid inconsistencies in geological map data, e.g. at the edges of maps along borders – the so-called "map edge distortions". It is divided into 15 categories and contains 516 terms, hierarchy names, definitions, sources and uniform resource names (URN). 1G-E was written in English first. The technical terminology shall also be made available in the internet in other languages in the medium term.

The broadest category is stratigraphy with 197 terms. These terms were compiled according to the globally established ICS standard (International Commission on Stratigraphy). The Precambrian period (4.6 billion to 542 million years ago) was supplemented by 27 new epochs. This is particularly important for the Scandinavian region because the very large distribution of Precambrian rocks here requires much more detailed subdivision to properly understand the geological history.

Another 163 terms are available for the lithology (rocks). 82 terms in all describe the genesis (origin), with a further subdivision into two categories to differentiate between depositional conditions and formation processes. The description of metamorphic rocks (altered rocks) is divided into facies (characteristic mineral associations which allow the formation conditions to be interpreted) and metamorphic grade (characteristic pressure and temperature zones). The new vocabulary also encompasses other aspects including structures, faults, orogenesis (mountain building processes) and contact types such as marginal ice zones or the outline of a volcanic collapse zone (caldera).

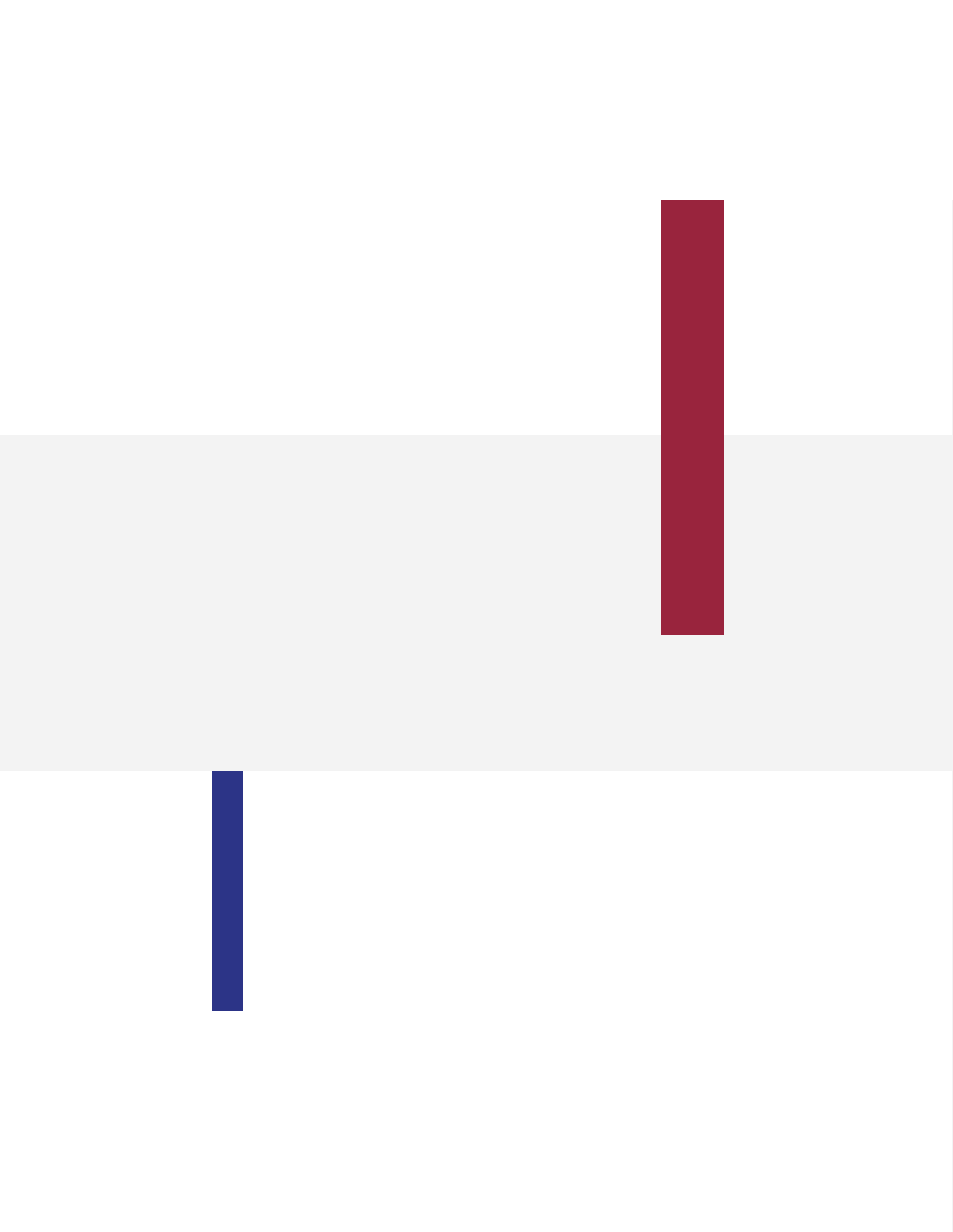
The standardisation project is financed by the EU. In addition to 20 national geological surveys, digital data is also supplied by 9 research institutes and companies who participate as project partners. 1G-E is the first step towards creating a digital world map under the 'OneGeology' heading. The internet project aims to provide a global insight into the geology of the whole planet for the first time.



# Outlook

**B**GR is committed to international development goals and strives to sustainably alleviate poverty and structural deficits in accordance with the UN Millennium Declaration. The key elements determining the international cooperation activities of BGR continue to be strengthening good governance, self-responsibility, and self-help resources in developing countries. This is achieved on the back of the

professional evaluation of resource potentials by creating the conditions required for society's participation in development decision-making as well as by strengthening institutional bodies, and expanding the scientific competence of state decision-making structures in the sectors of groundwater management, soil protection, regional development and regional planning, energy resources, the use of mineral resources, etc.



# *Polar Research*



# Introduction

**T**he polar regions are key areas for earth system research. Their significance for the whole of humanity was impressively underlined not for the last time by the International Polar Year 2007 – 09. Because of its ice cover, and the extreme climate, access to the polar regions continues to be very difficult even in our highly technologized world. This is why large swathes of the polar regions are still “white patches” on the world geological map.

The polar regions have a unique history. The geological, biological and climatological processes taking place there have a major influence on today’s earth system. However, we still do not know enough about how these processes interact with one another. Exploring the polar regions is therefore essential to gain an overall picture of the development and the geological structure of the earth’s crust, including its exploitation potential, as well as understanding the interaction between the solid earth, oceans, glaciation, atmosphere, orbital changes and the living world. Understanding these relationships is essential for making reliable forecasts so that we can respond properly at a scientific and socio-political level to the future changes in the global system.

BGR has been carrying out continental geological research in the polar regions since 1979. That was when BGR started its first land expedition GANOVEX I (German Antarctic North Victoria Land Expedition), which has been followed up until the present day by nine further expeditions. In those days, large areas were truly “white patches” on the world geological map. Many of today’s valid models did not exist in 1979 and have only developed on the basis of numerous separate investiga-

tions and detailed mapping work. This is why many of the new geographical names in North Victoria Land have references to BGR’s Antarctic research (e.g. BGR Nevé, GANOVEX Range). And in response to the changed political situation after the collapse of the Soviet Union, BGR has also been running the successful international CASE programme (Circum-Arctic Structural Events) since 1992 in the still largely unexplored Arctic. As part of a national delegation of responsibilities which led to BGR being assigned responsibility for undertaking the terrestrial components of geoscientific polar research, BGR has worked reliably and continuously with the Alfred-Wegener Institute for Polar and Marine Research (AWI) and German universities. With its polar research activities, BGR assists the German government in the pursuit of its political goals, such as maintaining Germany’s consultative status within the Antarctic Treaty System, and strengthening Germany’s voice in economic, environmental and research policy strategy meetings on the Arctic.

Through its planning, organisation and implementation of geoscientific expeditions conducted on a broad scientific basis and in cooperation with national and international institutions, it makes an important contribution to the primarily basic geoscientific polar research to which the Federal Republic of Germany is committed in line with its co-responsibility for the global environment. By incorporating the geoscientific projects of the German Research Foundation (DFG) in the BGR polar programmes, interdisciplinary research has been built up over the years which has produced internationally praised results. This will continue to be a major feature of BGR’s polar research activities in future.

## AGAP and GANOVEX X: Searching for geoscientific clues in the Antarctic

**B**GR geoscientists in cooperation with German universities and research institutions, as well as foreign institutions, have been carrying out research into the structure and development of the Antarctic since 1979.

The main geographical focus of BGR's Antarctic research activities is North Victoria Land and the Ross Sea region of West Antarctica – as part of its GANOVEX research programme (German Antarctic North Victoria Land Expedition). BGR has also organised expeditions in East Antarctica, in the Shackleton Range and the central Transantarctic Mountains. The common goal of all of these activities is to investigate the continents and their margins to understand the early history of the earth, particularly the formation of the Gondwana supercontinent and its precursor Rodinia – as well as their break-up and the development of today's Antarctic continent and its shelf regions. BGR makes a major contribution here to the main scientific goals of German Antarctic research.

The research activities conducted by BGR in the Antarctic are partially incorporated in long-term international cooperation agreements and contracts. Together with the Alfred-Wegener Institute for Polar and Marine Research (AWI), BGR upholds Germany's consultative status within the Antarctic Treaty, and is therefore obliged to carry out regular research expeditions in the Antarctic. This is realised by a delegation of responsibilities between AWI and BGR where BGR is mainly responsible for the terrestrial geoscientific components of German Antarctic research. And by using BGR logistics, numerous geoscientific programmes run by university groups – funded by the German Research Foundation as part of its priority programme "Antarctic research with comparative investigations in Arctic ice areas" – could be provided with assistance, which in some cases, made the projects feasible in the first place.

### The international AGAP project

BGR scientists joined colleagues from six different countries between December 2008 and February 2009 on the international AGAP expedition (Antarctica's Gamburtsev Province), which was one of the key research projects in the International Polar Year. The AGAP expedition went to one of the most poorly accessible parts of the Antarctic lying on the highest and probably coldest place in East Antarctica not far from the "Pole of Inaccessibility". This is the location of the over 300,000 km<sup>2</sup> Gamburtsev Mountains which lie beneath the polar ice cap and which have hardly undergone any exploration since being discovered in the International Geophysical Year 1957 – 58. No information had previously been available on whether it is a simple mountain range or had alpine character, or which rock formations formed the mountain range. It is also strange that mountains of this kind even exist in the area because the great

age of the East Antarctic crust meant that one would expect a less prominent morphology, such as that found on the Canadian Shield. Were they perhaps the result of a "hot spot", such as that responsible for the Hawaiian chain of volcanoes? Exploration of the geological structure of the Gamburtsev Mountains was therefore one of the key objectives of the International Polar Year.

Their association with other structures such as subglacial lakes and graben systems was also unknown. Numerous lakes have been discovered under the Antarctic ice sheet since the middle of the 1990s. The best known is Lake Vostok whose origin and development is the subject of intense debate. Another objective of the AGAP project was the relationship between the Gamburtsev Mountains and the neighbouring Lambert Graben system and the tectonic structures in Prydz Bay on the Antarctic coast. The Lambert Graben extends for over 1000 km from the Gamburtsev Mountains to the Amery Ice Shelf and into Prydz Bay, and is interpreted as the inactive arm of a triple junction on the Antarctic plate. It is also home to the world's largest glacial system: the 40 – 50 km wide and 500 km long Lambert Glacier.

But AGAP was not only interested in geological aspects: a great deal of important data was collected which could help understand the development of the East Antarctic ice sheet. It is thought that the major glaciation of the central Antarctic might have begun in the Gamburtsev Mountains slightly more than 30 million years ago: one of the most interesting things is therefore the temporal relationship between the uplift of the Gamburtsev Mountains and the formation of the inland ice sheet. Did the East Antarctic ice sheet really start at this location?

Because of the long distances to the coastal stations and the extreme temperatures, of down to – 35 °C, even in the Antarctic summer, the AGAP project was a serious logistical challenge. The project could only be realised by pooling the resources of the participating countries. First, the expedition team was flown in large aircraft to the "Amundsen-Scott" South Pole station. The stay here was aimed at acclimatising the expedition members to the extreme elevations in the target area. The main camp "AGAP S" which was the base for the BGR scientists, lay at an elevation of 3,500 m and was located 630 km from the South Pole. The second base camp "AGAP N" was located at an elevation of 3000 m another 800 km to the north. One of the main efforts was supplying the expedition with fuel: this was transported by sledge from the South Pole to "AGAP S", and by C17 transport aircraft to the planned location of "AGAP N", where the fuel drums were thrown out of the aircraft on parachutes.

The team from the USA, UK, Australia, China, Japan and Germany undertook comprehensive geophysical surveys at the

AGAP project investigation area, from the ground as well as from the air. The surveys investigated the magnetic fields, the gravity field, and the thickness of the ice. The research programme also included seismic surveys.

The main focus of BGR's activities in this project were the aerogeophysical surveys which were flown using two "Twin Otter" aircraft provided by the US Antarctic Program and the British Antarctic Survey. 100,000 air kilometres were flown during the 110 surveying flights – more than twice the distance around the world. The surveys cover an area of around 240,000 square kilometres – around two thirds the size of Germany.

The first interpretations of the radar surveys indicate that the Gamburtsev Mountains are a relatively young mountain range analogous to the European Alps which was glaciated relatively quickly. Whilst the thickest ice layers are at the southern edge of the survey area and reach thicknesses of 3,500 to 4,000 metres, the ice thins over the peaks of the mountains in the northern part of the investigation area to thicknesses of less than 500 m. The team hopes to gain new insights into climate change from the evaluation of the data material. The project uniquely bundles the scientific expertise of an international research team with the objective of finding answers to fundamental questions of nature and the development of the southernmost continent.

## GANOVEX X: From Gondwana to today's southern continent

In the southern summer of 2009/10, BGR conducted geological and geophysical investigations as part of the GANOVEX research programme to study the crustal structure and tectonic development of North Victoria Land. The expedition was not only the tenth in the globally renowned GANOVEX programme, it also took place 30 years after the first expedition and Germany becoming a signatory to the Antarctic Treaty in 1979. The primary goal was to acquire detailed information on the geodynamic processes which led to the development of today's Antarctic continent, and to help us better understand processes taking place today as part of the continuing changes to the Antarctic plate.

In the early days of the Gondwana supercontinent, a mountain range comparable to today's Andes existed in North Victoria Land and was given the scientific name of the Ross Orogen. Just like the recent Andes, the mountain range was pushed up when the heavy Pacific plate was dragged underneath the lighter Gondwana continental plate. This 500 million year old mountain range was immediately exposed to intensive erosion and completely levelled out within a relatively short period of geological time. Over the next almost 300 million years, Gondwana was characterised by extensive shallow basins transected by broad branching river systems. Smaller and larger lakes repeatedly developed in these basins. The associated sediments are known in North Victoria Land as the Beacon Formation. Deposition of the Beacon Formation terminated in the Jurassic period when Gondwana was split by fractures and fissures

180 million years ago, opening the way for flood basalts to well up and cover many parts of Gondwana with extensive sheets of lava. These are called the Ferrar Volcanics in North Victoria Land.

18 scientists, plus technicians and logistics staff, took part in the expedition. Geological and geophysical methods were combined to investigate the ice and snow covered areas. Specific projects undertaken during the expedition looked at the sedimentology, geobiology, geochemistry, petrology, structural geology, geo- and thermo-chronology. Aerogeophysical and gravimetric surveys were also undertaken. In addition to BGR staff, scientists were also present from the universities of Bremen, Düsseldorf, Jena, Munich and Newcastle (Australia), and the German Aerospace Centre. The logistics side of the expedition was run in cooperation with the Italian Antarctic Programme. The expedition was also accompanied by a media team which meant that throughout the expedition and beyond, GANOVEX X was present in television, radio, print media and the internet. This offered a unique opportunity to communicate to society as a whole the activities and understanding acquired by polar research.

The expedition involved an ambitious and logistically complex programme, and was operated from four different locations throughout the duration of the expedition. The main base was BGR's Gondwana Station in Terra Nova Bay on the Ross Sea, not far from the Italian Mario Zucchelli station. The expedition logistics of the various programmes was co-ordinated from here, and some research projects were also carried out from this base. Gondwana Station is a pure summer station and has existed in its current form since GANOVEX V (1988/89).

Around 300 km further north, in the middle of the remote mountains and glaciers of the Transantarctic Mountains, sedimentologists carried out field work from several small tent satellite camps on the 300 to 200 million year old sandstone sequences of the Beacon Formation. This formation was deposited when Antarctica was covered by an earlier massive sheet of ice which melted completely away again after a subsequent period of global warming. A large number of stratigraphic sections were mapped in great detail at centimetre to decimetre scales. The findings overall led to a completely new interpretation of the previously valid stratigraphy, and to a new model of the geological and palaeoclimatic development of North Victoria Land during the Late Palaeozoic and Early Mesozoic.

The geophysical surveys operated out of a large base camp in the Mesa Range, 150 km north of the Gondwana Station. The base camp was primarily used as the starting point for the detailed aerogeophysical surveying of the region to scan the structures of the rocks hidden beneath the thick layer of ice. During 26 surveying flights, lasting 56.5 hours flying time in total, around 7,400 kilometres of surveying lines were collected over an area covering 3,300 km<sup>2</sup>. Scientists had reduced the distance between each of the lines flown during the survey to 500 m to help them define the fine geological structures. This tight surveying grid enabled rock layers and fault zones to be

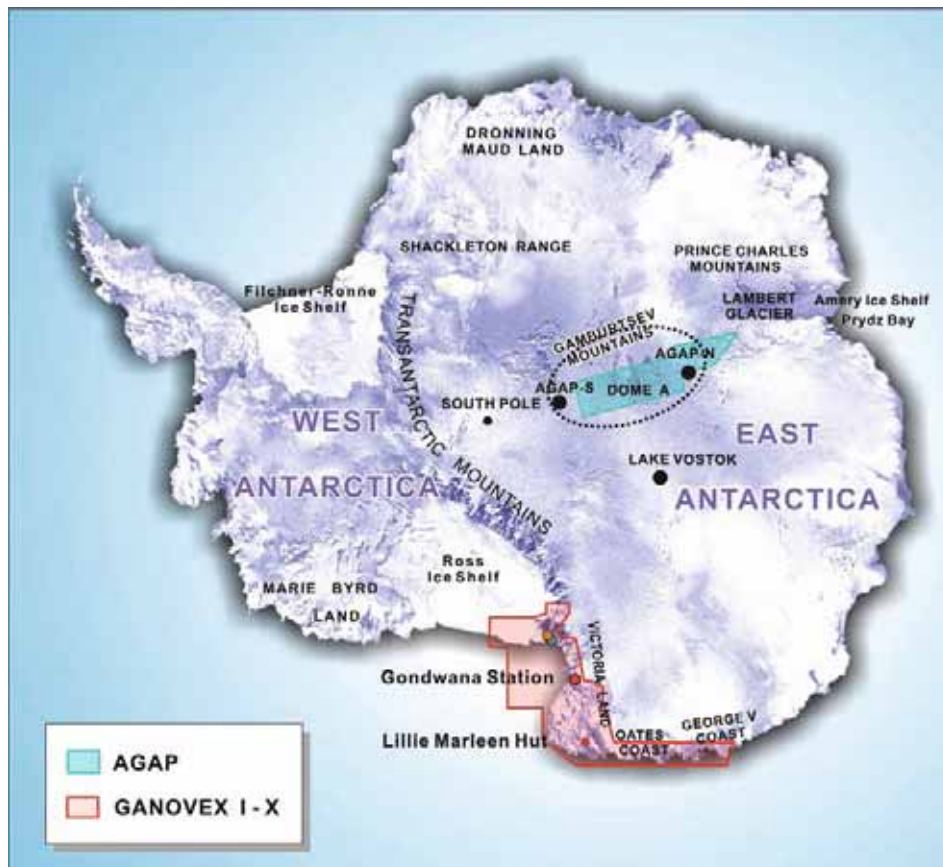
mapped under the ice. The survey produced a high resolution map of the magnetic field. The magnetic patterns support the interpretation that the Mesa Range is the remains of a former large flood basalt plain consisting of Jurassic Ferrar Volcanics. No signs were found of any volcanic pipes which were tentatively identified during older surveys from the presence of circular anomalies at some locations. This means that the sources of the volcanic rocks were not local but a long distance away outside of the area of investigation.

Paleomagnetic surveys were also carried out of the Jurassic Ferrar flood basalts in the Mesa Range. These surveys were aimed at determining the paleo-polarity of the Antarctic around 180 million years ago. The massive eruption of the basalt magmas and the associated release of climate gases and dust into the atmosphere could be one cause for one of the major extinction events during the course of the earth's history which was immediately preceded by the Ferrar volcanism.

Structural geological, petrological and thermo-chronological work was also carried out from the Gondwana Station and from the "M/V Italia" expedition ship at locations in land and

along the northern section of the Ross Sea coast. The research ship had been chartered jointly with the Italian Antarctic Programme. North Victoria Land boasts extremely contrasting landscapes: high Alpine peaks look down on an extensive plateau and hilly landscape. One of the main objectives of GANOVEX X was to understand how these landscapes formed and which processes interacted to create the mountains and plateaus: what was the influence of the glaciation of the Antarctic continent; what role was played by the uplift of the Transantarctic Mountains; and what was the impact of the types of rocks and their properties? Climate change and tectonics are closely interrelated in North Victoria Land. Only after Antarctica was completely cut off from Australia and South America slightly more than 30 million years ago, was it possible for the circum-Antarctic ring of cold ocean currents to form. And it was this isolation of the southern continent which had such a crucial influence on the global climatic system.

With this work in the Antarctic, BGR makes a major contribution to clarifying the role of polar regions in global changes affecting the earth system from the past and into the future, and their impact on human living conditions.



Location of the GANOVEX I-X and AGAP expedition areas.

## Antarctica: Development of a continent

Through most of Earth's history, Antarctica was not always an independent continent, but part of larger land masses. It lay in the central part of the Rodinia supercontinent which formed around 1.1 billion years ago during a huge global event, and which began to break up again around 800 – 700 million years ago. During this break-up, North America, which lay directly adjacent to the Antarctic at the time, separated off from the Rodinia assemblage initially as a result of the formation of a continental graben. This expanded to form an ocean – the Paleo Pacific.

The Antarctic was also at the heart of the Gondwana supercontinent which formed around 600 – 500 million years ago after the collision of continental plates caused the merger of all of today's southern continents. Gondwana survived up to around 180 million years ago before huge basalt eruptions heralded its break-up. Africa, India, Australia and South America successively moved away from the Antarctic, which finally led to its taking up its isolated position today at the South Pole and the formation of today's global oceanic current systems and climatic conditions.



*The Italian expedition ship 'MIV Italica' used for GANOVEX X lying at anchor in Terra Nova Bay, Ross Sea.*



*Satellite camp used by GANOVEX X sedimentologists on the Neall Massif, approximately 300 km north of Gondwana Station.*



*Taking geological samples in the Transantarctic Mountains.*



*The up to over 4,000 m high ice-covered Transantarctic Mountains in North Victoria Land, the main target of the GANOVEX X geoscientists.*



## Scientists investigate the geology of Spitsbergen

Even in our own high-tech age, the Arctic is still one of the least understood parts of the planet. The remoteness of the expedition areas, the many logistics problems, and the financial hurdles, continue to be major challenges for the organisation of expeditions and the exploration of the geology around the Arctic Ocean. Everything required for the survival of an Arctic expedition and mobility in the research area has to be transported up to 1,000 kilometres from the nearest harbour or airfield.

It is frequently reported that the Arctic may hold up to a quarter of the world's remaining hydrocarbon reserves. This estimate is based on statistical calculations – however, there is hardly any direct geological evidence and therefore only guesses about large parts of the Arctic, e.g. the widest continental shelf on the earth along the Eurasian coast. BGR's CASE project is specifically aimed at filling this information gap: the objective is to carry out comprehensive, detailed and interdisciplinary geoscientific investigations in the circum-Arctic land areas. This not only means exploring the status quo, in other words the current structure of the earth's crust, but doing research to understand the development of these areas over the last 1,000 million years. Speculating about the hydrocarbon potential of Arctic sedimentary basins for instance is only viable when the plate tectonic constellations are known when the sediments were deposited in these basins. This is because these sedimentary basins were also torn apart during the break-up of the Laurasian supercontinent during the Cretaceous, and particularly during the Tertiary, and now appear to form isolated basin systems located all around the Arctic Ocean. It is therefore very important to also study the geological development of the older and deeper earth's crust. This development is the platform for interpreting the puzzle and identifying the conditions required for the formation of possible oil and gas fields.

### Little CASE 2009 Spitsbergen I: Nordaustlandet

The main objective of the work on the Nordaustlandet expedition was geologically mapping the region as part of Norway's NOMAP mapping programme on Svalbard. The previously published geological maps gave rise to erroneous or patchy interpretations of the development history of this area and its correlation with other parts of the Arctic. This is a typical example of the importance even today of the need to very carefully map inadequately explored areas. Plate tectonic interpretations and reconstructions of a transregional area such as the Arctic are only possible on the basis of precise geological maps and the accompanying structural geological investigations, and determination of the geological associations and ages.



*With Russian geologists in the primeval landscape on the north coast of Nordaustlandet. The residual mountains are made up of 550 to 1,000 million year old sediments.*

The work carried out by BGR is closely related to the earlier BGR expeditions – CASE 10 to Spitsbergen (2007), and CASE 11 to Pearya (2008) on the north coast of Ellesmere Island – and revealed that the effects of the Caledonian orogeny around 450 million years ago were the most significant event in the northeast Svalbard archipelago. Neoprotozoic sedimentary basins and Caledonian magmatites are exposed here which were affected by extensive lateral fault movement during the late stages of the Caledonides. Similar relationships were identified during the BGR "CASE 11" expedition on Pearya. This improves the ability to reconstruct the plate tectonic constellations which led to the formation of the Laurasian supercontinent. This formed the basement for the accumulation of the Carboniferous to Late Tertiary sedimentary basin sediments which are the most important candidates for potential oil and gas fields in the Arctic.

### Little CASE 2009 Spitsbergen II: Isfjorden

Around 70 samples of sediments were collected from outcrops in the side valleys of the Isfjorden and the southern Adventdalen, and sent for geochemical analysis. The analysis results acquired to far indicate that the Triassic claystones and marls of the Vikinghøgda and Botneheia Formations in particular, which have high concentrations of organic matter, and contain marine material in the Botneheia Formation in particular, could be potential hydrocarbon source rocks in the region. The Agardhfjellet Formation deposited under marine conditions in the Jurassic also has significant source rock potential, whilst younger sediments in particular tend to contain organic material which is largely derived from land plants.



*Geological camp on the remote tundra at the end of Wahlenbergfjorden on Nordaustlandet.*

The thermal maturity of the Lower Triassic organic material has already entered the main oil window, whilst the thermal maturity of the overlying and younger Jurassic sediments is only slightly lower. Lower Cretaceous sediments (Helvetiafjellet Formation) have only reached the top of the oil window in the Isfjorden area. The sediments in the Lower Cretaceous Carolinefjellet Formation south of Adventdalen, as well as the Paleogene sediments (Firkanten Formation) have much higher vitrinite reflectance values, which is attributable to the deeper subsidence of this region.

In addition to the collection of samples for geochemical analysis to determine the hydrocarbon potential of the Mesozoic to Tertiary sediments in the Spitsbergen Basin, structural-geological field work was also undertaken. During the restructuring of the plate tectonic constellation of the Arctic, and the formation of the Arctic Ocean prior to the separation of Greenland and the Barents Shelf, the west coast of Spitsbergen was affected by intense deformation during the early Tertiary around 40 million years ago (West Spitsbergen Fold-and-Thrust Belt), which also affected the interior of the Spitsbergen Basin to a lesser degree. Fold structures and faults were found in the Triassic to Tertiary sediments along the north coast of Nordenskiöld Land studied during the "Little CASE 2009" expedition, which is attributable to the early Tertiary deformation. In addition, a fracture and shear surface system developed which cut the folds and faults and subsequently formed lateral faults which are linked to the separation of Greenland and Spitsbergen. This enabled an indirect dating of the hydrocarbon systems in this region: the beds near the faults smell of petroleum and may be a migration path for hydrocarbons. Because the deformation took place during the development of the west Spitsbergen Fold-and-Thrust Belt, which probably occurred in the Eocene around 40 million years ago, the formation of the potential migration paths can be dated as post-Eocene.

The geochemical analysis also indicated the migration of hydrocarbons, for instance in the sediments of the Botneheia Formation where the smell of petroleum was detected at various outcrops.

## Little CASE 2010: Ellef Ringnes Island

BGR had two reasons for participating in the Canadian expedition: firstly, to carry out structural-geological investigations of the NNE-SSW and around E-W running fault systems in the northern part of Ellef Ringnes Island, and secondly, to take geochemical samples to investigate the hydrocarbon potential of Mesozoic sediments and compare them with sediments of similar age from Spitsbergen and the Khatanga-Anabar region in Siberia.

The structural-geological part of the expedition was closely tied to the fault kinematics discovered by BGR geologists on expeditions to Pearya on the northern edge of Ellesmere Island ("CASE 6, 7 and 11"). Extensive fault systems are exposed here which run parallel to today's passive North American continental margin. On the basis of their field work, the BGR geologists expected to see left-lateral faulting, but the field work conducted on Pearya revealed that all of the faults were right-lateral – which contradicted the transregional tectonic regime.

The faults in the north of Ellef Ringnes Island were therefore targeted during "Little CASE 2010" to determine whether the Pearya tectonics was merely a localised phenomenon. Despite the poor outcrops on Ellef Ringnes Island, the structural-geological work clearly showed that the fault systems here are also characterised by right-lateral movement. This is the dominant structural trend and must have played an important role in the development of today's passive North American continental



*Solid ice at Nordenskiöldbukta at the edge of Nordaustlandet mid July 2009. The view from this remote coast at latitude 80° North looks directly towards the North Pole located only 1,100 kilometres away.*

margin during the opening of the Amerasian and Eurasian basins. However, the reasons for this “counteractive” direction of movement is completely unexplained.

Ellef Ringnes Island was formed by the upward movement of salt domes – in a similar way to the situation in north Germany – which dragged up deeper lying rocks and exposed them on the earth’s surface. These Mesozoic rocks filled the Sverdrup Basin in the surrounding marine areas in which very large gas fields are known. Ellef Ringnes is therefore a geological window revealing the structure and georesource geology of the deeper parts of the sedimentary basin. Rock samples of potential oil and gas source rocks were therefore collected during the 2010 expedition. These have been analysed in the laboratory to determine their oil and gas source potential, and to detect any possible traces of hydrocarbon migration. The results of these measurements on Ellef Ringnes Island are another piece in the jigsaw puzzle of circum-Arctic source rock potential now recorded in the BGR database.



*Approximately 45 million year old horizontally bedded sandstones of Tertiary age at Larsbreen above the Norwegian settlement of Longyearbyen (Spitzbergen).*



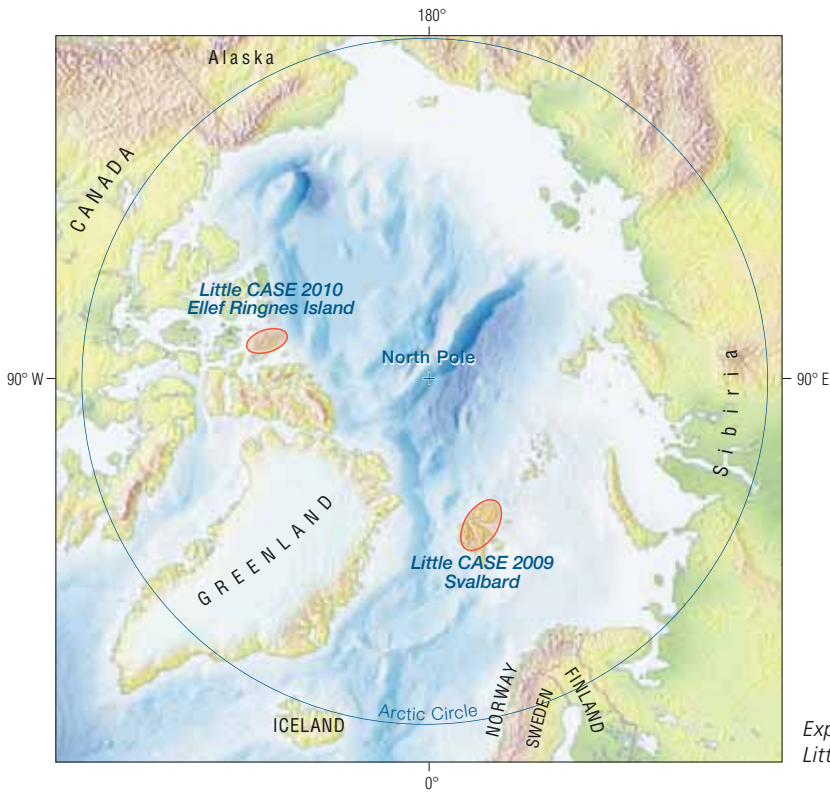
*Erosion residues – so-called hoodoos – of formerly continuous thick sandstone beds in the north of Ellef Ringnes Island.*

## Polar expeditions Little CASE 2009 and 2010

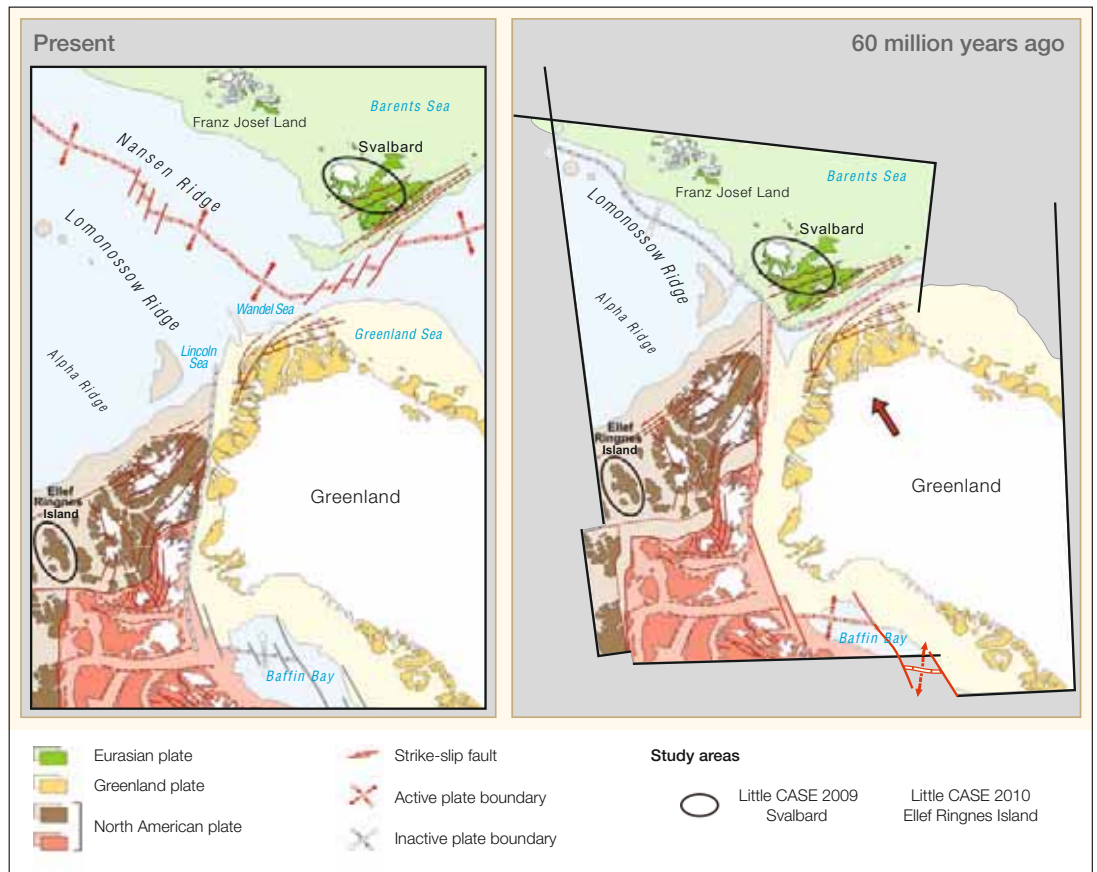
BGR geologists took part in three field work expeditions in the Arctic as part of the Circum-Arctic Structural Events CASE project in the summers of 2009 and 2010. BGR participated in a three-week expedition in July 2009 organised by the Norsk Polarinstitut (NPI Tromsø) along the remote north-eastern island of Nordaustlandet in the Svalbard archipelago (Little CASE 2009 Spitsbergen I). In August of the same year, BGR cooperated with the Karpinsky Geological Research Institute St. Petersburg (VSEGEI) to carry out field work on the south coast of Isfjorden in the centre of Spitsbergen to the east of Longyearbyen (Little CASE 2009 Spitsbergen II). BGR was invited by the Geological Survey of Canada (GSC Calgary) to take part in a three-week expedition in July 2010 on Ellef Ringnes Island on the edge of the Arctic Ocean in the Canadian Arctic (Little CASE 2010 Ellef Ringnes Island).



*Canadian geologists on around 200 million year old sandstones in the typically monotonous landscape of Ellef Ringnes Island at the edge of the Arctic Ocean in the Canadian-Arctic archipelago.*



Expedition areas looked at during Little Case 2009 and 2010.



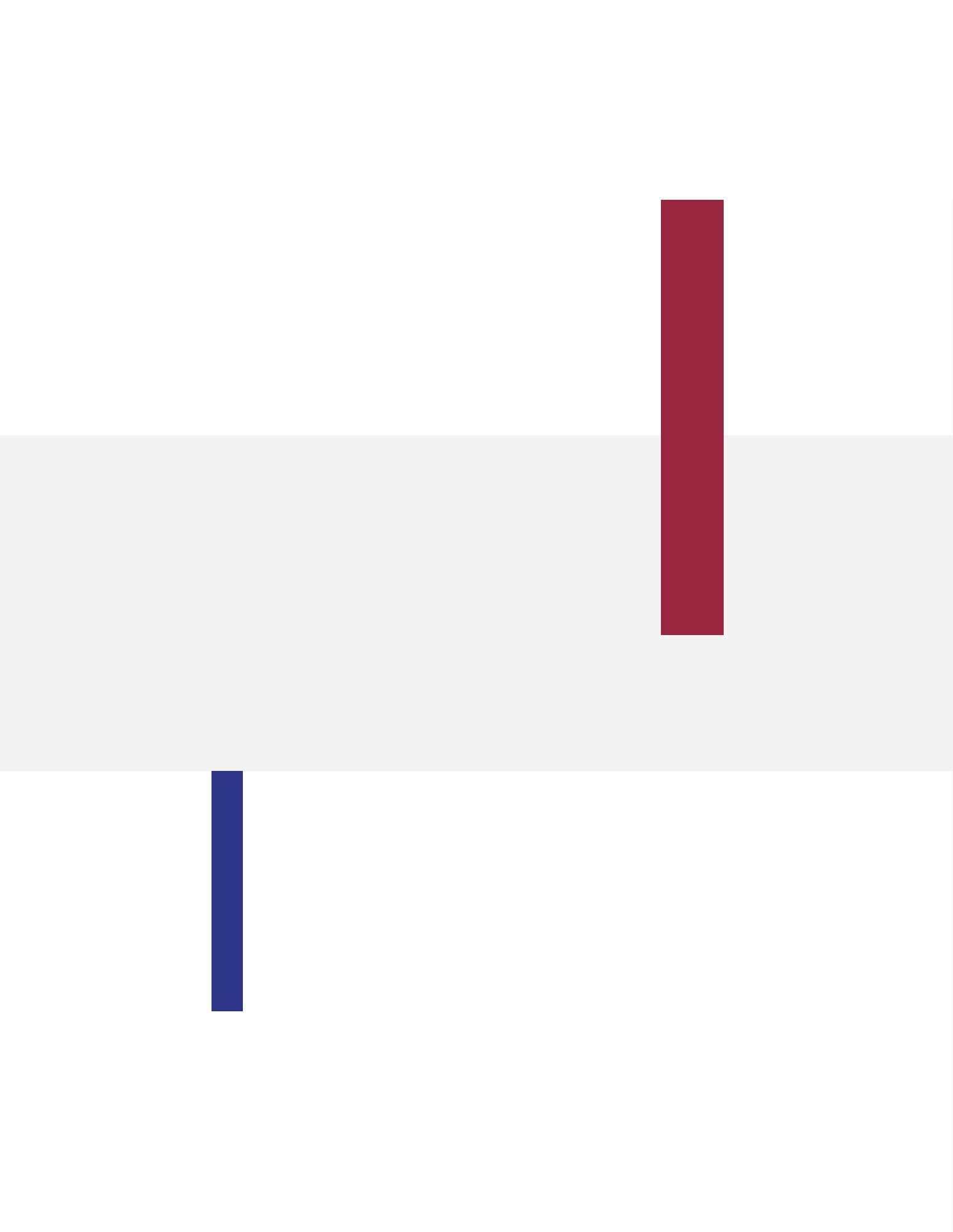
# Outlook

In close cooperation with the Alfred-Wegener Institute for Polar and Marine Research (AWI) and the Belgian Antarctic Programme, BGR organised the first expedition of a long-term project called GEA (Geodynamic Evolution of East Antarctica) in the Antarctic season 2010/11. This project uses geological and geophysical methods to investigate the structure of the crust and the geodynamic development of East Antarctica and the creation of today's landscape. A multi-disciplinary geo-scientific research programme with helicopter and aircraft support will be conducted as part of the GEA project during the Antarctic season 2011/12 from the Belgian Princess-Elisabeth Station in eastern Dronning Maud Land. Another third season is planned dependent on the results of this expedition. No specific date has yet been scheduled.

After ten GANOVEX expeditions over the years, BGR is currently planning its 11th expedition in North Victoria Land and the surrounding Ross Sea region – GANOVEX XI is to take place in the southern summer 2012/13. The work will again encompass a comprehensive multi-disciplinary geological and geophysical research programme. As in the two previous expeditions, BGR's Gondwana Station at Terra Nova Bay on the Ross Sea will be the main base camp for the expedition. The main logistics and scientific cooperation partner will probably be the Ko-

rean Polar Research Institute which has plans to strengthen its activities in the future in the Ross Sea region and is a new BGR partner institute.

The CASE programme begun back in 1992 can now look back on eleven major expeditions, and a few smaller expeditions to almost all of the countries surrounding the Arctic Ocean. BGR will operate three expeditions in the Arctic in the northern summer 2011. Together with AWI, an aerogeophysical and gravimetric survey along the north coast of Greenland will be conducted as part of the NOGRAM project (Northern Gravity and Aeromagnetism). This data will then be directly compared with the findings from the CASE land expeditions. The main priority is the scientific evaluation and interpretation of the Morris Jessup Plateau, and mapping the structure of the passive continental margin at the land/sea boundary. CASE 12 will also take place in 2011 and involves a combined geological-aerogeophysical expedition at Vendom Fiord on Ellesmere Island in the Canadian Arctic opposite Greenland. And finally the ship-based CASE 13 expedition will be conducted in cooperation with VSEGEI (A. P. Karpinsky All-Russian Geological Research Institute) in St. Petersburg. The expedition will go to the New Siberian Islands in the Russian Arctic.



# *Special Topics*


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## 'Resource': New brochure with information on current BGR projects

The range of information made available by BGR continues to evolve. 'Resource' is the name of the new brochure which gives an insight into the most important research projects to be conducted by BGR during the next four years.

"The brochure is aimed at a broad circle of customers and users, as well as interested members of the public," says BGR President Prof. Dr. Hans-Joachim Kuempel. "The content and layout is very different to earlier research reports which were exclusively aimed at readers with a technical background. 'Resource' provides information in an attractive and lively way on the latest questions, challenges and solutions involved in the exciting activities currently being conducted by BGR," says Kuempel describing the new brochure. 'Resource' has around 50 pages providing information on key projects spanning 2010 to 2014 and covering topics including energy and mineral georesources, soil, aerogeophysics, CCS, radioactive waste repositories, geothermal energy, seismicity, polar research and mapping.

 **The brochure is available in German and is free of charge. It can be ordered by e-mail from [info@geozentrum-hannover.de](mailto:info@geozentrum-hannover.de) or downloaded from [www.bgr.bund.de/resource](http://www.bgr.bund.de/resource)**



*'Resource' provides information on the current research projects.*

## New source of information: BGR launches newsletter

The Federal Institute for Geosciences and Natural Resources (BGR) has enlarged its range of information sources. The first digital 'BGR Newsletter' with ten exciting articles from the geoscientific world was published for the first time on 21 July 2009.

The 'BGR Newsletter' will be published quarterly in future. "With this new channel, we wish to provide people involved in politics, industry, science and the media with even more up-to-date and more specific and more comprehensive information on our many activities and the latest results of our research," says BGR President Prof. Dr. Hans-Joachim Kuempel. "The newsletter is BGR's visiting card. It should provide an insight to the public at large on the work carried out by our scientists, as well as the quality of our geoproducts," explains the BGR President.

The articles in the newsletter reflect BGR's fields of activity. As the German government's geoscientific competence centre, BGR provides politics and industry with advice and information on all geoscientific and georesource industry questions, and has done so for more than 50 years. The topics include energy and mineral georesources, groundwater and soil, the subsurface as a storage and economic zone, as well as geoscientific information and international cooperation. "BGR has been assigned the task of undertaking research and providing advice on maintaining and where possible improving living conditions by the responsible use of georesources. BGR's activities are therefore of extremely high public relevance," says Kuempel.

The first newsletter contained an article on BGR's new organisational structure. It also includes reports on new projects and products, in-depth analysis of geoscientific questions and events, as well as an article on the ceremony celebrating the 50<sup>th</sup> anniversary of cooperation between BGR and the Hashemite Kingdom of Jordan.

Interested parties can subscribe immediately to the 'BGR Newsletter' by submitting their e-mail address. The 'Newsletter' link ([www.bgr.bund.de/newsletter](http://www.bgr.bund.de/newsletter)) is in the internet on BGR's homepage. Subscribers can choose between an HTML and a text version. After submitting your order, you will receive an automatically generated e-mail containing a link to confirm your order. The order only becomes effective by clicking on this link.

The newsletter is sent out by e-mail. Every article contains a direct link to the BGR website where more detailed information is provided on each topic.



## Hans-Joachim-Martini-Prize 2008 and 2009

The Hans-Joachim-Martini-Foundation set up to honour the memory of the long-standing president of the former Federal Institute for Geological Research (today's BGR), Prof. Dr. Hans-Joachim Martini, was established in 1987 and sponsors geoscientific work conducted at BGR. The Hans-Joachim-Martini-Prize is worth Euro 3,000 and the foundation's junior scientist prize is worth Euro 1,500.

### 2008

Awards for two BGR scientists: The mineralogist Dr. Kristian Ufer was awarded the Hans-Joachim-Martini-Prize for his pioneering work in model development, and publications on mineral analysis. The microbiologist Dr. Dagmar Kock received the young scientist prize awarded by the foundation for her thesis presenting a new method for biological metal extraction. "The awards highlight the high scientific calibre of the basic research carried out at BGR," says BGR President Prof. Dr. Hans-Joachim Kuempel who handed over the foundation prizes on behalf of the Hans-Joachim-Martini-Foundation.

Dr. Kristian Ufer does research at BGR as a guest scientist from the Technical University BA Freiberg in the field of engineering mineralogy and clay mineralogy, looking specifically at the 'Development of structural models for the Rietveld quantification of swelling illite/smectite intercalated minerals in rocks'. His work won the award because he found a practicable solution to what had been considered for decades as an unsolvable problem. Dr. Ufer developed structural models which use software which can be operated by non-specialists to properly quantify the proportions in typical mineral-rich sedimentary rocks. The precision with which the weighed-in mineral constituents of model mixtures – even with completely different starting values for crystallographic parameters – can be identified is remarkable. After the start of refinement, the software user no longer has to do anything – this also reduces the sources of error. In this way, the innovative scientific approaches applied by Dr. Ufer have created an extremely efficient analytical tool which can help e.g. the oil industry, to improve its forecasts of the underground geology when exploring for oil and gas fields.

Dr. Kock works in BGR's Geomicrobiology department and received her PhD from the Leibniz University Hannover. In her PhD thesis 'Investigations for the quantification of microorganisms in sulfidic mine waste dumps', she has successfully used microbiological methods for the first time for the quantitative analysis of microbial communities in three different mine tips. Various metals, including copper, are increasingly being extracted around the world with the help of environmentally-compatible biological heap leaching. The methods established by Dr. Koch can be used for monitoring as well as optimising biological leaching processes. The methods enable the number of active microorganisms to be determined within a few hours. High numbers of bacteria correspond to greater efficiency in biotechnological metal extraction.

### 2009

The geophysicist Dr. Katrin Schwalenberg was awarded the Hans-Joachim-Martini-Prize in 2009 for her pioneering work in the development of new methods in the field of marine electromagnetics. The geologist Dennis Lemke received the young scientist prize awarded by the foundation for his outstanding scientific degree dissertation where he discusses proposals for improving the methodology used to determine groundwater regeneration.

"The work undertaken by both prize winners confirms the high scientific calibre of BGR's basic research," explains BGR President Prof. Dr. Hans-Joachim Kuempel at the prize-giving ceremony. Dr. Schwalenberg's research work makes a key contribution to the development of marine electromagnetic surveying methods. Her work is also part of the SUGAR-A joint research project funded by the Federal Ministry of Education and Research (BMBF). BGR's work as part of this research project led to the development of a surveying system towed along the seafloor (HYDRA) which measures the electrical properties of the sediments beneath the seabed. This method can be used to explore for submarine gas hydrates as well as conventionally extractable hydrocarbons such as oil and gas. This area of application has raised the interest of the offshore oil and gas industry in electromagnetic surveying methods.

The surveying equipment is towed along the seafloor behind a research ship. The equipment consists of an electrical transmission dipole and several receiver dipoles connected to a data cable (max. 1 kilometre long). The transmission dipole sends out a radial electromagnetic signal which changes depending on the properties of the geology beneath the seafloor. Poor electrical conductors such as oil and gas hydrates, stand out clearly in the data. This modular system can be flexibly adapted for a whole range of surveying tasks.

Lemke's degree dissertation provides practise-oriented recommendations for qualitatively improved methods to determine the amount of groundwater recharge. Recharge takes place when water from precipitation or surface water percolates underground into the groundwater. Information on the amount of groundwater recharge is very important for determining the amount of groundwater which can be sustainably extracted, and therefore to define drinking water protection areas. In the dissertation which he did at Leibniz University Hannover in cooperation with the State Office for Mining, Energy and Geology (LBEG) of Lower Saxony, Lemke compared the existing methods with one another and used this analysis to develop recommendations for water resource management.

### International Geosport tournament at the GEOZENTRUM Hannover

The international Geosport tournament 2010 in Hannover finished with a victory by the Czech Geological Survey (CGS). The host BGR, together with athletic colleagues from the State Authority for Mining, Energy and Geology (LBEG) and the Leibniz Institute for Applied Geophysics (LIAG), bundled their sporting resources within the GEOZENTRUM Hannover team (GZH) and came in second place.

Over 120 scientists from four countries fought in five disciplines for points, goals and seconds. In addition to the victorious Czech team and the host team, the four-day Geosport tournament also involved teams from the French Geological Survey (BRGM) and the Polish Geological survey (PGI). The competition takes place every two years, being hosted alternately by the four national geological surveys and their affiliated sports associations.

The SBL-Bodenforschung e.V. sports association based at the GEOZENTRUM organised this year's meeting, and added a special new challenge to the competition programme by including a dragon boat race alongside the four classic disciplines of football, tennis, volleyball and badminton. The race on the Maschsee lake in the middle of Hannover, which was preceded by a welcome speech from Hannover's mayor Ingrid Lange, was the spectacular highlight of this competition of sporting power and stamina. The Czech team pipped the host team at the post by a tiny margin to win the first discipline, laying the foundations for its subsequent overall win.

The sporting scientists enthusiastically celebrated the end of the competition at the awards ceremony in the GEOZENTRUM canteen. The Czech team contributed beer, their French colleagues donated wine. In the presence of BRGM Director Jacques Varet, PGI Deputy Director Dr. Grzegorz Pienkowski and BGR President Prof. Dr. Hans-Joachim Kuempel, thunderous applause greeted the head of the Czech delegation, Zdenek Novotny, when he announced their willingness to organise the international Geosport tournament 2012 in Prague.

This now traditional sports event was the brain child of the former president of the BGR and the former Niedersachsen Geological Survey Prof. Dr. Hans-Joachim Martini. The Geosport tournaments began in 1968 with a football match between Czech and German staff from the two institutions. Tournaments have taken place regularly since 1978. "Many friendships have developed over the years," says Hajo Schnier, the main organiser of this year's meeting. This is helped by the informal atmosphere of the tournaments – including accommodating some of the guests from Prague, Orléans and Warsaw in the homes of GEOZENTRUM staff. Schnier: "In this way, the Geosport meeting makes a small contribution to international understanding and breaking down barriers in Europe."

## Future Day: Boys and girls on discovery day at the GEOZENTRUM

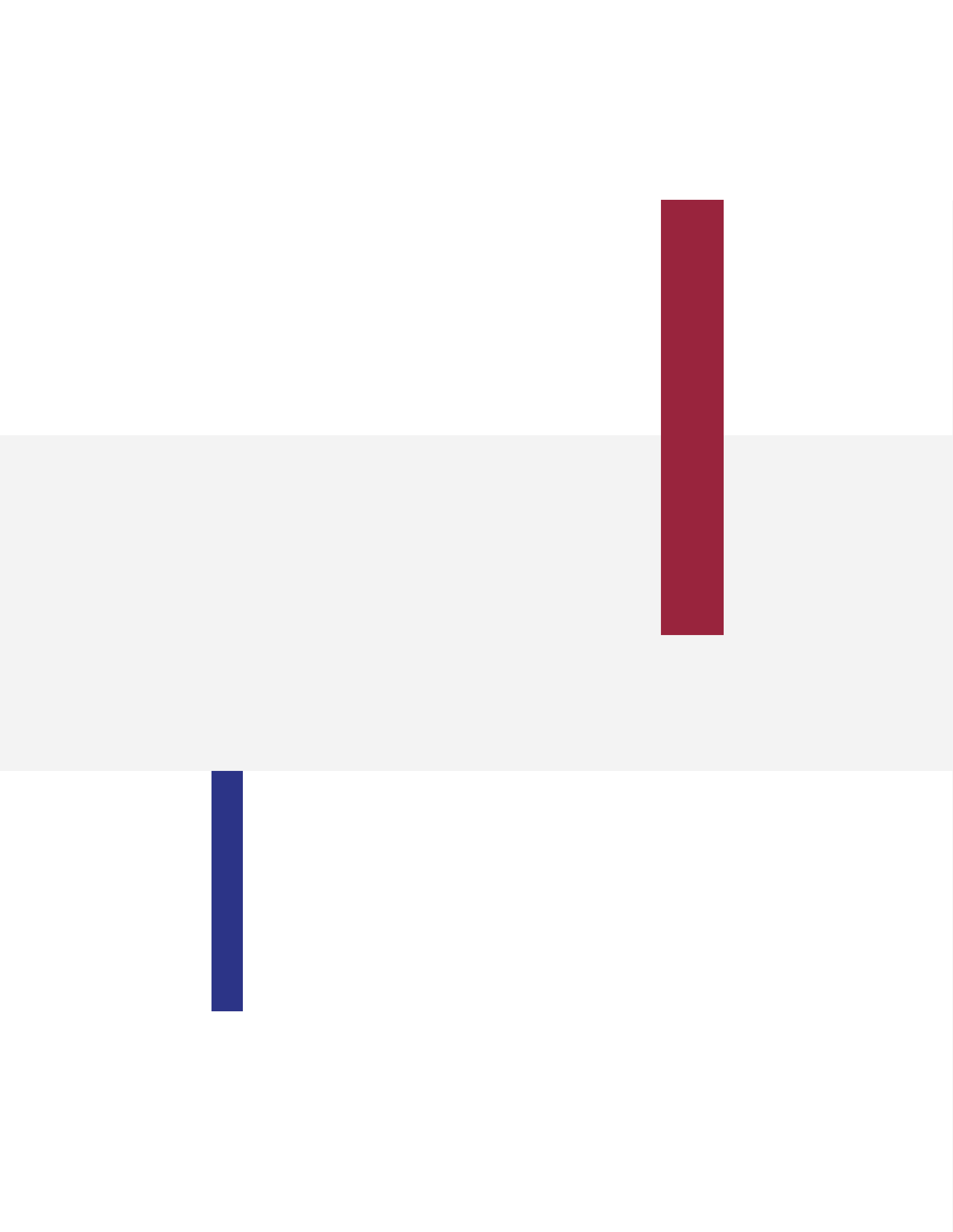
What do rocks tell us about life on earth? Why are there earthquakes? Which georesources do we need to make computers and mobile phones? Answers to these and many other exciting questions were presented to children at Future Day 2009 and 2010 in the GEOZENTRUM Hannover.

Experts from BGR, the State Office for Mining, Energy and Geology (LBEG) of Lower Saxony and the Leibniz Institute for Applied Geophysics (LIAG) showed them the importance of geosciences for our everyday lives. In this way, the geo-experts make an important contribution to the search for new sources of georesources, are actively involved in the protection of soil and groundwater, and make important information available in geoscientific databases.

The boys and girls were able to put their new found knowledge directly into practise in a few small exercises. The pupils learnt that researchers can use fossils to interpret climatic conditions existing several million years ago. And that valuable georesources such as gold, copper and tin can be found in computers, and that rock salt can withstand loads weighing several tonnes.



*BGR President Prof. Dr. Hans-Joachim Kuempel welcoming boys and girls at Future Day 2009 in the large conference room of the GEOZENTRUM.*



# Annex



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### Final Disposal of Radioactive Waste

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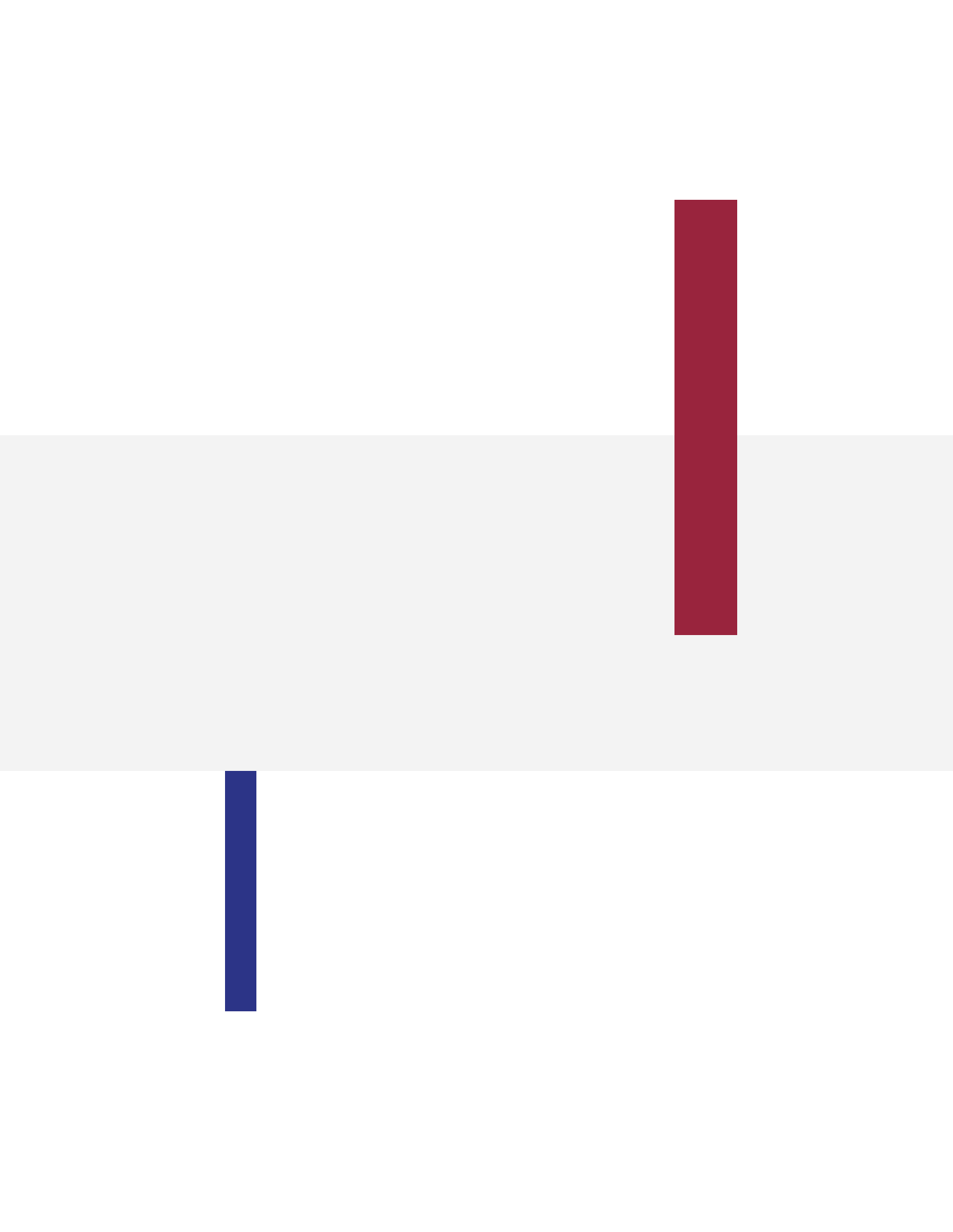
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Photographs with no named source are from present and former staff at the Geozentrum Hannover.





# Imprint



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## **Editorial Office**

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JANINE SEIBEL, HANS-JOACHIM STURM and SIEGFRIED PIETRZOK

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MHD – Druck und Service GmbH  
Harmsstraße 6  
29320 Hermannsburg