50 Years BGR
an Activity Report

Bundesanstalt für Geowissenschaften und Rohstoffe
Federal Institute for Geosciences and Natural Resources




1958
2008




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an Activity Report

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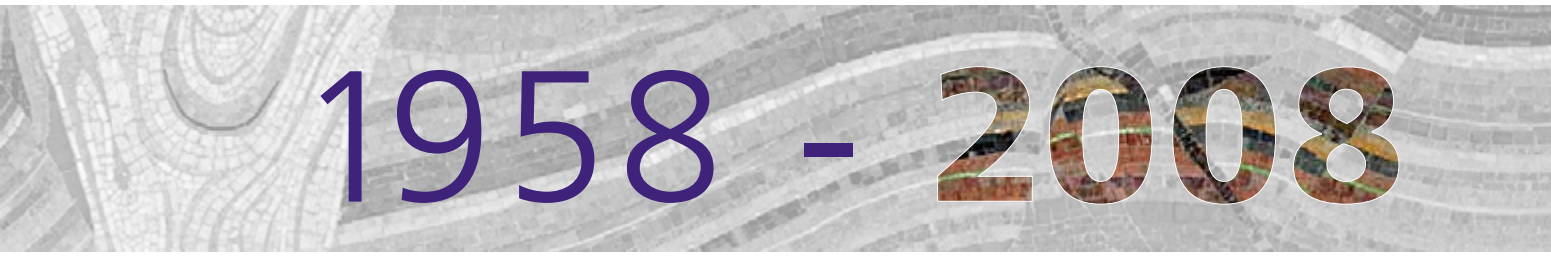
Federal Institute for Geosciences and Natural Resources



Hanover,
March 2009

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Foreword of the President of BGR

Dear Readers,

This biennial report from the Federal Institute for Geosciences and Natural Resources contains not only particularly noteworthy events for the period 2007 and 2008, but also highlights from the past 50 years. The reason: it is BGR's 50th anniversary.

BGR was founded as the *Bundesanstalt für Bodenforschung* (B.f.B. – Federal Institute for Ground Exploration) on 1 December 1958 on the initiative and by decree of the then Federal Minister of Economics, Prof. Ludwig Erhard. At the time, thirteen years after the end of the Second World War, the population had put a little distance between themselves and the period that had brought indescribable suffering to many people; the economic boom had begun. With hindsight, it still seems rather close to the turmoil of war.

It is worth noting that the three main tasks transferred to the Federal Institute upon its foundation are still being carried out today. They comprise:

- Execution and evaluation of investigations in the field of overseas ground exploration, inasmuch as such tasks are necessary in the course of international relationships,
- Advising the Federal Ministries on ground exploration issues,
- Scientific work in the field of ground exploration.

In 1975 the name was changed to the current Federal Institute for Geosciences and Natural Resources. It was renamed because 'outsiders' would not fully appreciate the extensive range of the Federal Institute's responsibilities.

This volume provides an insight into the diversity of the activities carried out by today's BGR and into the continued relevance of the scope of its work over the last five decades. We hope you enjoy reading it.

My thanks go to the Federal Minister of Economics and Technology Michael Glos, President Lothar Lohff, Director Prof. Ugur Yaramanci and the chairman of the BGR board of trustees Prof. Kurt M. Reinicke, for their opening words, and in addition to everybody involved in making this volume possible. I would also like to thank all former and current BGR staff, whose excellent work over the past 50 years has made the BGR what it is today: the federal government's geoscientific centre of excellence for energy resources, mineral resources, groundwater, soil and the underground space for storage and economic use.

It is a happy coincidence that BGR can celebrate its jubilee in the core year of the International Year of Planet Earth (IYPE), as proclaimed by UNESCO. You will therefore find the IYPE logo at a prominent place in this volume.

If you have any questions about what we do – perhaps as a result of reading this report – or about the projects detailed here, please call me or send me an email.

Yours

Prof. Dr. Hans-Joachim Kümpel
BGR President

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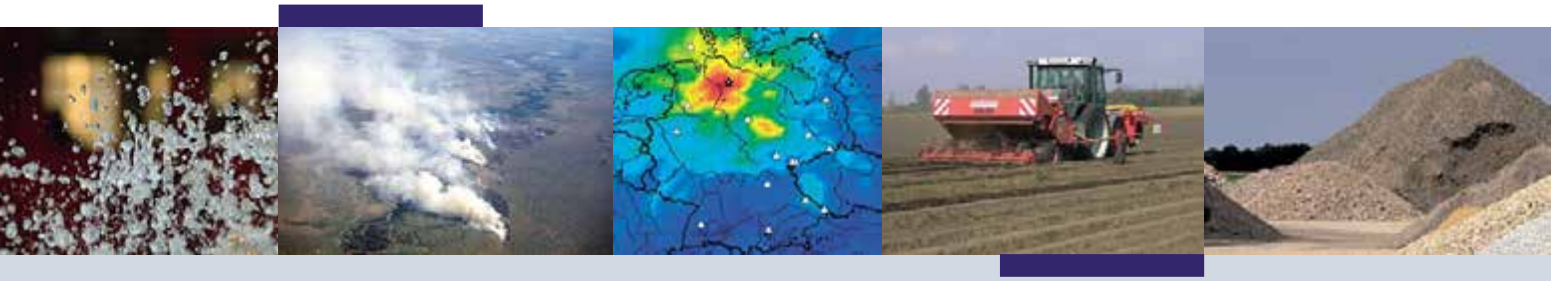





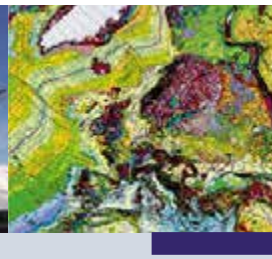

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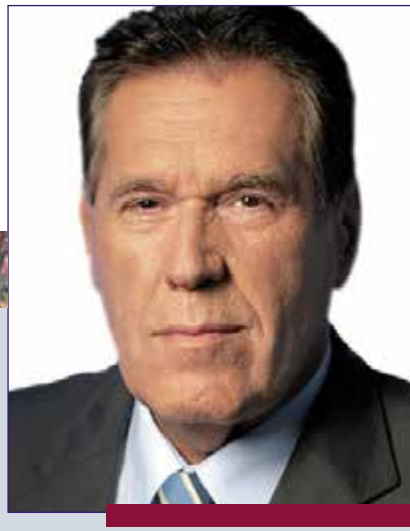


The Federal Minister of Economics

Dear Readers!

The BGR will soon be celebrating a milestone birthday. This is of course a fitting reason for congratulations, but also provides an opportunity to look back at the past and forwards to the future. It was fifty years ago, on 26 November 1958, that Ludwig Erhard, the first Federal Minister of Economics, established the BGR by decree as the federal government's central geoscientific advisory body. In terms of a human lifetime, 50 years is a fairly long period of time, but one that we can comprehend. However, to geoscientists, it must appear relatively short, as on a geological time scale of several billion years, 50 years is not much more than a brief flash.

Today, just as 50 years ago, the BGR makes a vital contribution to providing Germany with secure natural resources. During the last few years prices for energy and metallic resources, in particular, have risen drastically. Germany is largely dependent on imports for these important resources, which our economy requires to maintain prosperity and jobs. We therefore continue to rely on the work of the BGR in prospecting for and exploring previously undiscovered resource deposits, which can help us to secure supplies for industry.

The BGR can build on many years of experience in the field of hydrocarbons exploration. One example is the research work being carried out in the Russian Arctic. Based on information gained from research in the Laptev Sea in the 1980s and '90s, the BGR is currently carrying out research into oil/gas systems in close scientific cooperation with the All Russian Research Geological Institute (VSEGEI) in St. Petersburg. The results of such investigations are helping to relieve the tensions on the resource markets in the medium term. I would greatly welcome early support for this research from German industrial partners.

In addition, the BGR is an important and expert contact for the federal government in the international seismological monitoring of the Comprehensive Test Ban Treaty (CTBT). Our common objective is to work towards a permanent worldwide cessation of nuclear tests. The BGR supports us in achieving this objective by operating four of a total of 321 monitoring stations planned worldwide and running a national seismological data centre. This is a vital contribution to securing world peace.

The importance of the BGR is reflected not only in resource, foreign and defence policy issues, but also in questions of economic and technology policy in the broader sense. For example, let me emphasise the role of the BGR in the INSPIRE1 process (INSPIRE – Infrastructure for Spatial Information in Europe).

Through its active participation in formulating the EU Directive on establishing an EU-wide geodata infrastructure, which came into force on 15 May 2007, the BGR also helped to develop the technical aspects of this directive.

The BGR's expertise is also indispensable in the development of power stations that burn fossil fuels, but produce only little CO_2. This work represents active climate protection. In this context the research and development work carried out by the BGR on the safe and environmentally friendly sequestration of CO_2 in the geological underground is absolutely crucial to the German power industry and to energy policy as a whole.

I was particularly pleased with the result of the Science Council's evaluation of the BGR, in which it found the institute to be an excellently staffed and managed scientific-technical federal institute under the auspices of the Federal Ministry of Economics.

This is consistent with the excellent impression I gained of the georesearchers during my visit to the BGR on 5 July 2007. We have taken on board the recommendations of the Science Council, and the new leadership and our board of trustees will work together to improve the BGR even further and to achieve the optimum possible strategic positioning.

I would like to see the BGR succeed in maintaining and improving its excellent position in the German and international geoscientific community. We will actively support the BGR in this undertaking.

Good luck!
Yours

Michael Glos
Federal Minister of Economics and Technology

The President of the LBEG

Dear Readers!

The Club of Rome certainly drew the world's attention to resources as a limiting factor to the growth of our civilisation in its 1972 report 'The Limits of Growth'. And later on the Club of Rome certainly also intended to draw our attention to this vital basis for the development of human civilisation with new information on the state of our resources. And human civilisation today certainly does not have the knowledge or the experience to know when it must end the Resource Age.

But there is one thing we do know:

By ceaselessly searching, and with extraordinary energy, geologists and engineers worldwide have again and again extended the resource base whenever resource prices have made it possible. Other great inventive minds have developed technologies that bring about continuous development away from, for example, energy resources towards new energy production or more economic technologies in the face of rising resources prices.

Working closely with politics, science and industry, the finest intellects will prepare the way to make the end of the Resource Age and our richness of resources as smooth a transition as possible.

The work of the Federal Institute for Geosciences and Natural Resources contributes greatly to finding this way forward, especially with regard to the scientific aspect. It successfully supports the federal government and industry in finding the correct framework for decisions that will shape the future.

It does not focus solely on the Earth's resource base, but also on the 'new technologies'. It does this today in the same internationally recognised way as it has over the last 50 years, when it faced challenges of a completely different nature.

I hope that we and our colleagues at the BGR may share in solving the problems that our future poses, using the modern technology available.

Glückauf!

Lothar Lohff
President of the *Landesamt*
für Bergbau, Energie und Geologie

The Director of the GGA-Institute

The 50-year anniversary of the Federal Institute for Geosciences and Natural Resources marks more than merely the time it has been in existence! To view this agency purely as a legal body would too short-sighted. In actual fact this jubilee reflects the work, the will to shape the future, the scientific inquisitiveness, the love of order and the very personal commitment of the people who have worked both in and for this scientific agency over the past 50 years. On this occasion my opening words can therefore only be directed at the men and women who have used their work and innovative abilities to shape the BGR, and whose activities have benefited the Federal Republic and also further afield.

The scientists and technicians at the GGA Institute have been working under one roof with their colleagues at the BGR for many years, and their great mutual esteem cannot be valued highly enough by either institute. This produces numerous synergy effects, some of which are clear to see, but most of which are generally unspectacular, yet have a powerful effect.

The *Geozentrum* in Hanover houses the large Federal Institute for Geosciences and Natural Resources. Together with the LBEG and GGA Institute, it is a centre of excellence for geosciences and geotechnologies, focussing on well-founded, long-term and sustainable scientific and consultation services rather than short-lived sensationalism.

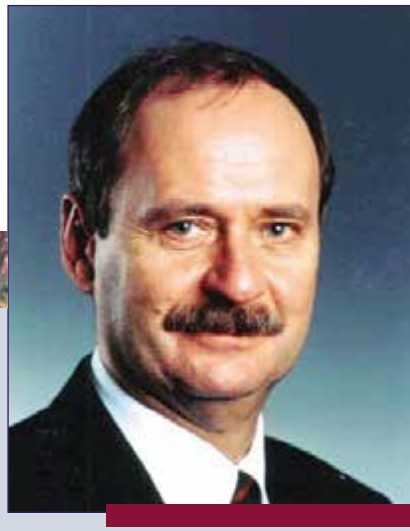
We would like to thank the BGR and its staff, and also those people in positions of responsibility in ministries, and on supervisory and consultative bodies, and express our great respect for 50 years of expert service and continuity.

It only remains to say that we hope that the good ship BGR can be held on this precise course in the future, a course which is oriented to the benefit of the Federal Republic of Germany, of Europe and even further afield, and that it continues to maintain its scientific and technical integrity, even where controversial topics are involved. I need not emphasise that success automatically guaranteed, but must be achieved again and again and thus requires continuous effort. The GGA Institute wishes all BGR staff and executive bodies the best of luck in their endeavours.

Good luck

Prof. Dr. Ugur Yaramanci
Director of the *Institut*
für Geowissenschaftliche Gemeinschaftsaufgaben

The Chairman of the BGR Board of Trustees



Dear Readers!

The Board of Trustees congratulates the BGR and its staff on its 50th birthday.

During the past five decades the BGR has developed into an irreplaceable advisor in all geoscientific and resource policy issues and worldwide representative for German geoscientific expertise. Its work for the federal government and the German economy is indispensable and increasingly important. If the BGR did not already exist, it would have to be invented and immediately established today.

The BGR's work helps to secure our living conditions by extending our knowledge in the fields of natural resources, the use of water, soil and subsurface storage. Worldwide changes in energy and mineral resource markets and associated displacements in production and supply structures, the increase in world population and the concomitant increase in energy consumption, foreseeable bottlenecks in water supplies and many other global factors are also highly relevant to Germany. Analysis of these factors in conjunction with in-house research on the topics involved puts the BGR in a leading position both nationally and internationally, thanks to the expertise of its staff and the quality of their work.

The BGR's early years were characterised right into the 1970s by the reconstruction of post-war Germany. The rate of economic growth in Germany was high, and in order to facilitate further growth questions of resource and energy resource security, both domestic and overseas, had to be urgently addressed. Pioneering work in this field includes exploration and mapping of the deep subsurface of the Federal Republic of Germany and ground-breaking work in preparation for worldwide industrial activities, e.g. geophysical surveying in the North Sea, in northern Norway, off the coast of west Africa, in the Arctic and Antarctic, and fundamental work on deposits of natural mineral resources and studies relating to undersea mining.

Mounting damage to the environment and spectacular accidents in the 1970s and 80s (Seveso, Amoco Cadiz, Chernobyl) resulted in the increasing importance of environment-related topics and a new focus on water and soil science at the BGR, aimed at contributing to active and preventive environmental protection. The BGR thus increasingly began to work towards sustainably satisfying the basic needs of water and soil, in particular for developing and emerging economies. The final disposal of radioactive waste was one of the focal points, a topic that will continue to occupy the BGR for a long time, despite the fundamental work already carried out.

The surplus of resources during the late 1980s and 90s as a consequence of energy and resource savings and successes in resource exploration, resulted in price collapses and considerable cut-backs in exploration and development activity. This had consequences for the geoscientific field in particular. The industry redundancies were accompanied by unremitting efforts to achieve greater effectiveness and efficiency by improving management. Many of the management practices developed in industry in this context were adopted by the BGR thanks to the support of the Board of Trustees. Examples include the introduction of a fixed planning cycle with a research plan and programme budget, cost and performance accounting, regular reviews for monitoring our own performance, etc.

Quite correctly, from the very beginning the BGR has aimed at close cooperation with both the private sector and the scientific community at national and international level and has thus attained a wide knowledge base on a broad front.

As has happened in the past, the altered environmental conditions of recent times, characterised among other things by high resource prices, the development of renewables, the climate discussion and the CO_2 problem, Europeisation and globalisation, plus the world's increasing population, is reflected in the orientation of the BGR's work. By continuously adapting to new situations the BGR has managed to integrate such changes and thus to maintain and advance its leading position. This course will be continued. The important factor here is continued focus on the core tasks and core expertise, and constant readjustment of the balance between short-, medium- and long-term projects.

The Board of Trustees is also happy to continue offering advice to the BGR management and the Federal Minister of Economics and Technology both on these questions and on the future evolution of the organisation, further increasing efficiency and links to industry.

The Trustees, the BGR management and all employees are very pleased with the performance of the past five decades. We wish you continued success and recognition in the future.

Good luck on behalf of the Board of Trustees

Prof. Dr. Kurt M. Reinicke

The BGR – looking ahead

A review of highlights from the past 50 years such as those presented in this volume also encourages us to look to the future. Quo vadis BGR? Which developments will shape its work? Where do the greatest challenges lie?

Although the tasks transferred to BGR in its founding decree have lost none of their relevance, the social and science policy environment in Germany has changed dramatically since then – as it has in the rest of the world. Three cases emphasise this:

1. A number of important non-university research institutions in Germany have either been established or fundamentally reformed, particularly since the 1980s, and have been carrying out excellent research in geoscientific fields: the Alfred Wegener Institute for Polar and Marine Research, the German Research Centre for Geosciences Potsdam in the Helmholtz Association (GFZ), the Helmholtz Centre for Environmental Research (UFZ) in Leipzig, the Leibniz Institute of Marine Sciences (IfM-GEOMAR) in Kiel, the Leibniz Institute for Applied Geosciences (GGA) in Hanover and the geoscience-oriented Institutes at the Jülich Research Centre are just some examples.

   Today, BGR undertakes joint projects with all of these institutions or coordinates new projects with them during the planning stage. Many of their management personnel are reciprocally members of scientific advisory boards or the boards of trustees for the respective institutions.

2. The geosciences themselves have made giant strides over the last 50 years. The revolutionary theory of plate tectonics – in conjunction with the paradigm change that the appearance of the Earth is characterised less by vertical than by horizontal displacements of large areas of the Earth's surface – was not firmly established until the end of the 1960s. For many of the disciplines in which research was once carried out separately at universities, such as geology/palaeontology, geophysics, mineralogy/crystallography, pedology, geodesy, geochemistry and more, it has finally been recognised that the great geoscientific problems need to be addressed together.

   These developments have led to strong growth in, or the creation of new, generally topic-related fields of research, which take a holistic view of the Earth system. Examples include geo-risk research, climate research, ecosystem research and sustainability research. Clear demarcation of these fields of research – and this is characteristic of modern geoscience disciplines – is not possible. Recognition of the fragility of our existence and its total dependency on the condition of our planet and the course of the numerous dynamic processes taking place upon it demand considerably more comprehensive, broader-based research efforts than our scientific teachers imagined 50 years ago.

3. And finally, the degree of globalisation is far greater today than it was in the 1950s. For example, where overseas visits by high-ranking civil servants were previously relatively rare events, today they are part of day-to-day business. The extent of trans-boundary goods traffic on land, on water and in the air has increased by orders of magnitude – and forms the backbone of our economy and prosperity. Natural resources play a decisive role in this.

   As a result, the extent of consultation for ministries and industry carried out by BGR staff has increased considerably over the past few decades. Numerous internationally active scientific organisations and institutions have been established and BGR performs important coordinating functions in a number of them, for example the International Union of Geological Sciences (IUGS), the International Union of Geodesy and Geophysics (IUGG), the Integrated Ocean Drilling Programme (IODP) and its precursor the Ocean Drilling Programme (ODP) and in EuroGeoSurveys, the Association of the Geological Surveys of Europe.

Against this background, looking at BGR's future was also the subject of a recent evaluation by the Science Council of the federal government. In its final report, dated 9 November 2007, the council recognises that BGR's research and development work and its knowledge-based services are of great public importance; these services secure sustainable supplies of both energy and mineral resources for the economy and the public. In this context the services of the Federal Institute are acknowledged as attaining a high scientific standard and BGR is identified as an internationally leading state geological survey.

Among the Science Council's statements on BGR's fields of activity is the request to maintain the existing research component at 40% – as the basis for qualified advice to politics and industry. BGR itself views this as advance and applied research, and it is anticipated that the results will be implemented in the foreseeable future, i.e. from several years to a few decades. BGR thus also supports the initiatives of several different groups aiming to see geoscientific research serving the most important requirements of society more strongly than has previously been the case. This aim is also expressed in the 2007–2017 programme of the United States Geological Survey (USGS). The USGS sees the most important primary objective as maintaining or reinstating ecosystems which can promote human well-being and lead to a healthy existence. Taking the provision of society with the necessary natural resources into consideration, this view incorporates the sustainability aspect and thus the preservation of ecosystems, which comprise the zones of the geological subsurface, the groundwater regime, soil, the Earth's surface, the hydrosphere and the air envelope, including the biodiversity existing therein.

The fields of expertise of BGR within the geosciences lie clearly in the georesources discipline. This includes natural mineral resources and energy resources, groundwater and soil, and also underground space, which provides possibilities for geological CO_2 storage or for final repositories for radioactive substances. BGR also has a high degree of expertise in the field of geo-safety. Last but not least, geodata and information systems also represent a 'resource'; they have played an important role in the work of BGR since its establishment and will continue to do so.

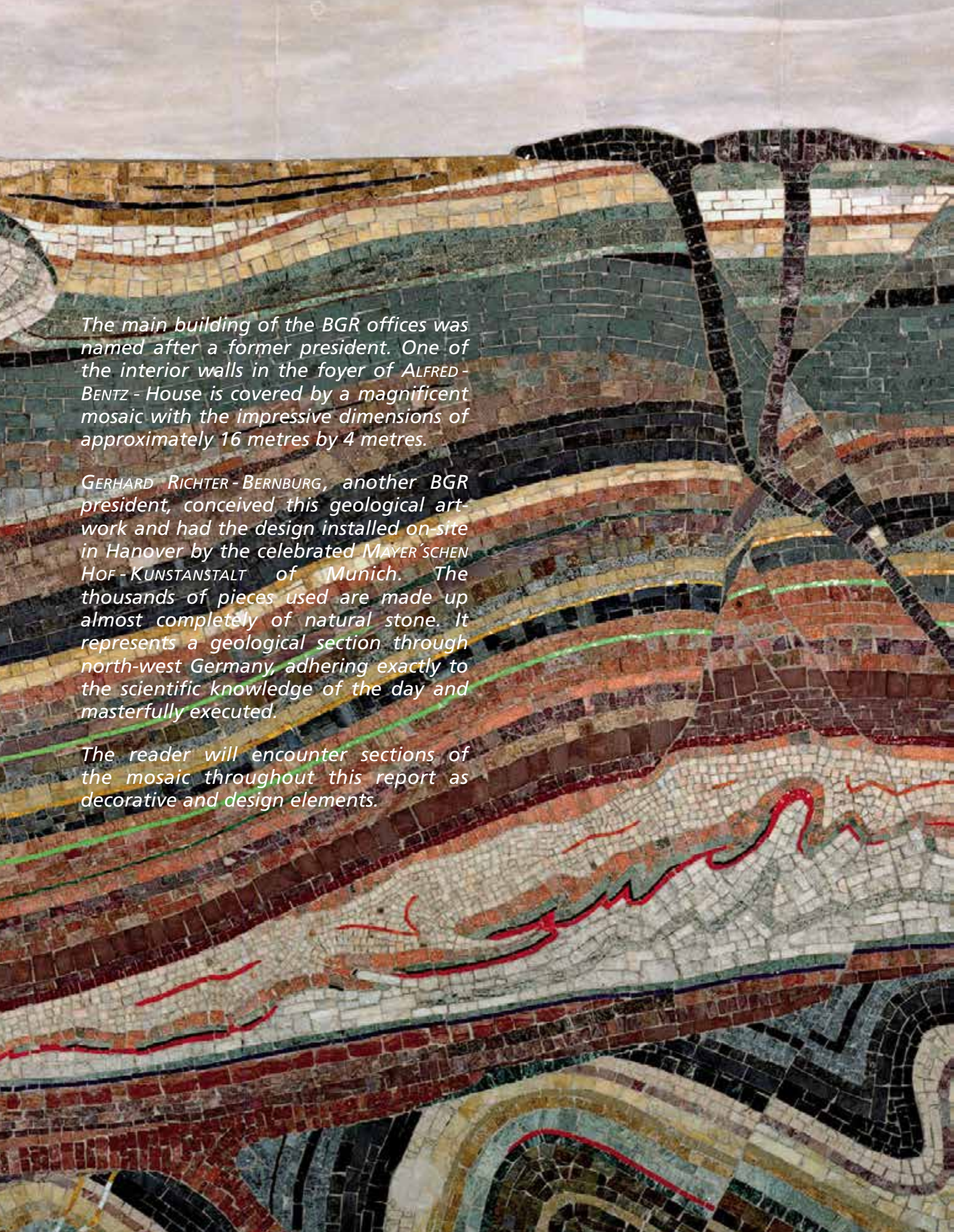
The importance of georesources for our existence is obvious in view of the recent drastic price developments in terms of natural mineral and energy resources, and the often dramatic scarcity of clean water and fertile agricultural land. This is in conjunction with an increasing world population and the advancing industrialisation of heavily populated countries in Asia, Africa and South America. Georesources will therefore increasingly be the frame for the activities of BGR. In the distribution of responsibilities with the geological surveys of the federal states, whose tasks lie within Germany, the fields of groundwater, soil and natural resources, are primarily European and overseas tasks for BGR, predominantly as part of projects involving technical cooperation. In this respect, sharpening the profile of BGR activities follows one of the principle recommendations of the Science Council, whose members I would like to thank again at this point for their valuable work.

At the end of 2007 BGR established a number of project groups, whose work is coordinated by a project team, to implement the recommendations of the Science Council. The aim of the proposed measures is to further increase the effectiveness of BGR and to cement its recognised position in social and scientific policy. This applies equally to the research sector, which is the focus of the Science Council's report, and the service-oriented sector. One of the actions taken will be greater monitoring of the numerous services for affiliates of BGR. In addition, special attention will be paid to new geoscientific topics for improving living conditions and the provision of public utilities and services, internal task reviews and flexibility. Externally, BGR will continue to seek further networking opportunities with other institutions so as to continue to offer a broad spectrum of geoscientific consultations as an independent agency in the future.

Cooperation with universities will be expanded for the mutual benefit of the universities, the BGR and young scientists. And finally, BGR will make additional efforts to make their work known in the scientific community and to the broader public. This includes raising public awareness of the topics dealt with by BGR to the population.

With these objectives in mind, BGR can look with confidence to the future as the federal government's centre of geoscientific excellence.

Prof. Dr. Hans-Joachim Kümpel



The main building of the BGR offices was named after a former president. One of the interior walls in the foyer of Alfred-Bentz-House is covered by a magnificent mosaic with the impressive dimensions of approximately 16 metres by 4 metres.

Gerhard Richter-Bernburg, another BGR president, conceived this geological art-work and had the design installed on-site in Hanover by the celebrated Mayer'schen Hof-Kunstanstalt of Munich. The thousands of pieces used are made up almost completely of natural stone. It represents a geological section through north-west Germany, adhering exactly to the scientific knowledge of the day and masterfully executed.

The reader will encounter sections of the mosaic throughout this report as decorative and design elements.

Board of Trustees

The German Minister for 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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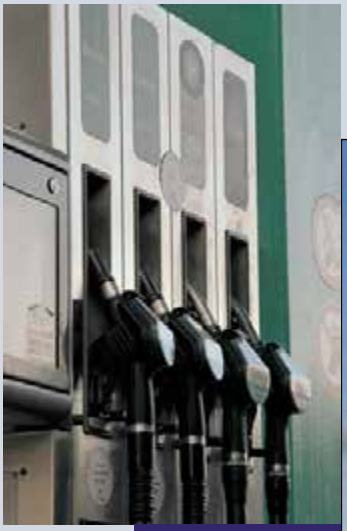
Natural Resources

Natural gas drilling at Lilienthal-South.

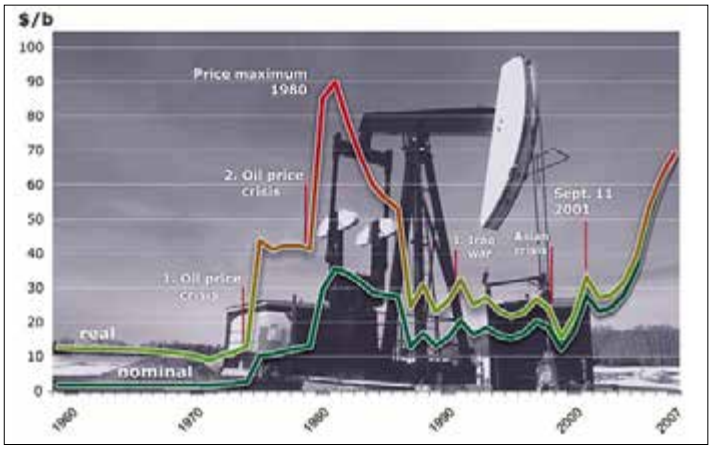
Energy Resources



50 Years of Energy Resources

The energy resources sector has seen great changes over the past 50 years. While crude oil cost only $2 per barrel in 1958, at the beginning of March 2008 it was over $100. Between these two dates the price of oil has fluctuated, influenced by numerous major events; the most important of these include:

- Autumn 1973: First oil crisis
- 1978/79: Second oil crisis
- Oil price collapse after expansion of Saudi Arabian crude oil production
- 1998/99: Further oil price collapse to less than $10/barrel as a result of the Asian crisis
- As of 2003: Large oil price increases.



Oil price development during the last 50 years.

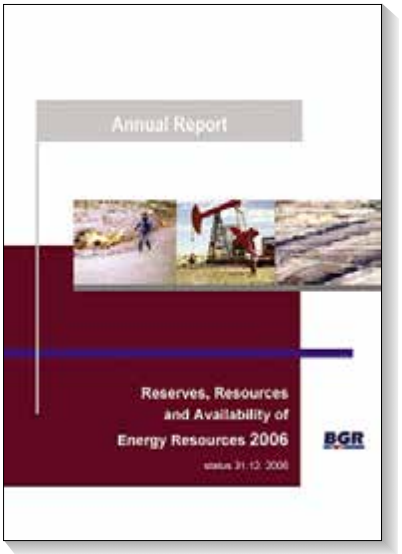
These developments had consequences for both the activities of international oil companies and for other energy resources, as their prices are indirectly coupled to the price of crude oil. The high oil prices of the mid-1970s to the mid-1980s initiated increased activity in exploration for, and research into, energy resources, which led to the discovery of rich natural gas and oil fields in the North Sea, among other things. At the same time, the high oil prices also initiated increased research activities into the use of non-conventional energy resources, i.e. resources only extractable at high cost, such as oil sands and shales, and in the field of alternative energy sources. In contrast to this, the oil price collapse of the mid-1980s and at the end of the 1990s led to a considerable decrease in these activities.

The orientation of BGR's work in these fields was also influenced by these developments. It was nevertheless possible for us to maintain continuity in our work, despite some heavy redundancies, and thus to remain an expert consultation partner for politics and industry.

One important aspect of our advisory activity for the federal government included the compilation of energy studies on the global situation with respect to the finite energy resources crude oil, natural gas, coal and nuclear fuels, and geothermal energy. These exhaustive studies formed the basis for Germany's energy forecasts. An initial study of this kind was compiled in 1976 in cooperation with the German Institute for Economic Research (*Deutsche Institut für Wirtschaftsforschung, DIW*). Further studies were carried out about every five years. Our global database represents an important building block in the compilation of these studies, which are also an important source of information for universities, industry and the general public.

BGR-publications: **Reports on Energy**

1976	**Die künftige Entwicklung der Energienachfrage und deren Deckung** *Future Development of the Demand for Energy and its Fulfillment* – Prospects until 2000 – Part III: The Supply of Energy Resources
1980	**Survey of Energy Resources 1980** (for 11th World Energy Congress, Munich)
1989	**Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen** *Reserves, Resources and Availibility of Energy Resources*
1995	**Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen**
1998	**Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen**
2003	**Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen**
since 2005	Annual Report (also in German as "***Kurzstudie***"): **Reserves, Resources and Availibility of Energy Resources** (front page reproduced on the right)



In 1969 the federal government initiated a federal funding programme to improve Germany's crude oil supply. In particular, it supported the overseas activities of German companies involved in the exploration and production of crude oil and natural gas. The programme led to the establishment of the Deminex Oil Company (*Deutsche Erdölversorgungsgesellschaft mbH DEMINEX*). Funds of almost 2.4 billion German Marks were paid out as loans and grants by 1989, of which approx. 760 million German Marks were repaid by the end of 1997 when DEMINEX was either dissolved or split up. BGR accompanied this programme as expert witness for the federal government. In the period of DEMINEX's activities more than 200 million tonnes of oil equivalent were discovered, and more than 100 million tonnes of crude oil and 16 billion m³ of natural gas produced. First oil production resulting from this programme commenced in 1978 in the Thistle field in the British North Sea. Work was carried out on almost every continent, with the main focus in the North Sea, the Middle East, North Africa and Indonesia.

Technical cooperation with developing countries also played a prominent role and there have been major changes in this field in recent years. In the early years, the emphasis was on direct cooperation with partners in prospection and exploration, including exploration activities funded in part by us within the scope of financial cooperation. This led, among other things, to the discovery of natural gas deposits in Bangladesh. In recent years the emphasis has moved to training personnel and to consultation and building geological institutions. The importance of the resource sector declined considerably in line with the reorientation of development aid. It is only recently that consultations in this sector have regained some significance and BGR has become more active.

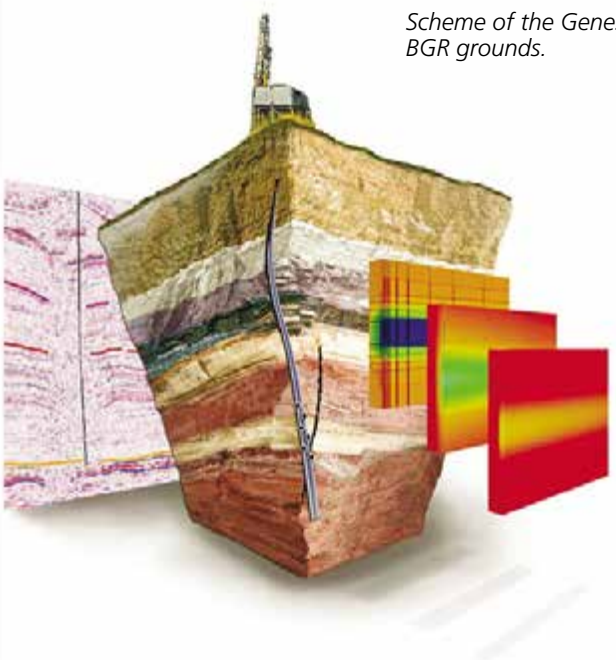
In almost 50 years of cooperation with developing countries BGR specialists have made important contributions to developing the resource base in many countries and on almost every continent. For example, in countries such as Bangladesh, Pakistan and Myanmar, the foundation was laid for the discovery of important natural gas deposits, in the Philippines, Turkey and Malaysia coal fields were discovered and uranium prospection has been supported in numerous countries. Even unconventional energy resources have been the subject of investigation. In the 1980s, for instance, BGR carried out extensive work in investigating oil shale deposits in Jordan; the results today form the basis for widespread industrial activity. Geothermal energy has been a significant field in recent years. East African countries and Chile were provided with support in the development and utilisation of geothermal energy in the course of the GEOTHERM programme. This field will continue to be important in the future.

BGR carried out wide-ranging research activities to support this work, comprising geophysical surveys, primarily offshore in seas, laboratory tests, and their joint evaluation and interpretation. This work profited from the many disciplines represented in BGR and their interdependencies, as well as intense cooperation with universities, research facilities and industry. The research work was related to both German domestic topics such as uranium and thorium prospection (1960s), deep natural gas exposure projects (1970s) and deep gas (1990s), in close cooperation with industry and universities, and to numerous international activities. These included the evaluation of buried grabens in Africa in terms of their hydrocarbon potential (1980s) and extensive offshore seismic work for industry investigating the great oceans' continental shelves as future crude oil and natural gas exploration zones. The great interest taken by industry in the results of this work underlines the relevance of the investigations – as with the present case of the Laptev Sea. BGR is closely integrated in the network of international cooperation. It sits on international panels and was crucially involved in the compilation of the NW European Gas Atlas. It is currently involved in the Southern Permian Basin Atlas (SPBA).

Besides investigating traditional energy resources, BGR is also involved in the use of geothermal energy. For example, it is participating in a research project in Sultz in the Alsace region, which is investigating the options for using geothermal energy for generating electricity. The options

available for more general utilisation of geothermal energy for heating purposes at any location will be demonstrated at BGR's grounds in Hanover. New methods are being tested in the GeneSys project. In preliminary investigations the methods involved were tested in a former natural gas borehole. It is planned to commence drilling a well in Hanover in the course of this year.

With its work in the energy resources field, BGR is making an important contribution to securing Germany's supply of resources. It is also playing an important role in providing the wider public with information on current issues regarding the availability of energy resources, thanks to activities including its participation in the 'peak oil' discussion and other 'hot' topics. In terms of future energy supply security, it is investigating potential energy sources such as gas hydrates, coal bed methane and methods for improving the yield of existing crude oil and natural gas deposits, but also utilising geothermal energy.



Scheme of the GeneSys project in BGR grounds.

Research for the estimation of the **Hydrocarbon Potential of Siberia´s** Marginal Arctic Seas

The arctic polar regions are regarded as prosperous 'frontier regions' for natural resources. However, this probably considerable resource potential remains relatively untouched yet.

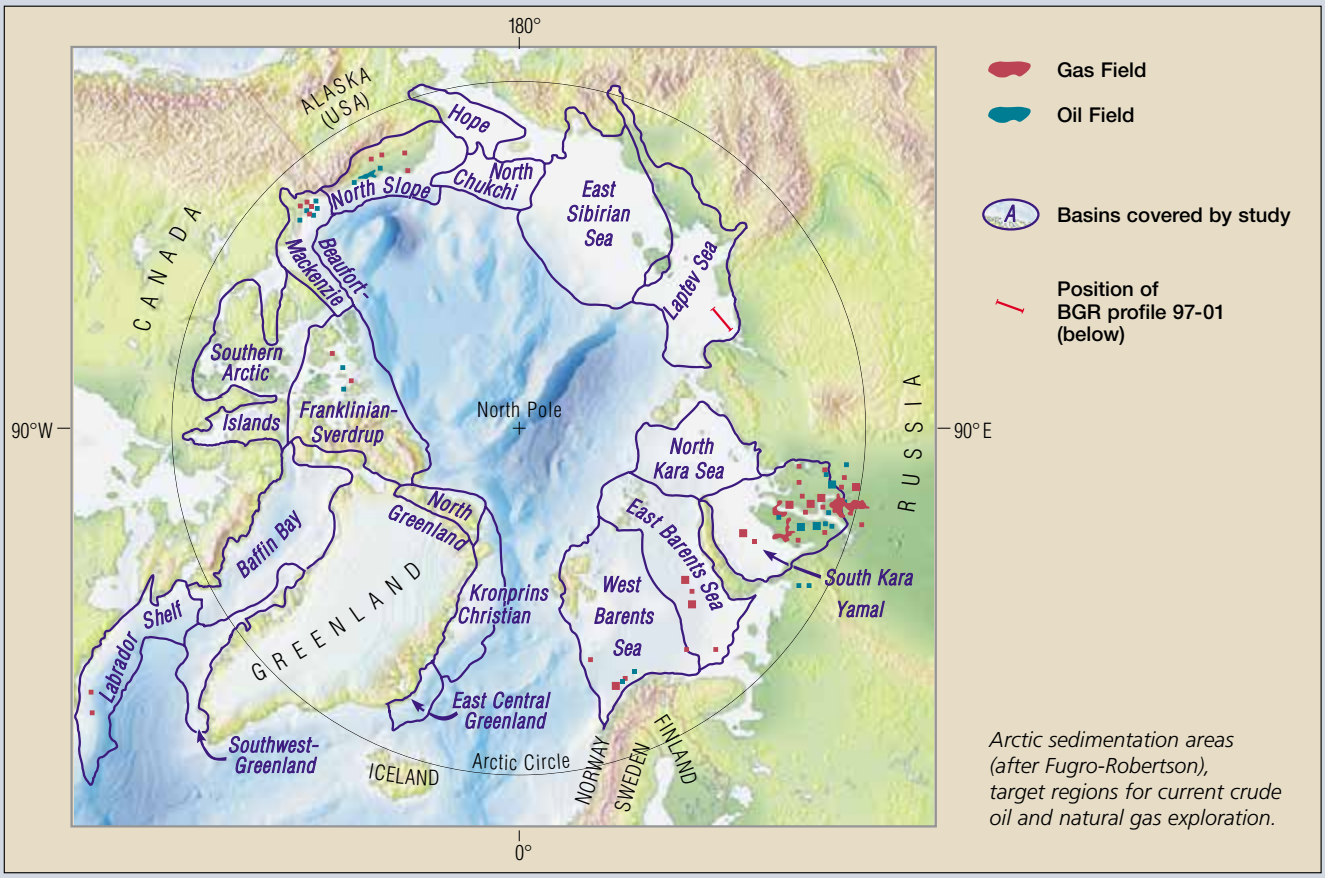
In the arctic shelf regions in particular, the crude oil and natural gas potential is thought to be very large due to the extensive sedimentary basins with significant sediment infill. However, reconnaissance and economic exploitation under arctic conditions represent considerable technical challenges and require enormous investments, influenced by the development of energy prices on the world markets.

Climate change and the projected retreat of arctic ice may, however, prove advantageous to the future development and utilisation of arctic resources, because the conditions for oil and gas production in the previously largely ice-covered Arctic Ocean may be altered and the arctic sea routes (for example the north-east passage) may evolve into useable transport routes for Siberian resources due to a decrease in ice cover.

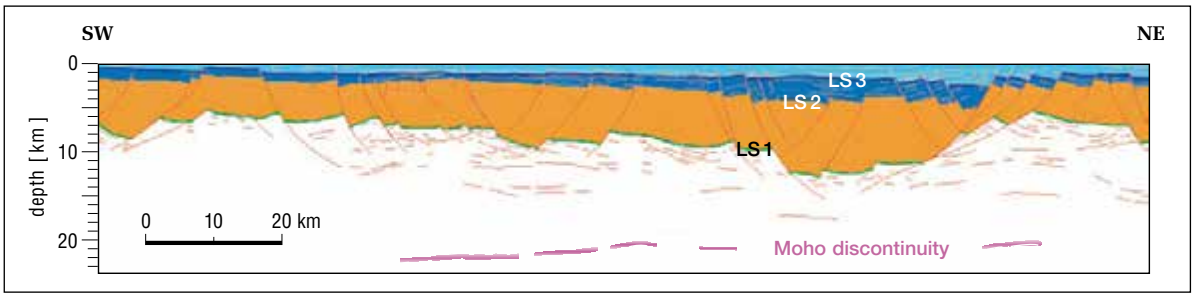
The arctic is defined as the region north of the Arctic Circle (latitude 66° 33" north) and covers an area of around 21 million km². The shelf area (water depths < 500 m) covers an area of around 7 million km², approximately the same area as the land areas. The USGS (United States Geological Survey) estimates that a quarter of all hypothetical crude oil and natural gas resources is situated within the Arctic. The potential crude oil and natural gas resources in the shelf regions are almost completely within the 200 nautical miles zones (exclusive economic zone) of the respective adjacent states.

A study by Fugro Robertson (Future of the arctic, November 2006) postulates that natural gas is far more likely to be discovered (85%) than crude oil (15%). Of the estimated gas reserves, 69% are located within Russia. More than 550 oil and gas fields (15% of the known global crude oil and natural gas resources) have already been discovered in the arctic, mainly in Russia. According to Russian information of April 2007 resources of more than 62.5 trillion m^3 of gas and 9 billion tonnes of crude oil are anticipated on the Russian shelf.

Research vessel in pack ice in the Laptev Sea.



Arctic sedimentation areas (after Fugro-Robertson), target regions for current crude oil and natural gas exploration.



Seismic profile 97-01 through the western region of the Laptev Sea. The principal regional horizons are: LS1 - Cretaceous/ Tertiary boundary, LS2 - Early Oligocene, LS3 - Late Miocene. The interpreted location of the Moho discontinuity marks the boundary between the crust and the mantle.

Offshore arctic production has previously been primarily concentrated in the shallow water zones off the coasts of Alaska, Canada and Norway. Currently, offshore production in the Russian Arctic takes place in the Barents Sea and the southern Kara Sea only. Besides these verified natural gas-bearing regions, the frontier regions northern Kara Sea, Laptev Sea and East Siberian Sea may be regarded as prospects based on their general geological structure.

In the run-up to industrial-scale exploration, BGR is carrying out geoscientific investigations in such frontier regions to develop an information and decision-making base for long-term German energy policy.

BGR has already been involved in three marine seismic expeditions in the far eastern Laptev Sea and East Siberian Sea, together with Russian partners, in 1993, 1994 and 1997. The aim was to scientifically investigate the structure and genesis of the geological subsurface and thus to form the basis for estimating the hydrocarbon potential. Although further surveys have been carried out in this region by Russian institutions, BGR data is still of unique value.

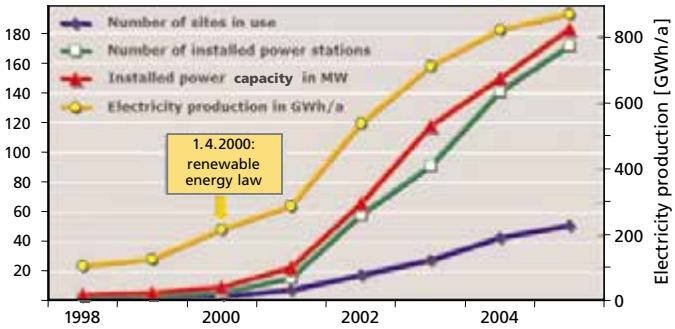
Because of the increased interest shown by energy companies in BGR's research results it can be seen that even these shelf regions in the Siberian Arctic, which are generally covered by pack ice, are increasingly the object of economic interest in line with increasing world market prices for crude oil and natural gas. Based on the information gained, a research agreement has been reached between several governmental or official institutions, including Russian, to investigate Siberia's Arctic sedimentary basin and its crude oil and natural gas potential. Research projects in cooperation with global companies from the oil industry make it possible to extend the knowledge gained, make available additional mechanisms for understanding the geological development of this frontier region and, based on this, make reliable estimates of prospects for the Laptev Sea and the East Siberian Sea.

A joint research project with an oil industry company is currently under way to reinterpret in detail the relevant data held by BGR. Together with the VSEGEI, BGR's Russian partner authority in St. Petersburg, the results of a joint VSEGEI/BGR land expedition to the mouths of the Khatanga and the Anabar rivers in the south-western Laptev Sea are currently being evaluated to facilitate the incorporation of geo-chemical and structural geology findings from the coastal regions. With this work, BGR is making crucial contributions to understanding the geological evolution of the arctic continental margins and to basic research for future exploration activities in the Siberian shelf regions. However, further investigations using 2D/3D seismic surveys and trial bores are needed to gain reliable estimates of the hydrocarbon potential of this previously largely unexplored region.

Mine Gas **Methane – Hazard** or **Energy** Source?

Methane gas is present in many mines worldwide. In coal mines in particular mine workers today still live with the danger of gas explosions. The reason for this is the gas methane (CH_4), which becomes explosive when mixed with air in a certain ratio. This can lead to devastating explosions causing enormous damage, sometimes even injury or death. This mine gas might also appear in salt and metal mining.

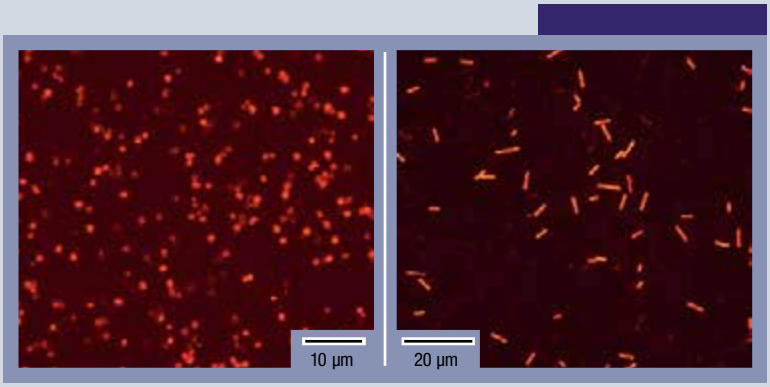
However, although mine gas is known to be extremely dangerous, it is also used as an energy resource. Both active mines and closed and abandoned mining areas, in which methane is still being released, are used for this. In the U.S. mine gas has been collected and utilised for energy production for many years, but this energy resource is also used in Europe (e. g. Germany, Great Britain, France, Poland, Czech Republic) . Frequently, at sites where mining is carried out – for example in the Ruhr Basin – regionally important small power stations are being developed and used for electricity generation or heat production. Unfortunately, the operation time of these power stations is not easy to predict, since not enough is known about the usable gas volume and the origin of the gas.

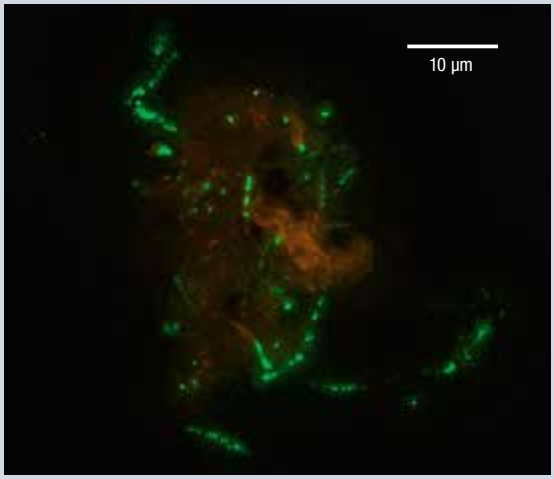


Development of mine gas utilisation in Germany.

Consequently, the Federal Institute for Geosciences and Natural Resources (BGR) is dealing with the question of how the gas originates. The main objectives of the research were to find out:

Impressions from the sampling campaign below ground in abandoned coal mines in the Ruhr Basin.





Detection of different cell types of methanogenic Archaea in incubations with mine timber (left) and coal, using fluorescently labelled gene probes (FISH) (middle) and their autofluorescence on mine timber particles (right, Picture: University Oldenburg).

- Is the methane exclusively formed by the coal being heated in the upper earth crust?
- What role do microorganisms play in the development of the gas?
- How long can methane from mining be used as an energy resource?
- What is the extent of the ongoing formation?

The BGR has investigated selected mines in the Ruhr Basin, and in so doing was able to identify not only the coal itself but also the mine timber used for securing the mines as a source of methane. Based on isotopic fingerprinting of the gases, this already suspected recent formation of methane through microorganisms could for the first time now be shown in the BGR laboratories as well as in the mines itself. Furthermore, it could be demonstrated that, in contrast to previous assumptions, not only do the high temperatures below ground (thermogenic formation) lead to the presence of methane, but also that microorganisms are significantly contributing to methane generation.

Based on these results it will be more easily and reliably possible to judge and estimate:

- subsequent future utilisation,
- globally transferable results on generation conditions,
- the contribution of mine gas to worldwide gas resources (approx. 7%).

Here, BGR provides an important basis for world-wide estimates of the potential represented by mine methane. It is already evident that local utilisation of this energy resource will – despite the risks that still exist – be an interesting method of energy generation in the future.

Limestone production in the Elbingerode open cast mine, Germany.

Mineral Resources

Production and sale of rhyolite as building stone near a road in Ethiopia.

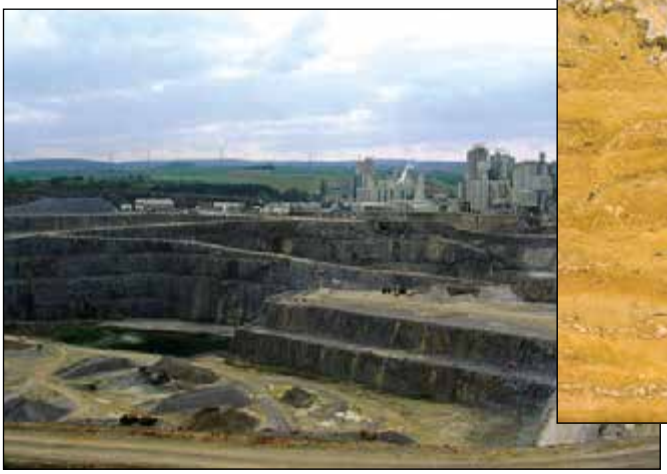
Production of quartz sand in the vicinity of Quedlinburg in Saxony-Anhalt, Germany.

Mineral Resources

Mineral resources are the basis of modern civilisation. They are used both for the manufacture of all metal products as well as building materials. Therefore, mineral resource mining is indispensable to our modern civilisation.

Processing of Co-As-ore in Bou Azzer, Morocco.

Travertine from Bad Canstatt is popular for the production of dimension stone slabs.



Limestone quarry and production unit in Rheinland-Pfalz, Germany.

Pt-Pd-mining in the Zwartfontein open cast mine (Platreef, Bushveld-complex in South-Africa).

50 Years of **Mineral** Resources

The term ´mineral resources´ covers a wide range of usable rocks occurring in nature. Mineral resources are gravel, sand, chalk, and clay, all of which are used mainly as building materials for roads and houses. The term also covers the sometimes unimpressive rocks containing gold, silver, and copper and also graphite, fluorspar and barite. Such rocks are called ores. Resources used for energy generation (e.g. coal) are not considered mineral resources, but are termed energy resources.

The development of our modern technical civilisation is causing a steadily increasing demand for mineral resources, and it is often reported that a specific resource will no longer be available in the near future. Such predictions are not true! It is more correct to state that it is increasingly difficult to find new profitable mineral deposits. One of the most important goals of BGR (and of the other geological surveys worldwide) is to support the mining industry in this increasingly difficult task.

Additional tasks for BGR are to manage and carry out technical cooperation projects in developing countries and to give advice on national politics and the economy. 50 years of BGR history have proven that all these tasks can be reasonably combined within the scope of the search for mineral resources.

One of the common goals of technical cooperation projects dealing with mineral resources is the search for possible new deposits in regions not yet explored. When a potentially interesting area is discovered, a set of samples is collected and brought to BGR where they are analysed in specialized laboratories by experienced scientists, who in turn may use the new data for the development of new scientific models and/or conclusions. Such research significantly contributes towards the understanding of the formation of ore deposits, which in turn helps to optimise prospection and exploration strategies. As soon as the formation of a particular ore deposit is understood, the systematic search for similar

geological situations worldwide can begin. As an example, during the research project 'metallogenesis of gold and platinum deposits' (end of the 1980s until beginning of the 1990s), the conditions required for the formation of economic deposits were identified. This was the basis for the development of a new and optimized strategy for searching for new deposits.

During the last 50 years BGR has gained significant knowledge about the formation of chromium, copper, and gold ores, which led to the discovery of several new deposits. The most significant are the copper deposit 'La Granja' in Peru (see below), the gold deposit 'Yamfo' in Ghana, and 'Song Toh', which is now the most important lead mine in Thailand.

However, BGR does not only operate in the field of metal ores but also in the field of non-metallic mineral resources. Extraordinary deposits were discovered in Jordan (phosphate) and Guatemala (gypsum) as well as in many other parts of the world (marble, clay, limestone). In some instances the projects were run until the establishment of the final production unit (e.g. brick-making plant in the case of clay deposits).

When a new deposit is discovered the national industry is contacted, which can help to define the actual value of the deposit and of course can also benefit from the economic potential. This has led to several long-term engagements of German companies, such as Knauf Gips KG and Süd-Chemie AG in Argentina, and Schaeferkalk GmbH in Malaysia. Since 1991 there has been increased activity by German companies in the field of non-metallic resource mining abroad. In contrast the few important German companies which used to be involved in metal ore mining have pulled out of active foreign mining. According to the recent study 'German mining abroad', most of these companies are now focusing exclusively on importing ores.

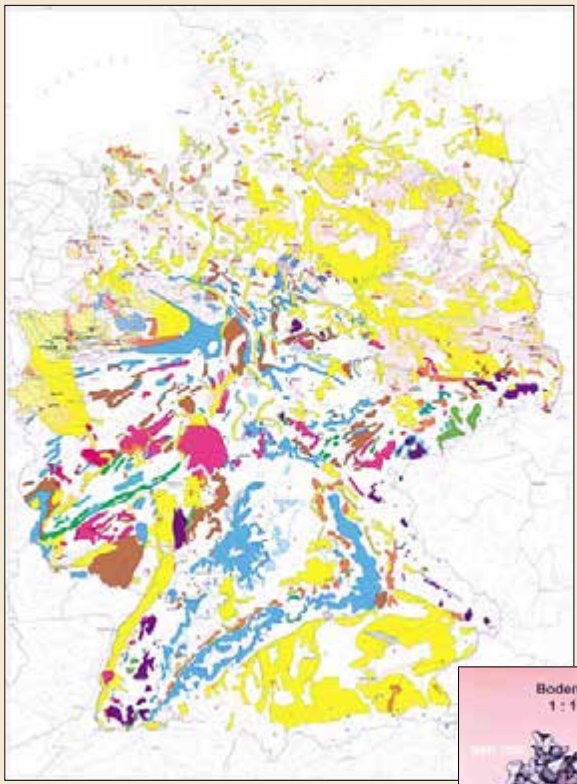
Only a few companies (commonly family enterprises) are still benefiting from the potential of metal ore deposits abroad, sometimes with remarkable success. Due to this, and because of rising resource prices, it is conceivable that at least some of the big German companies will start to revise their opinion and restart their activities abroad. BGR, of course, supports such projects particularly with advice regarding the specific situation of the different countries and the resulting challenges. To be able to give optimum advice to the companies, it is essential to be able to assess the current worldwide resource situation, offering opportunities as well as risks.

Because of the wide variety of mineral resources and the huge amount of data available, it makes sense to collect different types of information in data bases. In this respect BGR has been cooperating with other well established geological surveys for decades, e.g. the USGS (US Geological Survey) since 1975. As the only German institution managing different types of comprehensive mineral resource data bases, BGR is able to interpret the data correctly. The most important data bases are, for example, the resource data base providing information about the production, reserves and consumption of mineral resources, and secondly a data base containing the prices of different resources. These data bases are essential for giving politicians optimum advice. In addition, based on the interpreted summaries gained from these data bases, BGR publishes the 'Resource Reports' (*'Rohstoffberichte'*) and the 'Country Resource Reports' (*'Rohstoffwirtschafltiche Länderstudien'*), which provide information on the resource situation of specific countries. An additional report concerns the resource situation in Germany and is published annually (*'Bundesrepublik Deutschland – Rohstoffsituation'*). Finally, since 1979 the prices of 38 different mineral resources have been published (nowadays on the Internet) and updated monthly.

Geodata, on the other hand, can be used for the production of resource maps. An iron ore map of Germany was established as early as 1964. Several important maps followed, e.g. the 'Map of Near-surface Mineral Resources of the Federal Republic of Germany 1: 200 000' *(Karte der oberflächennahen Rohstoffe der Bundesrepublik Deutschland* 1 : 200 000, 'KOR200') and very recently the map 'Resources of the Federal Republic of Germany 1 : 1 000 000, (*Bodenschätze der Bundesrepublik Deutschland 1 : 1 000 000, 'BSK1000'*). Resource maps are also produced in and for foreign countries, often in the course of technical cooperation projects. At the end of the 1980s, for example, BGR established the map 'The Lake Victoria goldfields,

Tanzania´ which was used by different companies for ore exploration. This map is still requested frequently, but unfortunately is out of stock.

A high level of expertise, particularly with regard to ongoing scientific and economical developments, is required to achieve the aforementioned BGR tasks. This is ensured mainly through BGR's own resource research. In cooperation with the geophysical sections, as an example, for the past 50 years innovative exploration methods have been developed and tested which allow for the fast and safe identification of potential mineral resource deposits. BGR research, however, does not only focus on new methods of exploration but also deals with the optimization of the extraction of metals from the ores. A modern environmentally friendly method is bio-leaching, in which special bacteria and/or fungi are used to selectively extract the valuable metals. BGR has already been investigating this method for 20 years and as a result special methods for the extraction of Ni, Cu, Au, and Mn have been developed. All analytical methods providing the basis for scientific success are continuously updated in the BGR laboratories. In this respect BGR is also working on the resources of the future, for example with the manganese deposits in the Persian gulf which, based on current technology, cannot be mined economically yet. Early in the 1980s BGR had already gained fundamental knowledge about the formation of these ores which are now being investigated, particularly with respect to innovative mining processes that could possibly make them cost-effective. Consequently, in 2005 BGR was granted a licence by the international agency for marine mining for scientific work in a small area (75 000 km²) in the Pacific ocean. Future work will show if these resources can be mined economically.

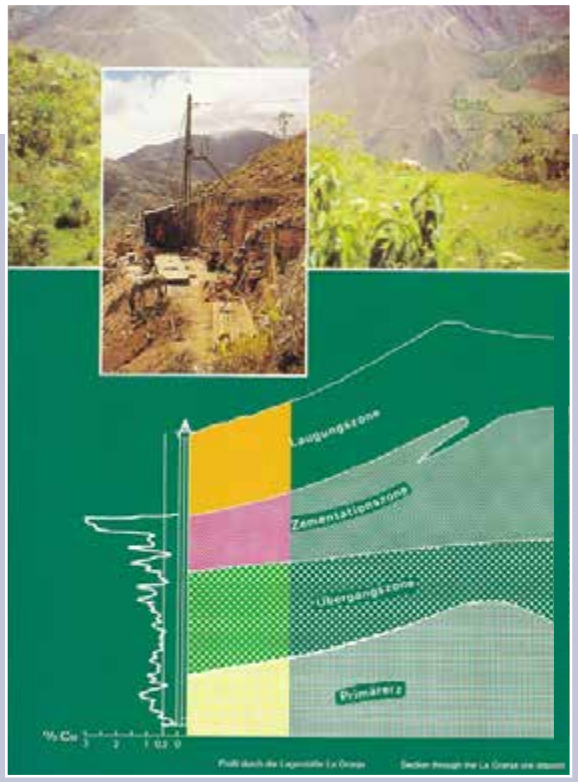


*The **BSK 1000**, map of natural resources of the Federal Republic of Germany was printed in 2007 (small: picture of the cover).*

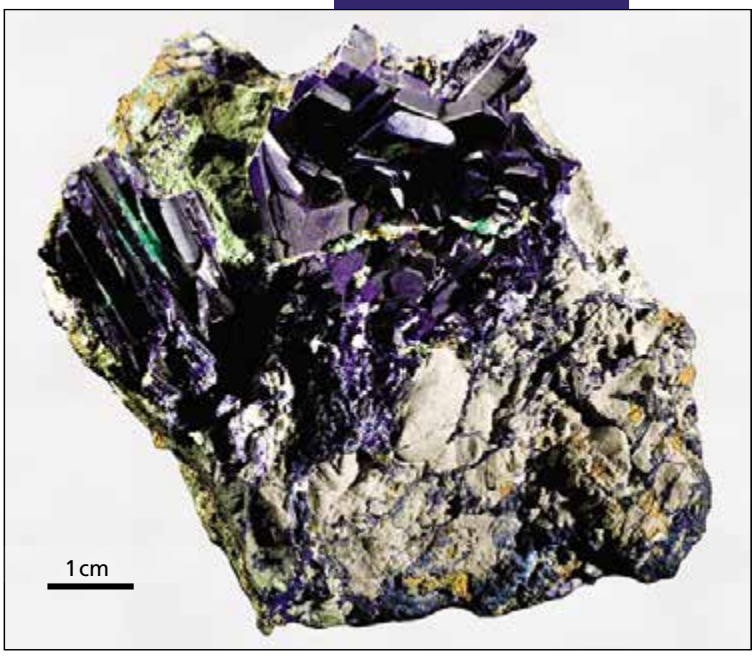
La Granja

One of BGR's most spectacular discoveries was the copper deposit La Granja (Peru) in the 1970s. Copper is one of the most important metals for the high-tech society. It is mainly used in the electrical industry owing to its extraordinary electrical conductivity. Because of its exceptional heat conductivity copper is also used for soldering guns, brew kettles, heating and cooling pipes. In addition copper or copper alloys are used in the production of statues, coins, roof coverings, bullet casings, and blasting caps (amongst other things). In nature copper can occur as native copper, however this is not an important ore. Most of the copper is produced from copper minerals which are either sulphides, sulphates, or carbonates. By far the most important copper ores are sulphides. Generally, copper ores can be easily recognized by their blue to green colour. Large crystals of these minerals occur in gangues which were used for copper production in ancient times. Today most of the copper which is produced is associated with granitic rocks in which the copper occurs as disseminated ore. Such deposits are called copper porphyry.

The 'La Granja' copper deposit is a typical copper porphyry deposit with an interesting history. At the end of the 1960s English and Peruvian geologists discovered a large Cu anomaly in a stream. They established a model to explain their findings. This anomaly – amongst others – was considered further in the course of a BGR technical cooperation project. In 1980 the existence of an extensive copper deposit was proven based on special mappings, geochemical investigations, and specific drilling. In the same year a detailed exploration campaign was conducted in cooperation with a German company. Two years later, however, exploration was stopped owing to the significant decrease of copper prices, but when the copper price recovered German companies were no longer interested in the deposit. Finally, La Granja was bought by the Canadian company Cambior.



The investigations around La Granja were already reported in the BGR annual report 1981/1982. The above photograph shows the reduced figure which originally covered the entire page. The photograph on the right shows the landscape around La Granja and the photograph below was taken throughout an expedition in the 1980s.



Azurite crystal.

In 2000 La Granja was bought by BHB Billiton which surrendered two years later. In 2005 the Peruvian government sold La Granja for 22 million US$ to Rio Tinto which calculated with additional 60 million US$ capital expenditure.

Currently, the reserves account for more than three billion tons of copper ore with an average copper content of 0.6%. Rio Tinto has now successfully tested bio-leaching to extract the copper. This process is particularly environmentally friendly and so can be considered innovative, although it is not applied area-wide. Thus La Granja is now leading the way with this sustainable mining process. According to Rio Tinto´s general manager, based on its enormous reserves, La Granja currently belongs to the largest copper deposits worldwide. La Granja, therefore, is to provide copper for the world market well into the future.

Typical porphyry copper ore.

Certification
of Mineral Resources

Mining of mineral resources significantly influences both the economic and social development of a region and its natural environment. The impact of mining activities is generally much greater than the size of the actual mining operations. Although mining accounts for just ~1.5% of production value worldwide, its products form an indispensable prerequisite for industrial production. Based on this, mining may initiate or actively support sustainable development but, on the other hand, may also be responsible for environmental destruction or the continuation of armed conflicts.

So far there has been no generally accepted mechanism, based on compliance with criteria such as sustainability or development standards, and allowing differentiation between products, for the mining sector. However, such criteria already exist for the forestry and fishing industries in the form of seals of approval. The certification of trading chains in the mining sector represents a newly established tool for political activity in the field of mineral resources, and aims to fill this gap.

The Federal Institute for Geosciences and Natural Resources (BGR) was commissioned by the German Ministry for Economics and Technology to propose a concept for mining activities in developing countries, focusing on minimum social and ecological standards. This paper was available for the G8 Summit in Heiligendamm (June 2007) and was prominently incorporated into the Summit Declaration of the G8 countries (Article 86).

86. … In order to better support the development of sustainable livelihoods and positive developmental impacts associated with artisanal and small-scale mineral production, we…

- support a pilot study, in co-operation with the World Bank and its initiatives, concerning the feasibility of a designed certification system for selected raw materials. …The pilot study shall strive on the basis of the existing principles and guidelines to comply with internationally recognised minimum standards by verifying the process of mineral resource extraction and trading.

(Extract from the summit declaration of the G8-Summit in Heiligendamm June 7, 2007)

The regional focus of the pilot project is Africa, as suggested by BGR. Here, mineral resources have an extraordinary potential for the development of society. Furthermore, regulation and administrative control are not well developed in the mining sector leading to a lack in transparency and sustainability in many cases. The central focus of the pilot project is directed at small-scale mining, which is steadily gaining importance in terms of regional development and poverty reduction. About 10 to 30 percent of world production of some commodities originates from small-scale mining operations. Promising commodities for a pilot study are tantalum (Coltan), tin or tungsten ores. Commissioned by the German Ministry for Economic Cooperation and Development, BGR is presently developing a methodological approach capable of distinguishing the origin of tantalum ores (fingerprinting). This analytical procedure will be used to verify trading chains in cases of doubt.

Analytical Proof of Origin of Tantalum (Coltan-Fingerprinting)

Tantalum is a rare metal which has a wide range of applications in the industry due to its high thermal and chemical resistance. Tantalum is of special importance in the field of microelectronics; it is an indispensable raw material for the production of tiny capacitors with high electrical capacitance. Such capacitors are vital in the production of modern mobile phones, laptops and flat screens.

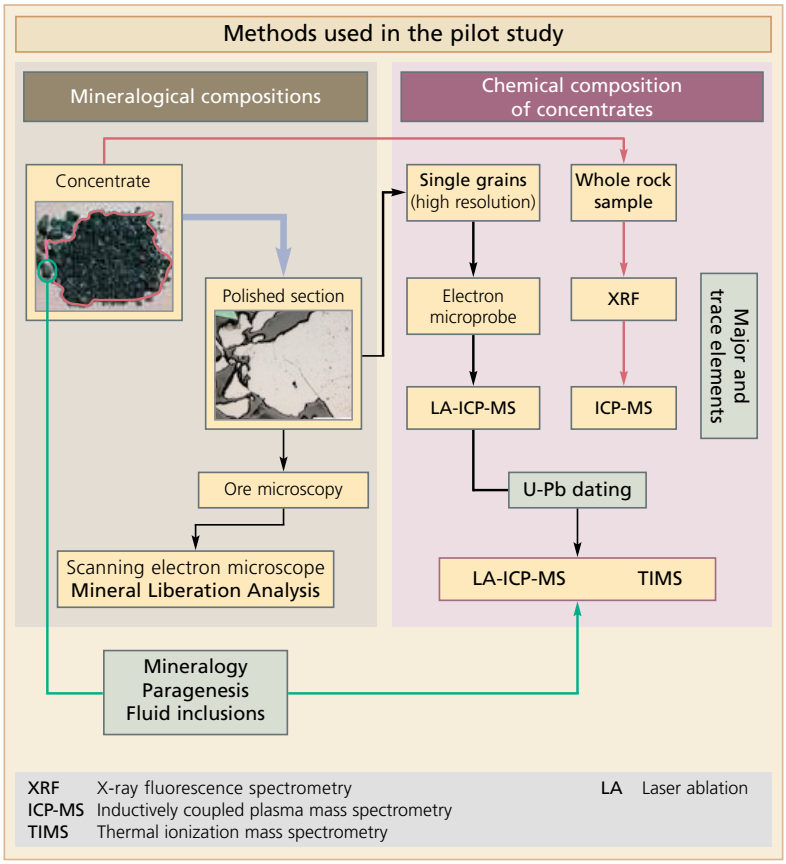
In 2006, the worldwide demand for tantalum of about 1400 t per annum was supplied by mining operations in Australia (61%), Brazil (18%), Canada (5%), and in some African countries (16%). The industrial producers of tantalum in Australia, Brazil and Canada are not very flexible, so the much more flexible small-scale mining operations in Africa are playing an increasing role in satisfying the rapid changes in the demand for tantalum on the world market. However, this flexibility has its price. The mining sector in some African countries is characterized by a lack of transparency concerning the origin of the products and how the profit from the mining activities is used, plus the miners have poor working and living conditions. There is solid evidence that tantalum produced in the Democratic Republic of the Congo (DRC) fuelled fighting in the eastern provinces of the DRC. Despite proscription by the United Nations, columbite-tantalite ore concentrates (Coltan) are still being smuggled from the DRC into its neighbouring countries to be sold illegally on the world market. Establishing a supply of tantalum for the electronics industry from African sources is therefore closely linked to the creation of a tool which can be used to trace the origin and legality of the traded ore concentrates. The methodology for an analytical proof of origin of tantalum ores developed by BGR could be used as such a tool.

Coltan

Central African trade name of mineral concentrates chiefly composed of members of the columbite-tantalite-group – solid solution series with the chemical formula $(Fe,Mn)(Nb,Ta)_2O_6$ – from which the metal tantalum is extracted.

Coltan concentrates are composed of a large variety of minerals which themselves have strongly variable chemical compositions. Although confusing at first, these large variations offer the chance to develop

Coltan mining operation in Mutala, Mosambique, in 2007.



Analytical methods used for fingerprinting Coltan. Important parameters for the discrimination of various sources of the concentrates are the mineralogical compositions of the ore concentrates, the major and trace element composition of individual columbite-tantalite crystals and their radiometric ages. A first classification of the concentrates into ore provinces is often possible using the mineralogical compositions of the ore concentrates.

a scheme for proof of origin. Mineralogical and chemical variations within individual coltan ore concentrates will provide proof of their origin, which is generally a pegmatite body. The applied procedure represents what is known as fingerprint or footprint methodology.

The fingerprint of a coltan deposit is based on determination of the most promising mineralogical and chemical parameters using state-of-the-art techniques; these parameters are selected to enable discrimination between different sources with the utmost precision. Discrimination starts from an ore province scale (supra-regional) and proceeds to a local scale of individual pegmatite bodies. In the future, the combination of selected data (factors) will achieve a degree of discrimination which will make it possible to assign samples of unknown origin to ore provinces, ore districts or even to individual deposits.

Columbite-tantalite can accommodate relatively large amounts of uranium and excludes common lead almost completely. It is thus potentially suited for uranium-lead dating. The measured ratios between uranium and radiogenic lead concentrations as produced by the decaying of uranium are indicative of the age of the analysed mineral grain. Four age populations are evident for African Coltan concentrates so far: >2500, ~2000, ~1000 und <600 million years. Material from the deposits in the conflict region of the eastern provinces of the DRC (Kivu Province) always has an age of 1000 to 900 million years. Based on this knowledge, measurement of ages of individual grains in a concentrate will make it possible to detect an ore province, and will also provide evidence in cases where material from different provinces has been mixed.

However, the trace element concentrations in the coltan minerals also play a substantial role in the methodology for discrimination of tantalum provinces in Africa. Even if tantalum occurrences with similar ages of formation are examined (e.g. occurrences in the Great Lakes Region, Kivu Province of the DRC, Rwanda, Burundi and Uganda), a discrimination of ore districts appears possible based on trace element concentrations or elemental ratios.

Certified Trading Chains (CTC) in Mineral Production

BGR's concept of certification aims at achieving minimum standards in the production and trade of certain mineral resources by ensuring a traceable and controllable trading chain. Widespread implementation of CTC can gradually bring about a network of responsible use of mineral resources in the processing industry that is effective worldwide. The approach of promoting sustainable development in a subset of projects seems to be more pragmatic for the short term than the challenge of regulating the international resource economy.

The core of CTC lies in the certification of process and production methods rather than in the mining product itself – thus increasing the scope of application of the scheme and at the same time reducing costs for laborious and time-consuming research and analyses in mineral production. On the ground, the process verification builds on company audits and the tracking of volumes of production, trade and stockpile, while the industrial partner assumes responsibility for the transparent and ethical production of mineral resources.

Pilot Project Implementation

The pilot project focuses on certifying the production of the commodities tantalum (Coltan), tungsten and tin in Rwanda. In the past few years Rwanda, and specifically the country's military elite, has been accused of illegally exploiting and trading mineral resources from the eastern parts of DR Congo. But Rwanda actually has deposits of natural resources of its own. Enhancing national mineral production offers the country the possibility of developing its domestic and local economy. At the moment the 50 to 100 thousand artisanal and small-scale miners comprise the entire workforce in Rwanda's mining sector. This adds up to approximately half a million people, meaning that about 15% of the total population is indirectly dependent on mining as a livelihood. Thus the pilot project is contributing to enhancing the transparency and stabilisation of the resource economy in the region of the Great Lakes.

The project partners on the side of the producers are locally based companies that took over concessions from the state company Régie des Mines du Rwanda (Redemi) when the mining sector was restructured in 2006.

The business concept lies in further employing the current staff by continuously improving the operational facilities and production equipment, their current operations will gradually result in regular mining activities gaining adequately in efficiency. Metal-producing companies in industrial countries with the strategic objective of securing the acquisition of natural resources from Central Africa are the partners on the side of the buyer in the trading chain. Supplying concentrates of the respective ores of tin, tungsten und tantalum (Coltan) from ethically responsible production from Rwanda to Europe is part of the partnership agreement between the primary producers and processors of mineral resources.

The OECD Guidelines for Multinational Enterprises and the OECD Risk Awareness Tool for Multinational Enterprises in Weak Governance Zones were adapted to the reality of artisanal and small-scale mining and serve as basic principles for auditing the trading chain. The initial conditions of the planned supply relationship were scrutinized by independent auditors. On this basis, BGR is establishing a set of provisions that guarantee minimum ethical standards. The analytical proof of origin will make it possible to ensure that the minerals stem from a known and registered mine site. If the method is used as forensic proof, it can also identify dubious lots from possible areas of conflict.

Mine Waste Heaps –
Potentials und Risks

Introduction

Mineral resources, in particular those from which metals are produced, are not naturally completely pure. Generally, a rock must therefore be extracted and the valuable substances are produced from them in a number of complex steps. The remaining (barren) material is disposed of on waste heaps. Waste originating from the mining process (waste rock heaps) and from ore processing (tailings) are differentiated.

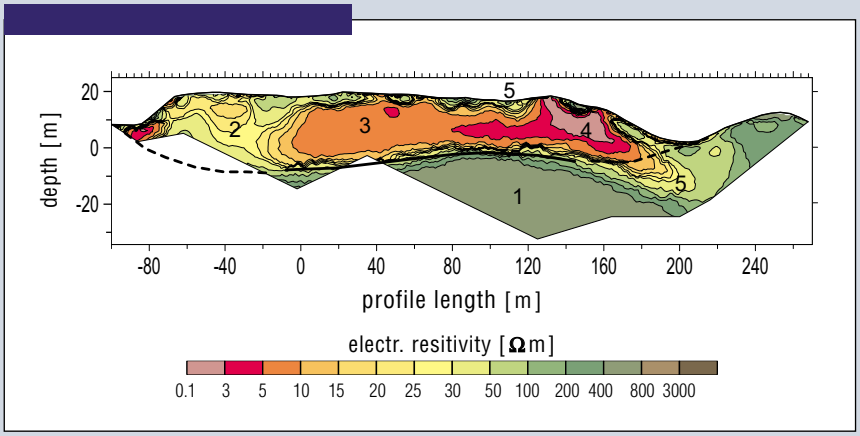
Separation of the valuable substances from unusable rock is seldom complete. Besides toxic substances, the heap material often contains utilisable elements and minerals. Heaps consequently offer economic potential, but also present a risk to the environment. On the one hand, it may be possible to extract the elements if improved processing methods become available; on the other hand, should rainwater and oxygen enter the heap, minerals may be dissolved and thereby release pollutants. The latter can then enter the groundwater.

Heap Characterisation: Structure and Composition

Mining and processing lead to a reduction in grain size, redistribution and stockpiling of large quantities of rock and mineral processing residues. These anthropogenic landscapes display site-related characteristics. The type of dumped material varies, on the one hand, and the shape and structure of a heap are a result of the type of filling used.

Fundamental knowledge of the structure of heaps is essential for evaluating both the economic potential and the environmentally relevant risks. The structure of a heap can be investigated by non-destructive testing using geoelectrical methods. Trial pits and boreholes, and analysis of the minerals and elements aid the interpretation of geophysical data.

Internal structures in the spoil heap of an abandoned copper mine in the Iberian pyrite belt, visualised by contrasting electrical material properties (= vertical section through a 3-dimensional resistivity model).



1) Spoil heap bedrock base (rhyolitic shale), original topography
(2) Stockpiled spoil (barren rock)
(3, 4) Volcanic tuffs, blocky material with high levels of unweathered pyrite, highly mineralised porewater, pH < 2
(4) Assumed zone of weakness, where the highly mineralised waters infiltrate the bedrock via joints
(5) Partial hardpan formation on the spoil heap surface.

Hardpan Formation

In principle, it is assumed that the principal components of soluble pollutants can be easily leached from the body of the heap. The material is easily accessible and can therefore easily react with infiltrating rain water and atmospheric oxygen. Surprisingly, however, many spoil heaps have experienced internal reorganisation over the years, leading to changes in accessibility and to shallow natural sealing of the surface layers. This is the result of either partial or complete dissolution of special reactive minerals, where the released ions favour secondary mineral formation. The dissolved substances partially are released from the base of the waste heap as acid mine drainage. However, some of the dissolved substances are also transported along minute channels, the capillaries, opposing the direction of gravity. Evaporation occurs in the boundary zone between the capillary fringe (solid) and free reactants (liquid, gas) and thus leads to precipitation and crystallisation of secondary mineral phases. The capillary pore space is thereby sealed by successive layers and hardpan forms. However, they are not only limited to the capillary pore space, but also form on chemical interfaces or on the spoil heap surface.

Compared to the parent material, the hardpans display considerable differences in chemical and mineralogical composition, and in hydraulic behaviour. They are capable of suppressing wind transport of the loose material, reducing infiltration of rainwater into the waste heap, limiting air replacement and concentrating substantial quantities of pollutants or valuable substances. Finally, the quantity and chemical freight in the mine drainage are also reduced. This natural hardpan formation process can be supported by reapplying escaping waste heap water, for example. Hardpan formation occurs in all climatic zones. However, semiarid conditions and the reactivity of the material itself can accelerate the process considerably.

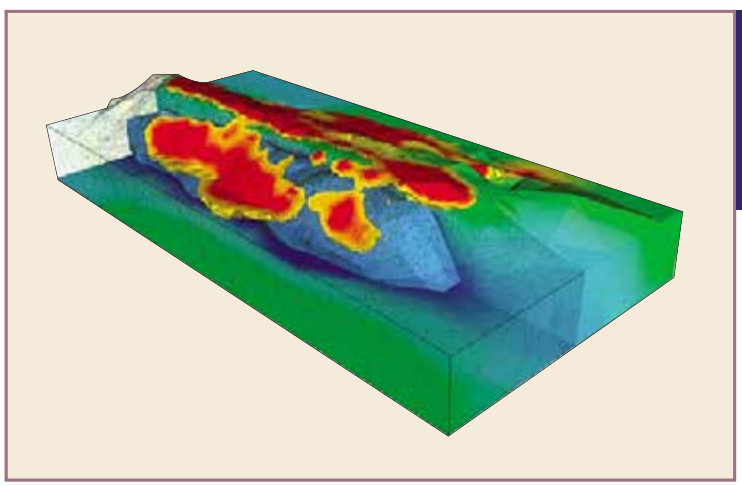
In a joint BGR project with the *Grundwasserforschungsinstitut Dresden* and *SARB Consulting* (Norway), a guide and an interdisciplinary approach for estimating the long-term stability potential of hardpan and for artificially encouraging hardpan formation were developed. The guide is aimed at waste heap operators and remediation players (e.g. authorities, consultants).

Interdisciplinary approach to problem-solving:

Coupling of research results from:

- hydrogeochemistry,
- mineralogy,
- geophysics,
- microbiology,

for temporally resolved reactive transport modelling based on geochemical and geophysical process parameters in waste heaps. This kind of modelling forms the foundation for predicting the future evolution of waste heaps.



Semi-transparent geoelectrical 3D model of an iron slag heap: The red zones of high electrical resistivity indicate the surface regions of the spoil heap impacted by hardpan formation. The interior is characterised by its low resistivity (blue), caused by the high alkali mineralisation of the porewater, even in the vadose zone (pH > 12).

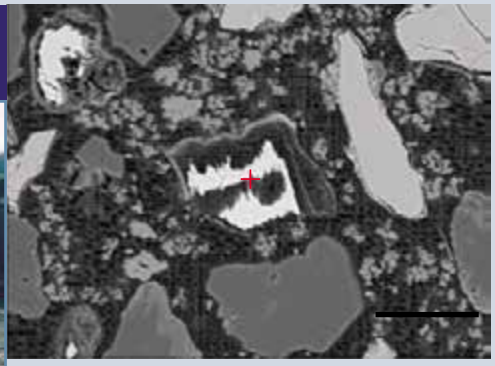
Metal Recovery from Mine Tailings Heaps

The smartest solution for a reduction in the release of toxic compounds from waste heaps is the recovery of the remaining valuable substances (metals). In a cooperation between BGR and TU Clausthal a process was developed which combines classical ore processing techniques with biotechnological methods. In a first step the gold- and silver-containing fine grained portion of the mine tailings is mechanically separated. Special microorganisms are used for the dissolution of the gold-containing minerals. Subsequently, gold and silver are chemically extracted from the solution. This process is economically feasible on a technical scale, because the increase in commodity prices over the last few years has made the recovery of the remaining valuable substances an economic option.

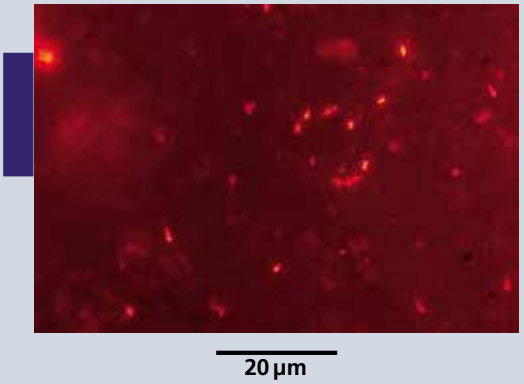
The dissolution of minerals with microorganisms has not only become of interest for tailings and spoil heaps recently. It has been increasingly applied commercially for copper recovery from ore heaps (metal bioleaching or biomining) for many years. Here ore heaps are constructed, and naturally occurring or specifically introduced microorganisms dissolve the copper minerals inside the heap and bring the copper in solution. The solution which percolates through the heap is then released on top of the heap. This circuit enables an enrichment of copper in the solution. Finally, the copper is electrochemically separated and concentrated.

The optimization and monitoring of metal bioleaching requires the determination of the number of microorganisms in the heaps. For this purpose molecular biological methods have been established in BGR, as part of a PhD-study, which allow the determination of the numbers of specific Archaea and Bacteria in a heap sample in a short time period. In one of these methods microorganisms are marked with gene probes and visualized under the microscope. Further studies in BGR include the description of novel metal leaching species of bacteria which were isolated from various mine waste heaps worldwide.

Mine tailings with metal-rich acid mine drainage in Peru.



Mineral partly dissolved by bacteria (in the centre of the picture marked with a red cross, picture generated using an electron microprobe).



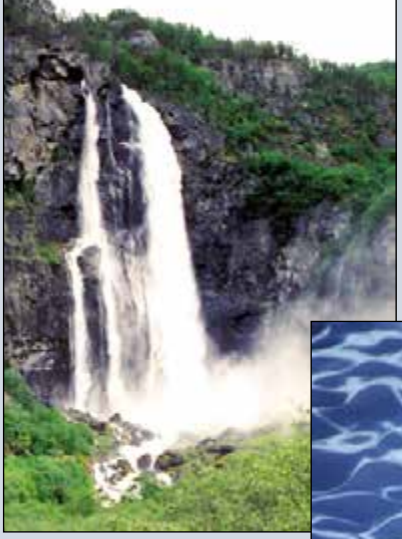
Microscopic picture of bacteria marked with gene probes in a mine waste heap sample.

Conclusion

The BGR and its cooperation partners have a broad knowledge in the field of '*Rohstoffsicherung*'. The strong interdisciplinary scientific focus on valuable and toxic compounds in a heap and the consideration of economic aspects provide a basis for a sustainable use of this georesource.

Water – life bringer!

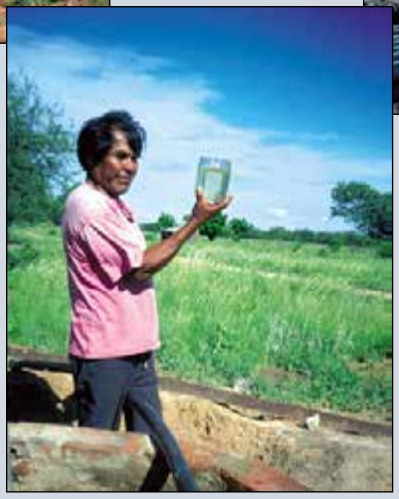
Georesource Groundwater





Groundwater

Globally, groundwater is the most widely distributed and largest resource. With an estimated amount of 10.5 million cubic kilometres it is also the most important available reserve of fresh water. In arid zones, in particular, groundwater is immensely valuable, because it is the only reliable water resource. Today, more than 1.5 billion people rely on groundwater. Because of population growth and climate change, the global importance of groundwater as a high-quality basis of water supplies will increase considerably in the future. If used sensibly and sustainably, groundwater can make an important contribution to solving regional water crises.

50 Years **Groundwater** Sector in **BGR**

A retrospective of history of the German federal geological survey illustrates the national and international importance of groundwater resources in the spectrum of BGR tasks. Even though, water in Germany is federal state business, the groundwater sector at BGR also assumes national duties such as compiling interstate thematic maps or conducting water research where relevant for final radioactive waste disposals. Internationally, the groundwater discipline focuses on technical cooperation projects in developing countries on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ).

Water Projects in a Changing World

Shortly after BGR's founding, activities in the groundwater sector were extended to almost every continent. Initially, large teams were sent out in so-called 'missions', in which hydrogeologists

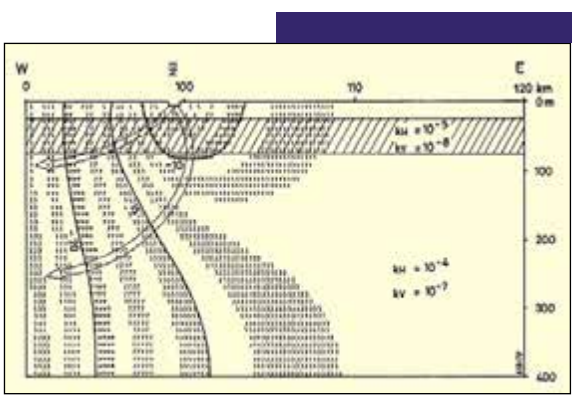
worked on groundwater exploration, together with other geoscientists and technicians involved in tasks such as exploration for energy and mineral resources. This was based on the approach that economically underdeveloped countries are better aided by comprehensive concepts than by standalone projects.

The advances in related natural sciences such as analytical chemistry and geophysics initiated a change in hydrogeological research and methods during the 1960s: the establishment of new water laboratories improved not only analytics of water composition, new techniques in isotope hydrology also allowed groundwater dating and estimates of recharge and flow patterns. The development and application of new geophysical methods in groundwater exploration enables the localisation of aquifers or the boundary between fresh and saline water, without expensive drilling. These hydrochemical and geophysical methods, initiated in the 1960s, are still in use and being developed further continuously. Therefore, the interdisciplinary cooperation in the groundwater sector has a long tradition at BGR.

Although raw material supply was at the forefront in 1970s for economical reasons, long-term security of water supply continued to be a fundamental human need, especially in the Earth's arid regions. In countries with low precipitation, both within and outside of Europe, there was a desire to cooperate with BGR hydrogeologists, so that the number of technical cooperation projects rose steadily. National research projects, in cooperation with the soil sector, demonstrated the importance of the unsaturated zone for groundwater protection and water balance. The hydrogeological thematic maps at a scale of 1 : 1 million developed in cooperation with the State Geological Surveys provided an initial basis for land-use regulations and water protection measures. The early use of IT systems, which allowed the development of the first numeric flow simulations, established to an important planning instrument in the following years, was a piece of pioneering work.

Hydrogeological activities of BGR were extended by an important national task at the beginning of the 1980s: the problem of final radioactive waste storage increasingly moved to the centre of public interest. The extensive hydrogeological investigation and evaluation of possible sites, in particular at Gorleben and Schacht Konrad, represented a core national duty of the groundwater sector into the 1990s. In addition, special hydrogeological problems such as the behaviour of fresh-saline water systems were worked on in the course of radioactive waste management and research. Overall, groundwater activities expanded during this period, not least due to the increasing importance of environmental protection. Similarly, environmental problems were increasingly the object of technical cooperation projects.

At Germany's reunification in the 1990s, existing hydrogeological data needed to be secured. In addition, the problem of soil and groundwater pollution from abandoned hazardous sites gained importance not only in the new federal states. BGR assisted the State Geological Surveys as an expert advisor with regard to these environmental issues. In technical cooperation projects, helicopters were used for the first time for groundwater exploration applying geophysical methods, for example in Pakistan and Namibia. This method has been used both at home and abroad for extensive groundwater exploration. In technical cooperation projects, hydrogeologic consulting service again increased in importance: The establishment of institutions and technical expertise in the partner countries was increasingly promoted. Besides exploration, the sustainable management and protection of groundwater resources took centre stage in foreign water projects.



A computer printout from the late 1970s shows the result of numeric simulation for a Sudanese research project.

Partner Country Jordan: a Case History

How does time and changes in framework conditions impact on hydrogeological activities in a partner country? The kingdom of Jordan is an example of long and successful collaboration with BGR in technical cooperation. It began in 1959 and is therefore almost as old as BGR itself.

The former Transjordan had shrugged off the British mandate in 1946 and achieved complete independence. Because there was no administrative infrastructure when the state was founded and Jordan had insufficient sources of income, it was dependent on outside support. Cooperation with BGR contributed greatly to establishing the necessary authorities in the field of geosciences.

While there was no Jordanian partner authority available for the first project – a hydrogeological investigation in the Irbid region – the focus of the following projects was always the creation and strengthening of suitable governmental institutions and capacity building for their staff. For example, the first major project (1960–1967) supported the establishment of the Jordanian geological survey (today: Natural Resources Authority, NRA). The national geological map produced by this project helped Jordan in the exploration and exploitation of the most important natural resource, phosphate, which has represented a substantial source of national income since then. The NRA remained the most important partner of BGR until the mid-1980s and was also responsible for the resource water, besides mineral resources.

At the end of the 1960s, the main phase of cooperation in the field of groundwater began. Aim of the Wadi Arja project (1968–1976) was to support the Bedouins in south Jordan to become sedentary and provide them with sufficient groundwater for agriculture. At the beginning of the 1970s, BGR was asked to participate in preparing the first National Water Master Plan, NWMP, which was completed in 1973. For many years, this was the most important planning instrument for Jordan's water supply. In the early 1980s, first geoelectrical surveys in the Wadi Araba led to the exploitation of additional groundwater resources in this extremely dry part of the country.

The Water Authority of Jordan (WAJ) was founded in 1984 and was henceforth responsible for all questions related to water supply and water resource management. Because the focus of German technical cooperation with Jordan simultaneously shifted to water issues, the WAJ and later the Ministry of Water and Irrigation (MWI, founded 1994) became the most important cooperation partners for BGR. The most significant work for the country was the comprehensive description and assessment of the national groundwater resources, conducted between 1986 and 2001. Modern groundwater exploration and management methods, such as numeric modelling, computer-aided mapping and database applications were both used and taught.

In the 1990s groundwater protection issues moved to the forefront of technical cooperation activities. This had become necessary because of pollution sources arising from increased agricultural cultivation of land and early industrialisation, which increasingly endangered the already scarce water resources. Groundwater vulnerability maps helped to prevent negative consequences for groundwater already at the planning stage. They were therefore compiled giving priority to rapidly developing areas. The results of this work were later incorporated in the compilation of a national, three-dimensional groundwater model and in the second National Water Master Plan of 2004.

Groundwater protection has developed into an important topic in technical cooperation with Jordan over recent years, since groundwater resources have long been overexploited and pollution has increased greatly due to the rapid development of the country over the past ten years. Water has therefore more and more become a limiting factor in Jordan's development. As a consequence, the current project attempts to protect from contamination around half of the wells and springs used for drinking water supplies by designating protection zones for groundwater and surface water sources. Besides the technical delineation of protection zones, raising awareness among the local population and constructions to protect water pumping sites are especially important.

Jordan has undergone fundamental changes over the past 50 years and has now become a modern state. However, due to strong population growth, living conditions have barely changed for parts of the population while the need for clean drinking water has greatly increased. 50 years of technical cooperation with Jordan have contributed not only to good bilateral relations between Jordan and Germany by means of manifold technical and personal contacts, but also made a contribution to stabilising this dry and politically sensitive region of the Middle East.

Current Situation and Outlook

Comprehensive hydrogeological advice to partner countries, in particular in hydrologic balance issues, will be continued in the new millennium. The interdisciplinary approach will be expanded in terms of integrated water resources management to meet the political, social and economic challenges posed by water-related projects.

International hydrogeological maps of Europe and the world will be compiled jointly by the European geological surveys and UNESCO. Interstate data will be generated in close cooperation with State Geological Surveys of the Federal Republic of Germany (SGD), forming the basis for the Hydrogeological Base Map of Germany (HÜK 200). This trend towards networking with national and international organisations will be intensified to meet the increasing national challenges, such as implementation of the European Water Framework Directive and the utilisation of transboundary groundwater resources. The successful cooperation between the groundwater, geophysics and pedology disciplines at BGR will be intensified.

During the last 50 years, numerous BGR scientists and technicians have been involved in around 70 water-related projects in more than 35 countries. The first countries to be advised on water issues are still important today in terms of Germany's political and economic interests. These include Afghanistan, Djibouti, Indonesia, Jordan, Namibia, Pakistan, Paraguay and Sudan, for example. Thanks to many years of activity in these countries, BGR has achieved great expertise in the water sector and will remain a reliable partner for the future.

Guaraní-Aquifer-Systems (SAG) – **Sustainable Use** of the Transboundary **Groundwater** Resource

The Guaraní Aquifer System (Sistema Acuífero Guaraní, SAG), with an area of almost 1.2 million km^2, covers the greatest part of the Paraná basin in South America and consists of sandstone aquifers, regionally overlain by basalts. With an estimated volume of 25,000 km^3 the Guaraní Aquifer System holds one of the largest contiguous fresh groundwater resources worldwide. Countries utilising this groundwater system are Argentina, Brazil, Paraguay and Uruguay.

The Guaraní Aquifer System is currently only utilised for drinking water supplies in regions where the groundwater can be tapped relatively close to the surface. The quality of this largely unprotected groundwater is already threatened by human impacts. As a result of the rapid development of urban settlements and the growing water demand, increased use of this transboundary groundwater resource is predictable. Therefore, joint management and protection of the Guaraní Aquifer System are necessary involving all neighbouring countries before negative consequences of uncontrolled use become obvious.

The Guaraní Aquifer System is strategically important for future water supply in the region. The GEF (Global Environment Facility) initiated a project in order to support the creation of the institutional and technical requirements for joint management and adequate sustainable use of the groundwater reservoir. The World Bank, the Organisation of American States and the national implementation organisations are involved. Whilst the Secretary General (SG) in Montevideo is responsible for the project coordination, the steering committee (CSDP) has a controlling function.

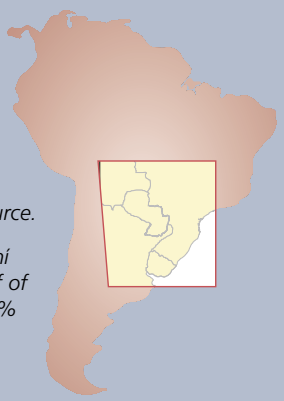
BGR advises the GEF project both in strategy development and by assimilating scientific-technical knowledge gained from the pilot study in Paraguay. Furthermore, as a member of the technical steering committee, BGR supports the transboundary management by disseminating methodological knowledge.

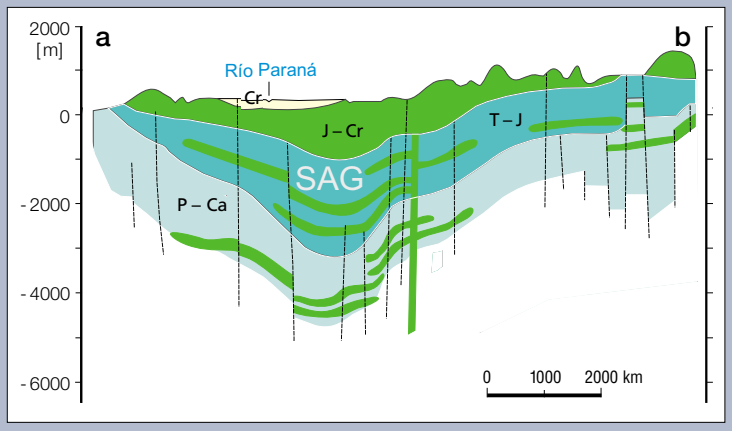
Paraguay, which is participating in the GEF project, is supported via the Ministry of Environment (SEAM) by the SAG-PY project by advice, technology and know-how transfer, leading to an overall strengthening of Paraguay's position in the joint venture of the Guaraní neighbouring states. Groundwater management methods for the section of the Guaraní Aquifer System within the borders of Paraguay are being developed. The project results are considered as Paraguay's contribution to the GEF project, and the expansion of the pilot area to neighbouring regions in Brazil and Argentina helps to verify transferability.

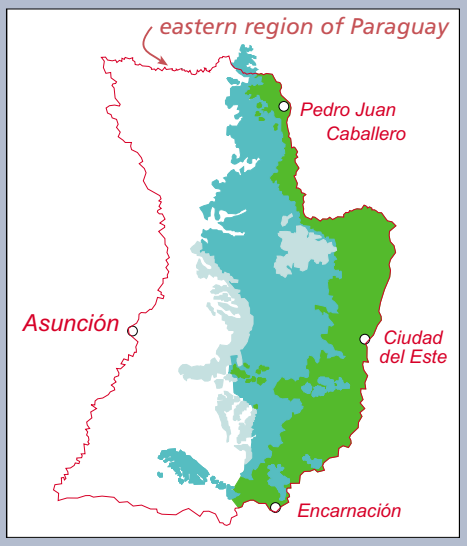
Timber transport (deforestation) in Paraguay's eastern region.

*The international **SAG** project (**S**istema **A**cuífero **G**uaraní) established the basis for sustainable use of the **Guaraní Aquifer System**'s transboundary groundwater resource.*

Paraguay's 71,700 km² share of the Guaraní Aquifer System is limited to the eastern half of the eastern region and thus amounts to 18% of the country's area.







Formación Alto Paraná	basalt (Jurassic + Cretaceous)
Formación Misiones	sandstone (Triassic + Jurassic)
Grupo Independencia / Coronel Oviedo	sandstone (Permian + Carboniferous)

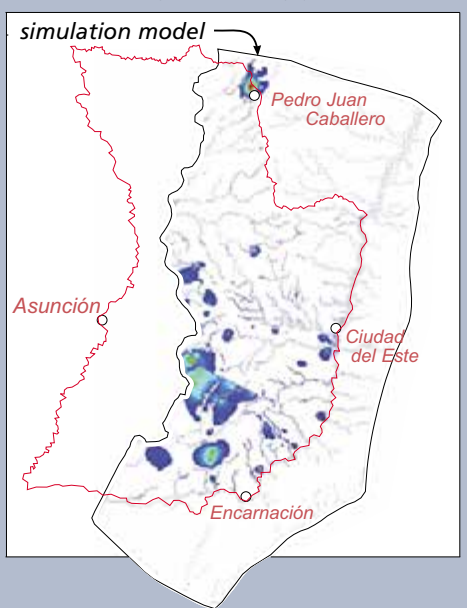
The SAG sandstones were formed during the Triassic and Jurassic periods (**T-J**) *and extensively covered by volcanic extrusives in the Jurassic and Cretaceous periods* (**J-Cr**).

Besides the sandstones (**T-J**) *of the Guaraní aquifer, the Permian sandstone group* (**P**) *is also important to the country in relation of water management, due to the relatively good hydraulic conductivity near the top of the groundwater system. The simulation accordingly takes into consideration both the basalt complex and the Permian and Carboniferous sandstones* (**P-Ca**) *(partially) as productive aquifers in Paraguay.*

The simulated groundwater system describes an area of more than 190,000 km² and includes parts of Brazil and Argentina. Future groundwater extraction will lead to the lowering of the groundwater level in the upper parts of the sandstone and basalt systems. This drawdown is marked as blue area in the lower map and is to be considered as an example of prognostic results.

Further information about SAG and the corresponding project work can be found on the Internet at

www.sag-py.org and www.sg-guarani.org



In Paraguay's eastern region: Livestock farming following slash-and-burn.

Ruins of a Jesuit settlement.

Besides compiling digital base and thematic maps of the eastern region, evaluation of the country's existing hydrogeological data formed part of the baseline-oriented project work in Paraguay. BGR field campaigns have increased and considerably improved the knowledge about the Guaraní Aquifer System. Based on conceptual modelling it was possible to develop a numerical groundwater model, which simulates the regional groundwater flow regime, including parts of the neighbouring countries Argentina and Brazil and calculates the groundwater budget. The model results from calibration and prediction form the basis for the development of national management and protection strategies.

Artesian well in Ciudad del Este.

Sandstone complex, exposed in the Departamento Amambay.

In addition, the SAG-PY project has contributed in many ways to national information and education about the vital importance of the resource groundwater, in particular from the 'Guaraní'.

A variety of activities result in a significant contribution to the protection of the Guaraní Aquifer System, whereby transboundary resource management approaches serve to a consensual and secure water supply for future generations.

Drinking Water for **Sambia´s** Southern Province

Motivation

Extreme aridity and drought periods are recurring phenomena in Zambia's Southern Province. The tropical, continental highland climate produces a hot, dry period from May until October in the 85,500 km^2 province and a rainy season from November until April. An average precipitation of 650–800 mm per year represents the minimum across Zambia, and the highly variable precipitation distribution exacerbates the situation. Rain-fed agriculture thus represents an unreliable source of food for the population.

The Southern Province falls into the catchment areas of two large rivers, which permanently carry water, the Zambezi in the south and east and the Kafue in the north. However, during the long dry season most tributaries dry up, so that the majority of the population must depend on alternative resources such as small reservoirs or groundwater. Because groundwater is available around the year, it represents the only reliable and safe water resource. Despite its importance, the use of groundwater in Zambia is not regulated. A draft bill providing the legal regulations on groundwater management exists for a short time, but has not yet been ratified by parliament.

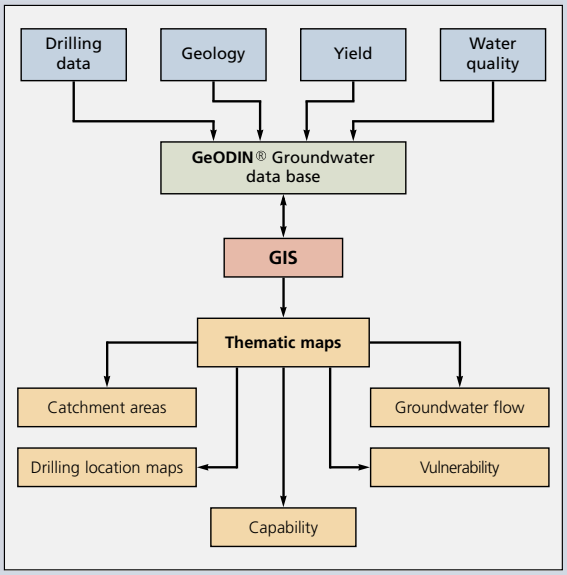
Planning with GIS

The BGR groundwater project began in May 2005 and will allow effective management of groundwater resources and strengthen administrative and technical capabilities in the Zambian water sector. This is only possible with correct, extensive and continuously updated information on surface and groundwater. An extensive survey of subsurface water generally comprises the following points:

- exploration and classification of regional groundwater systems and individual aquifers,
- assessment of groundwater yield and aquifer vulnerability,
- investigation of the interaction of aquifers and surface water bodies,
- continuous monitoring of subterranean flow regimes and water quality and
- monitoring of groundwater exploitation.

A groundwater information system was developed at the partner authority, the Department of Water Affairs (DWA), as a principal component of the project.

Conceptual model of a groundwater information system from data acquisition (blue) to the final products (orange-brown).



Rural housing.

Kafue River upstream Itezhi Tezhi Reservoir.

It includes a comprehensive groundwater database, which is linked to a geographic information system (GIS). The database now contains information on more than 3,000 water sources such as boreholes, springs, hand-dug wells and even failed exploration boreholes. Data from all major hydrogeological studies, carried out by various organisations since the mid-1970s in the Southern Province, are integrated in the database. It links information of a general character such as location, type and purpose of the water source with detailed technical information on the geological and hydraulic situation, borehole lining and water quality.

Women collecting water in a dry river bed.

Regional hydrogeological maps for Zambia were compiled for the first time based on this data, to facilitate the visualisation of groundwater information for extensive areas. Three 1 : 250 000 scale maps and a detailed 1 : 100 000 scale map cover 75% of the Southern Province. Map design and legends are based on international guidelines; they can set a standard for national groundwater maps in Zambia and other regions in southern Africa. In addition, the system allows cartographic visualisation of special topics such as regional groundwater flow or pollution risk of groundwater resources.

Results

The compiled hydrogeological information allows the extent of the groundwater systems in Zambia's Southern Province to be delineated and their potential to be reliably assessed for the first time.

Consolidated rocks such as Precambrian crystalline rocks, for example, and the sediments and basalts of the Karoo Formation (Permian to Early Jurassic), dominate around two-thirds of the Southern Province. Highly permeable unconsolidated sediments only locally form noteworthy aquifers. The rock formations are often highly heterogeneous, so that their groundwater storage capacity and yield are spatially highly variable. In the past this led to low success rates in large exploration projects: on average, one in five well drillings remained dry.

The use of the newly compiled groundwater information system, combined with the application of modern borehole siting methods like field geophysics, can lead to a considerable improvement in planning and thus in the success rate of exploration projects. However, a statistical evaluation of the data reveals that the potential in the Southern Province is generally limited. Groundwater resources allowing more than the barest minimum necessary

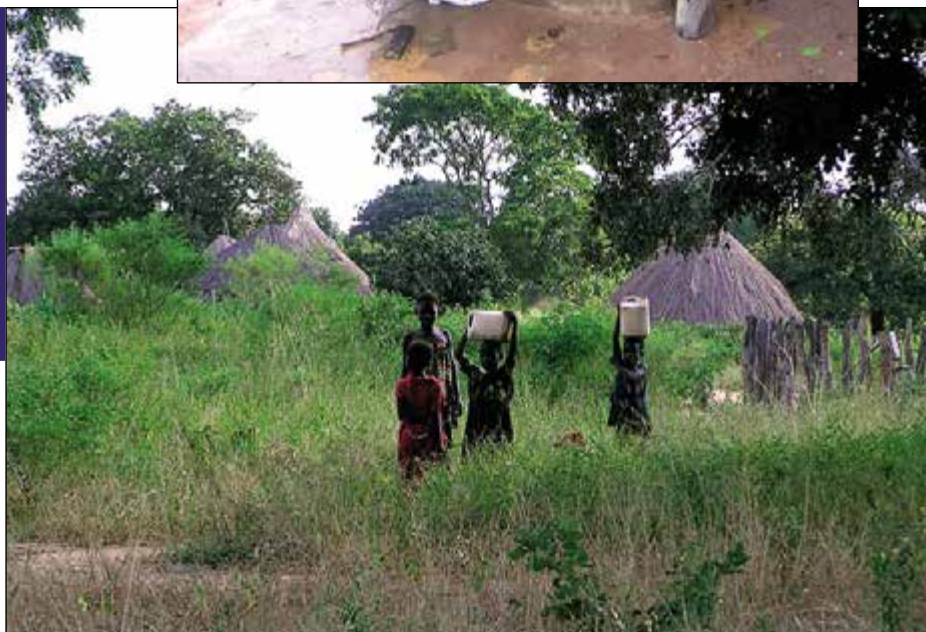
Water agency staff collecting data in the field.

Water kiosk near Monze.

A new groundwater information system was created with BGR support. The information derived from this supports efforts to better explore and more effectively manage groundwater resources in the Southern Province in order to secure water supplies for the people living there.

to provide the rural population with drinking and domestic water only exist locally. The groundwater is nevertheless generally of good quality; however, it is locally contaminated by pathogens close to larger settlements due to the poor sanitary conditions. Overall, the groundwater reserves are unsuitable for large-scale irrigation activities as required by industrialised agriculture. If managed sustainably it is sufficient to provide the rural population and that of small towns with long-term drinking water supplies.

Dug well near Muzoka.



Children fetching water.

Fields of asparagus in Lower Saxony.

Georesource

Soil

50 Years Soil Sector in BGR

Technical Cooperation with Cyprus: BGR Advises on Erosion Control

During BGR's first 30 years, one of the most important tasks of the pedology section was the investigation of soils in technical aid projects, and soil assessment with regard to sustainable land use. BGR soil scientists worked in many countries including Jordan, Afghanistan, Indonesia, and Brazil.

In 1963 BGR started providing Cyprus with technical aid. During the second half of the last century crop yields dropped dramatically. The main reasons for this were declining soil fertility, soil salinisation, and soil erosion. The Cypriot authorities became aware of this and started a technical project to develop plans for site-appropriate agriculture. Systematic measures for erosion control were introduced, mainly in vineyards.

In cooperation with the Department of Agriculture erosion was recorded on seven standardized plots. The following key parameters for soil erosion were measured: inclination, slope length, rain quantity and intensity, surface run-off, infiltration, soil texture, and percentage of vegetation cover. Between 1982 and 1986, BGR scientists and their Cypriot counterparts jointly carried out these measurements. After this, the Cypriots continued with the investigation program for another seven years. The results of these investigations later provided a basis for soil-specific recommendations on erosion control.

Due to the economic revival, many young people left rural areas and worked in tourist resorts. Thus many terraces decayed, and viniculture was neglected. Soil erosion affected more and more areas, in parts the soils on slopes were completely eroded.

Bulldozers were used for repairing decayed terraces and constructing new ones. BGR soil scientists gave advice to the Cypriots concerning the earth movement. They recommended first pushing aside the humous top soil, then levelling the terrace, and finally redistributing the top soil uniformly. Newly planted vines had better chances of survival, as the humous soil had a higher water storage capacity and was also a constant source of plant nutrients.

Standardized test plot for water erosion on Cyprus.

Fuhrberger Feld Natural Laboratory

There is probably no catchment area in Germany other than the Fuhrberger Feld area where more is known about the soil, hydrogeological and hydrogeochemical properties, as well as the water cycle and solute transport and transformation processes. As long ago as the 1960s a working group in the former Bundesanstalt für Bodenforschung (today: Bundesanstalt für Geowissenschaften und Rohstoffe) and the former Niedersächsischen Landesamt für Bodenforschung (today: Landesamt für Bergbau, Energie und Geologie) started researching and carrying out development studies in this area. The results of research projects are shown below to document how the Fuhrberger Feld 'Natural Laboratory' has been used throughout the last few decades for research on current topics.

Water Quantities in the Fuhrberger Feld
Groundwater resources are of great importance for the drinking water supply in north Germany. The Fuhrberger Feld aquifer is the largest water works in northern Germany. Falling groundwater levels in the Fuhrberger Feld from the 1960s until the 1980s, partly due to groundwater pumping for drinking water purposes, caused drastic changes in land use. Lowering of the groundwater table facilitated the change from former wet grassland into arable land, which mainly took place between 1954 and 1991, by ploughing. Due to the lowering of the groundwater table problems with the water supply for crops on arable land and for forests in the area increased, leading to reduced yields. Studies on groundwater recharge processes showed how groundwater recharge depends on land use and the depth of the groundwater table.

Solute Leaching from Arable Land into Groundwater
At the beginning of the 1970s fertilizer and pollutant leaching into groundwater was an important issue, because of the effect on the quality of groundwater for drinking water purposes. Nitrate leaching from arable land in particular caused deterioration of groundwater resources. Two different methods to determine the amount of solutes leached into groundwater were developed in research projects. The methods were later also often used by other research groups:

- measuring solute concentrations in the soil solution with suction probes
- measuring solute input into groundwater by sampling the uppermost groundwater using a hand auger/slit probe method.

Monitoring site in the Fuhrberger Feld to measure groundwater recharge and nitrate leaching into the groundwater.

In the Fuhrberger Feld: sampling of groundwater from different depths using a multi level sampling well.

Table: Mean area representative solute concentrations [mg l^{-1}] in the uppermost (first 10 cm) groundwater (1983-1990), recharge area of well 1 of Fuhrberg water works

	pH	Na	K	Ca	Mg	Al	NO_3	SO_4	Cl	Cu
arable land	4.8	11	15	50	9	2	128	64	32	23
coniferous forest	4.2	8	3	9	1	13	3	104	18	23

Table: Mean trace element concentration in the uppermost (first 10 cm) groundwater [mg l^{-1}] from samplings in 1986 and 1990

	As	Pb	Cd	Cr	Ni	Zn	Co	Cu
arable land	1.0	3.2	0.8	2.9	35	78	8.1	11
coniferous forest	1.2	2.0	1.3	5.2	60	213	17	9.5

Between 1983 and 1994 there were several sampling campaigns in the Fuhrberger Feld, taking samples of the uppermost groundwater from 40 sites at different times of the year. A statistical analysis of the data shows that, especially under arable land, you will find higher concentrations of nitrate, Ca, Mg, K, and Cl compared to forest areas.

Solute Input and Solute Transformation in the Aquifer

After it became clear that there was a rather high input of solutes from arable land into groundwater, the question was posed as to what processes were taking place in the aquifer. Could pollutants reach the pumping wells for drinking water? Up until then there were, for instance, no increased nitrate concentrations found in the pumped water for drinking purposes, but the water showed increased sulphate concentrations.

The interpretation of research in the groundwater aquifer showed the following:

- in the upper part of the aquifer there is a very effective process going on, which eliminates nitrate by a microbial denitrification process
- the denitrification reaction produces sulphate because reduced sulphur compounds are used for denitrification. Large grassland areas turned over to arable land caused high nitrate input into groundwater, which caused a high sulphate concentration due to subsequent denitrification of the nitrate
- rather slow sulphate reduction takes place in the lower part of the aquifer, which only causes a small reduction of the sulphate concentration in the groundwater aquifer.

Groundwater acidification Below Forests

In the 1980s the focus was on the acidification of soils and groundwater due to acidified rain. Research showed that the acidification of the sandy soils in the Fuhrberger Feld had already reached the groundwater. This also caused a higher input of trace elements in the groundwater aquifer. Buffering processes in the groundwater aquifer stopped the acidification front in the aquifer.

Research to quantify and model the penetration of an acidification front in the groundwater below forested sites.

Climate-relevant Trace Gases from the Fuhrberger Feld into the atmosphere
Due to an incomplete denitrification reaction in the soils and groundwater of the Fuhrberger Feld, nitrous oxide (N_2O) might be emitted into the atmosphere. N_2O is more than 300 times as detrimental as CO_2. Research will be conducted to determine the amount of N_2O emitted from soils and from groundwater.

FISBo BGR: Soil Data for Germany

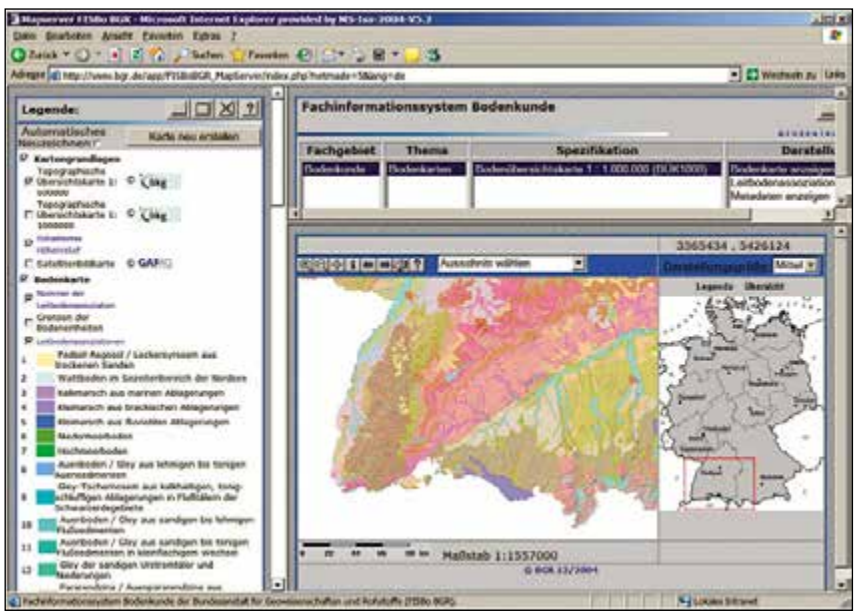
During the 1980s, interest in soil information in Germany greatly increased. At the time, the geological services of the German federal states ('*Bundeslaender*'), cooperating with BGR in the national working group '*Ad-hoc-AG Boden*', noted that an improved coordinating effort was needed to make harmonized information available on a national level. It was in this context that BGR became editor of the German soil mapping guideline ('*Bodenkundliche Kartieranleitung*', KA, version 4), and was asked to coordinate development of the new 1:200,000 national soil map (BÜK 200).

These requirements and the need for national, cross-state evaluations have led BGR to develop a **national soil information system** (FISBo BGR). These developments were influenced by the process of the German reunification in 1990, because a large proportion of soil data from eastern Germany would have been lost after the reorganization/ closure of many public institutions if such a national responsibility had not been established. Since then, the structure and data content of the FISBo BGR has been steadily developed and is now a frequently used source for information about soils in Germany.

Soil maps and corresponding data bases and applications as well as laboratory results represent the main geoscientific information sources produced and collected by the BGR together with the Geological Services of the '*Bundeslaender*'. Methods were developed in parallel to harmonize and assure the quality of that information, but also to evaluate it, for example the susceptibility of soil to degradation processes. In order to provide, improve and secure reliable scientific advice to ministries, research centres and the national economy, the content and structure of the FISBo is continuously updated and optimized. By using web-based techniques, which conform to international standards, a web soil service has been developed with the aim of making soil information easily accessible to the public. This effort has initially focused on small-scale soil maps, for which the results are already online.

The main structural and technical components of FISBo BGR are map data bases, the soil profile and analytical data base, and the method base.

The **map data bases** contain – for different maps – the borders of soil mapping units as digital geometries and additional semantic information (attribute data for mapping units).



Web map Server with a view of the National Soil Map 1:1,000,000.

The **soil profile and analytical data base** contains a large set of soil profile data (ca. 60,000), and roughly 2.1 million analytical data entries. A large proportion of the data is owned by the federal states; other sources are, for example, international aid projects with the involvement of BGR. This data base becomes increasingly important, with regard to developments in soil protection and environmental policies.

The third component of the FISBo BGR is the **method base**, which originates from a joint initiative between BGR and the *Ad-hoc-AG Boden*.

The aim is to document algorithms and models developed to assess the functional potential of soils (e.g. rate of seepage water as part of the ground water recharge), but also to estimate the susceptibility of soil to degradation (e.g. susceptibility to water erosion). Thus it was possible to compile and adapt methods to evaluate soil functioning as required under the Federal Soil Protection Act (*Bundes-Bodenschutzgesetz*, BBodSchG). A method base such as that of the FISBo BGR will play an increasing role in the near future, because soil can be evaluated using harmonized and agreed methods across borders and in a repeatable and verifiable manner.

Land-use stratified soil map 1:1,000,000 – Explanatory notes with maps.

Organic Matter Content in **Top Soils** in Germany

What does the organic matter affect in the soil?

In the last few years, legislators have recognized the significance of organic matter, which is reflected in a set of laws and regulations both on a national and European level. However, precise data on the actual content of organic matter required for the implementation of these laws does not exist.

Besides the oceans, soils store the most CO_2. They accumulate carbon in dead vegetable and animal remains. Microorganisms convert these materials into the final humus product, which is why the protection of soils has been receiving more attention during the last few years with regard to climate change and CO_2 emissions.

In addition to the significance for climatic evolution, humus content in soils plays a decisive role in environmental protection, because humus adsorbs plant nutrients and hazardous substances in the soil, thus preventing leaching into groundwater. In soils with a high organic matter content, both organic substances such as pesticides, and inorganic pollutants such as arsenic, cadmium, chromium and others are adsorbed to the organic matter and are not leached into groundwater by seepage, or only to a minor degree. Organic matter thus forms an efficient filter and protects groundwater against contamination.

Furthermore, humus is essential for plants, as it is a slow-running source of nutrients, and increases the water-retaining capacity of the soil. Soils with high humus contents have a fine stable structure (crumb structure). The topsoil is well aerated neverteheless has sufficient water for plants to survive normal dry spells without harm. Heavy rainfall can infiltrate rapidly without eroding the topsoil. This is why humus content is extremely important for agricultural production as well as for groundwater protection.

How Can Humus Content be Compared?

To compare the content of organic carbon in Germany's topsoils and determine its distribution, existing data must be collected, evaluated and harmonized.

In a BGR project all the information available on the content of organic matter in German topsoils was compiled and evaluated. Topsoils were considered to be the upper 10 cm below forest and grassland, and the upper 30 cm below arable land.

Site information was stored in BGR's Soil Information System (FISBo BGR). Data for some 14,000 soil profiles were available for analysis. Most of these data were provided by the state geological surveys. Minimum requirements, such as geographical coordinates, name of soil type, organic matter content or depth of sampling were defined for data evaluation. Since these data were missing for several profiles, the amount of spot data to be used decreased to approximately 9,000.

In the evaluation, soil properties, climate and land use were considered to be the decisive factors for the humus content in soils. In the land-use stratified soil map information on a scale of 1 : 1 000 000 is shown on the extension of soils and the main types of land-use (arable farming, forest, grassland). Climate is divided into the four zones described on next page:

Climatic zones in Germany (after Finke et al. 1998)	
Name – description	occurrence
temperate sub-oceanic ◇ medium to (in parts) high precipitation ◇ moderately cold winter and moderately warm summer ◇ growing season: 180 up to more than 210 days	northwest
temperate sub-oceanic to temperate sub-continental ◇ medium to (in parts) high precipitation ◇ temperatures depending on altitude (m a.s.l.) ◇ growing season: more than 150 days	south and southwest
temperate sub-continental ◇ medium to low precipitation ◇ moderately cold to cold winter, moderately warm to warm summer ◇ growing season: more than 150 days	east
temperate mountainous climate ◇ medium to high precipitation ◇ cold to very cold winter, moderately cold to moderately warm summer ◇ temperatures and growing season depending on altitude (m a.s.l.)	Alps

Who Finds it Useful to Know Humus Content?

With the data currently available it is possible to give sound information on nearly 90% of the area of Germany. On 70% of the area the soils have a low to medium content of organic carbon which is 1 to 4 percent by mass.

Looking at the regional distribution, the humus content in Eastern Germany is noticeably low; soils with a very low content of organic carbon predominate here. Due to low precipitation, and in many cases sandy soils, humus accumulation is very poor and the soils reach only 1 to 2% humus. In the hills of Central Germany, high precipitation and low temperatures have caused high humus contents.

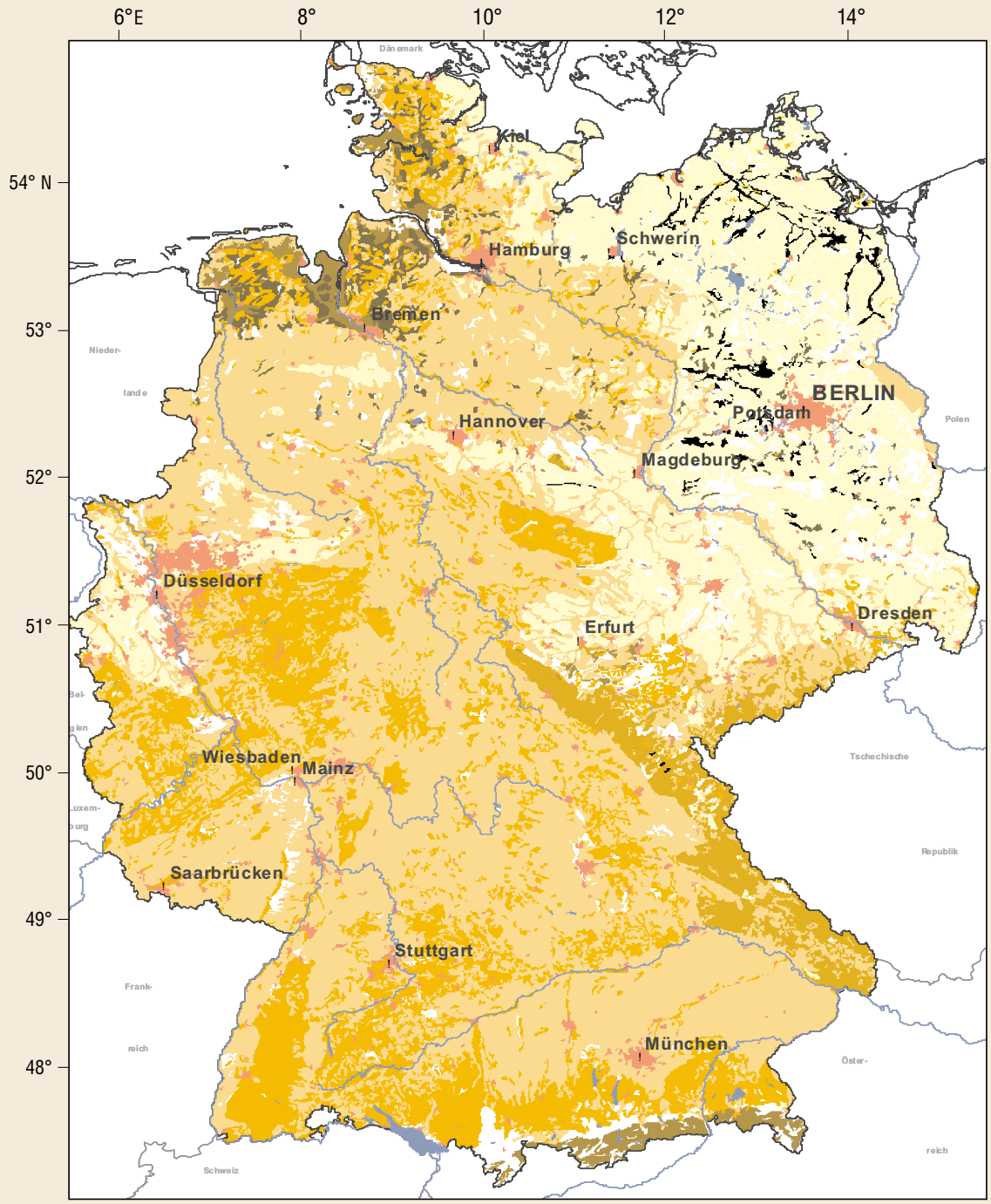
The content of organic carbon depends greatly on the land use. As expected, the humus content increases in the order of arable land – forest – grassland within the same climatic zone. In comparable soils the humus content in arable land is significantly lower than in grassland soils.

The data evaluation provided for the first time the presentation of the typical humus content in topsoils in Germany using a uniform and sound database. This study can be regarded as the basis for future scenarios, which are to cover climate change and hence the decomposition of humus. Furthermore, it shows the site-specific humus content which should be conserved according to the Federal Soil Protection Act. For this reason BGR provides an important basis for consulting agencies as well as monitoring and supervision authorities that need the typical humus content as a reference parameter. Research institutes also use these data as input parameter for modelling, for forecasting CO_2 emplacement in soils and for delineating areas with increased losses of organic matter.

Table: Ratings of humus contents in soils (after Bodenkundl. Kartieranleitung, 5th edition)

abbrev.	description	content [mass-%]
h 1	very low in humus	< 1
h 2	low in humus	1 to < 2
h 3	medium in humus	2 to < 4
h 4	high in humus	4 to < 8
h 5	very high in humus	8 to < 15
h 6	extremely high in humus, mucky	15 to < 30
h 7	organic, peat	≥ 30

Contents of organic matter in topsoils of Germany



Humus (organic matter)
[mass-%]

< 2.5	> 10 – 15	not determined
> 2.5 – 5	> 15 – 30	water
> 5 – 7.5	> 30	urban areas
> 7.5 – 10		

This map is greatly reduced in scale.
The original scale is 1 : 1 000 000.

Link: http://www.bgr.de/service/bodenkunde/humus1000_ob/v2.0/index.php.

Groundwater Protection begins with **Soil** Protection: Background Concentrations of **Trace Elements** in Percolation Water

Because rainfall is higher than evapotranspiration on most sites in Germany, percolation in soils and groundwater recharge can take place. In addition to the quantitative importance of this groundwater recharge for drinking water purposes, how the water quality is affected by land use and soil material is also important. While the water percolates through the soil, it picks up different solutes and leaches them into the groundwater.

In soil protection law and ordinance in Germany what are known as trigger values are defined to evaluate the soil-groundwater path. A sound scientific background is needed to determine these trigger values. Because relatively little data about the background concentrations of trace elements in the soil percolation water has been available to date, a national project to determine these background concentrations was initiated. The trace elements with their current trigger values according to the Federal German Soil Protection and Contaminated Sites Ordinance (BBodSchV) are listed in the table below.

Site Selection and Sampling

Percolation water sampling in the first phase of the project was concentrated on 3 groups of soil parent material:

- sandy soils
- glacial loam soils
- loess soils

Only sites with unconsolidated material in the transition zone between the unsaturated and the saturated zone and with a groundwater table less than 10 m below the soil surface were sampled.

Table: Analysed trace elements and the currently applicable trigger values in the German Federal Soil Protection and Contaminated Site Ordinance (**BBodSchV**)

organic pollutants	Sb	As	Pb	Cd	Cr	Co	Cu	Mo	Ni	Hg	Se	Zn	Sn
trigger value [µg/l]	10	10	25	5	50	50	50	50	50	1	10	500	40

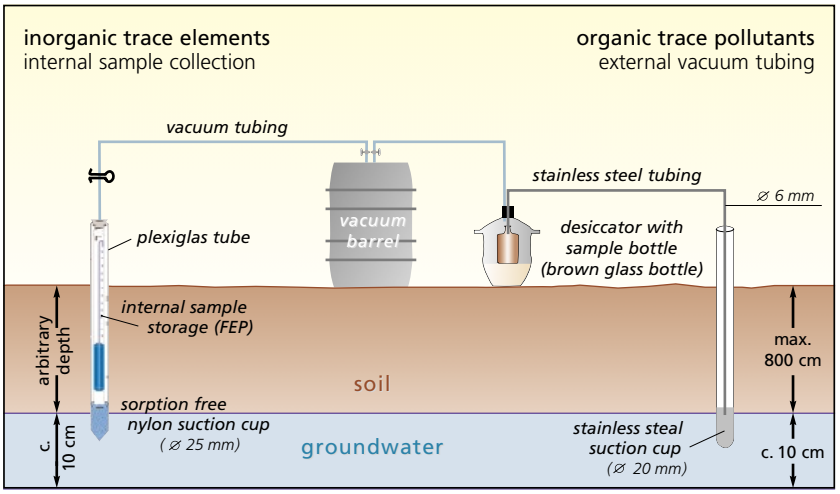
organic pollutants	PAH 16	TPH (C 10 – C 40)	HCH	DDT	PCB 6	VOC
trigger value [µg/l]	0,2	200	0.1	0.1	0.05	20

Inorganic trace elements:

Antimony (Sb), Arsenic (As), Lead (Pb), Cadmium (Cd), Chrome (Cr), Cobalt (Co), Copper (Cu), Molybden (Mo), Nickel (Ni), Mercury (Hg), Selenium (Se), Zinc (Zn), Tin (Sn), Platinum (Pt).

Selected organic pollutants:

Polyaromatic Hydrocarbons (PAK 16), Total Petroleum Hydrocarbons (TPH), organochlorides (among others HCH and HCB), insecticide (DDT), polychlorinated biphenyls (PCB6), volatile aromatic and halogenated hydrocarbons (VOC and BTEX).



Principle of percolation water sampling to determine inorganic trace elements and organic trace pollutants in the soil percolation water.

Further criteria for site selection are land use (arable land, grassland and forest), the geological and hydrogeological situation and the climatic condition of the sites. In most German states representative soil monitoring sites are available, and we selected our sites from this site group for our project, because all the relevant soil genetic and chemical/ physical soil data are available. In the first phase of the project the soil and percolation water at 50 sites in Northern Germany were sampled.

Mobile soil water sampling methods were specially developed at BGR to determine inorganic trace elements and organic trace pollutants. The water samples were extracted from the transition zone between the unsaturated and the saturated zones (see figure above). A borehole must be driven using a soil-specific method (e.g. rotating drilling auger, suction method, percussion drilling rod) down to the groundwater table to install the suction probes.

Percussion drilling.

Preparation of a sampling.

Soil profile.

Measured Background Concentrations

Pilot surveys were needed to clarify how many water samples there were per site and how often a site had to be sampled to get site representative background concentrations of trace elements. For this the spatial variability and the variability in time of the concentration of sites was determined. Based on this survey the sampling of sites is done once with at least 10 percolation water samples per site taken 10 m apart.

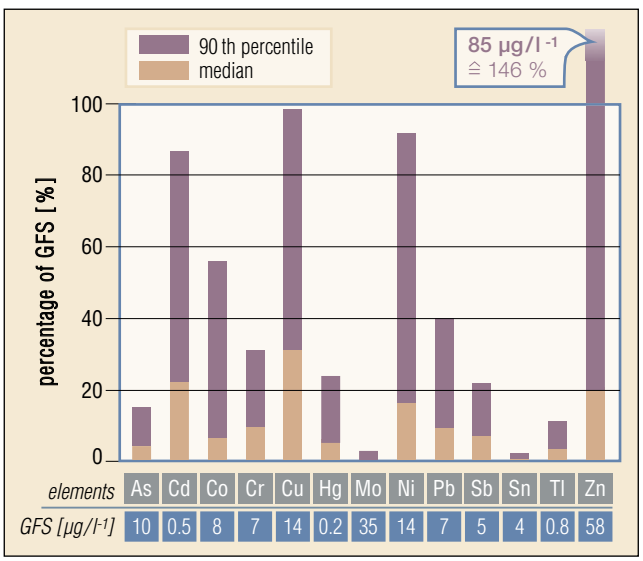
In the figure to the *right* the median and the 90th percentile of the background concentrations of 17 sites with sandy soils in northern Germany are presented relative to what are known as GFS-values. These GFS-values are German specific trigger values for groundwater quality. If they are exceeded, the groundwater is expected to be polluted. These GFS-values will most probably be the future trigger values to also evaluate the percolation water from soil. The results show that the 90th percentiles of most background concentrations are below the GFS-values. Concentrations above the GFS-values are only found for zinc (up to 85 µg L^{-1}).

Median and 90th percentile of Background Concentrations

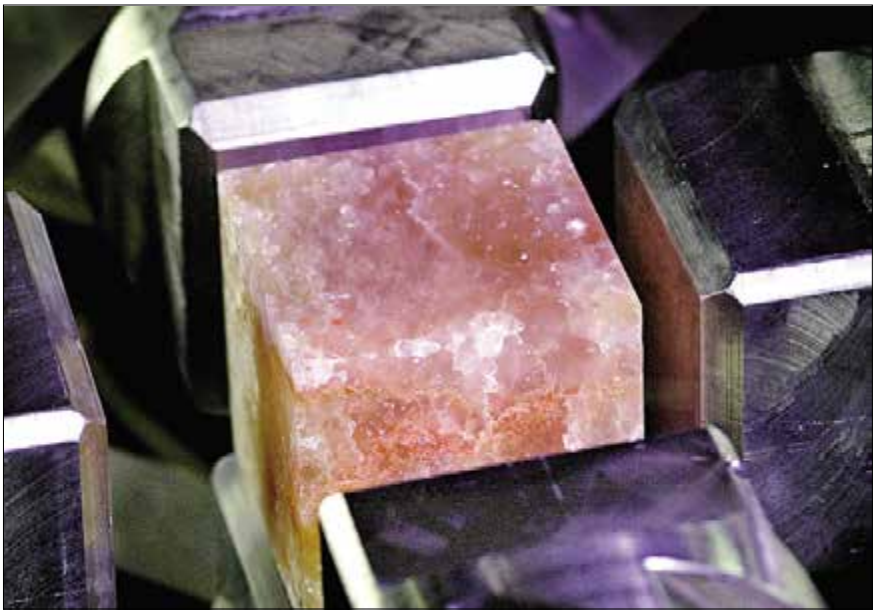
The median (or 50th percentile) is described as the number separating the top half of a sample from the bottom half. The 90th percentile marks the concentration below which 90% of the measured concentrations are found.

The **background concentration** in the soil percolation water is "the concentration in a soil water sample which is caused by the geogenic site properties and the ubiquitous contamination coming from diffuse emissions into the soil". In the research project only sites used as arable land, grassland and forest with normal atmospheric and land-use-specific inputs into the soil are sampled. Sites with urban-caused higher solute inputs or river flood plains, which might have higher inputs due to flooding by river water, are not sampled.

A very positive result was found for the sampling on organic trace pollutants: in the water samples from 9 sites with sandy soils only concentrations below the detection limit of the organic pollutants PAK16, PCB6, petroleum-derived hydrocarbon and chlor-organic pesticides in the percolation water were found.

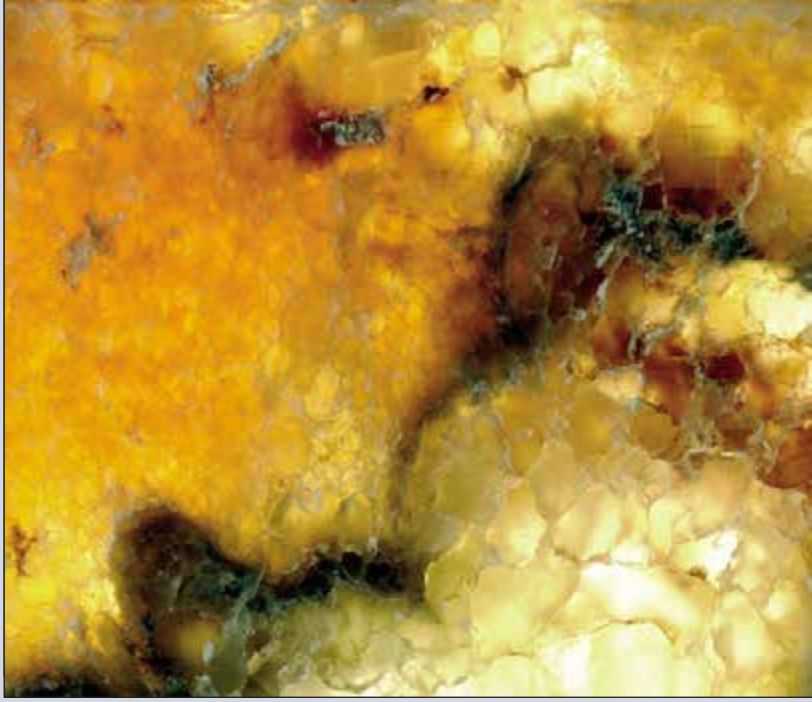


Background concentrations (median and 90th percentile) of trace elements in percolation water of sandy soils under arable land in Northern Germany relative to the GFS-values for groundwater.



Rock salt specimen before creep testing in a triaxial test rig.

Geotechnical Stability / Final Disposal



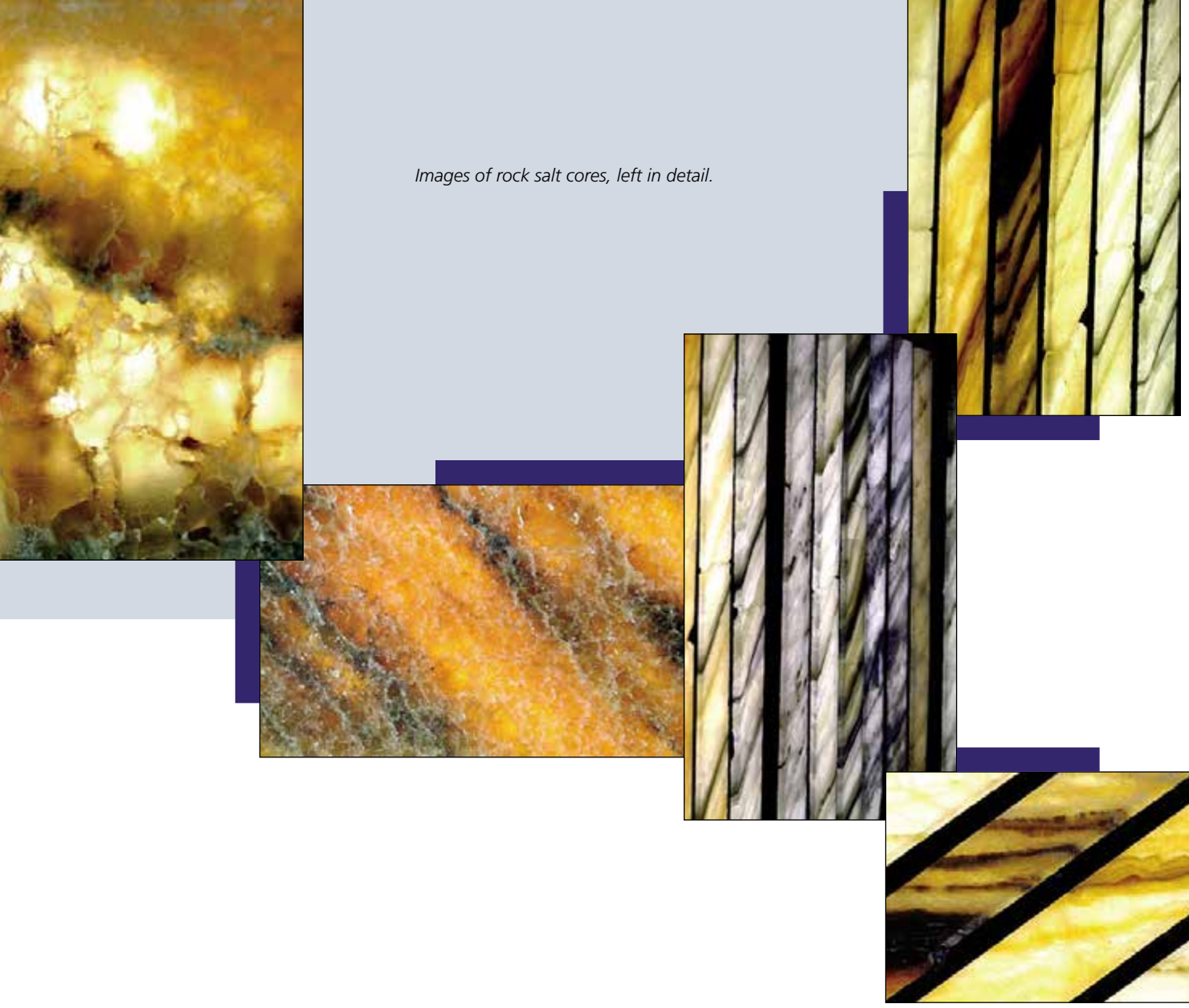
The **Discovery** of **Slowness:** Why Does **Salt Creep?**

Salt Mechanics – Birth and Development of a New Field of Research

At the time the Bundesanstalt für Bodenforschung (BfB) was founded, in the years of the 'economic miracle', securing energy supplies, improving infrastructure and waste disposal were important responsibilities of the still-young Federal Government.

Rapidly growing urban centres led to a reduction of living space. Where once underground cavities were generally associated with mining activities, underground structures became increasingly important for transport, supply and disposal systems, and for storing energy resources. From a safety and economics point of view, the subsurface also offers valuable solutions for goods storage and waste disposal.

However, underground exploration, the construction and stabilisation of cavities as well as guaranteeing their operating safety require intensive geoscientific and engineering investigations. BGR was an important partner and consultant to ministries and industry on such geotechnical issues, and remains so to this day. When evaluating the stability and suitability of underground cavities, in particular in terms of long-term stability assessments of waste depositories, BGR's wide ranging experience in linking geoscientific findings to engineering analyses and forecasts comes into its own.



Images of rock salt cores, left in detail.

Underground structures are permanently subject to numerous and various impacts. The mechanical behaviour of the rock is largely determined by its material properties and the stress condition in the rock mass. Additional impacts such as temperature, loading duration or the chemical environment also play a role. Constitutive models are required to predict the material behaviour – for example for estimating the deformation and stability of load-bearing elements in a mine. They consist of mathematical equations which should describe the effective processes acting on the rock. In addition to theoretical models, the results of experimental investigations and on-site findings form the basis of these constitutive models and their parameters.

The use of rheological models was well accepted in rock engineering by the mid-1960s. They provide the mathematically formulated correlation between the stress state and the resultant deformation which is required for post-processing of investigation results and thus also for predicting the anticipated rock behaviour. LANGER (postdoctoral thesis 1967) extensively discussed the complex combination of relevant rheological models, e. g. a Hooke element for elastic material behaviour with the model elements for viscous creep and plastic behaviour after passing a yield point.

Visit of the Lower Saxony minister Wilfried Hasselmann in the BGR rock mechanics laboratory. Prof. Dr. Michael Langer describes interesting details of salt specimens.

Salt is a suitable host rock for the final disposal of radioactive wastes. As early as December 1957 a memorandum of the German Atomic Commission, the first German nuclear programme, described the necessity for research into the disposal of radioactive wastes (the first German experimental nuclear power station began operating in 1960 in Kahl). In its founding year, the former Bundesanstalt für Bodenforschung drew up proposals to the ministries on the disposal of radioactive wastes in deep rock formations. Two years later a report on the geological-hydrogeological requirements for the final underground disposal of radioactive wastes followed. On 15 May 1963 the president of the Bundesanstalt für Bodenforschung, Prof. H.-J. Martini, recommended final disposal in rock salt formations. He based this recommendation on the excellent properties of salt rocks.

50 years of intensive BGR in-situ and laboratory research confirm former president Prof. H.-J. Martini's 1963 recommendation of final disposal in rock salt formations. Because of its deformation behaviour, rock salt has favourable rock mechanics properties, in particular for the final disposal of long-lived, high-level radioactive wastes. BGR investigations have played a decisive role in the characterisation of rock salt as a barrier rock and in its assessment with regard to its suitability as a host rock for radioactive wastes.

By 1973 at the latest, following the oil crisis, the 'rock salt' host came under the intensive scrutiny of engineering geology in projects for safe and maintenance free final disposal of (radio-)toxic wastes in the deep geological subsurface, and in the course of energy storage projects involving crude oil and natural gas in solution mined caverns. Repositories and storage projects require a host rock that does not lose any of its barrier functions in terms of pollutant propagation or loss of stored goods, either during the operating phase or during the long post-closure phase in the case of a permanent waste repository. Experience in mining in rock salt formations demonstrates that stable underground structures can be manufactured. Salt rocks react to continuous stresses by a slow, viscous movement, known as creep. This property implies that in a sufficiently dimensioned mine, stress conditions leading to damage and dilation of the rock will not occur in the disposal area. This particular aspect of mechanical behaviour means that rock salt creeps into cavities reducing their volume. This process is known as convergence. This leads to 'self-sealing' by cavity convergence, and the reinstatement of an undisturbed stress state. The barrier function of a host rock is thus retained. Proving of the long-term integrity against the propagation of dangerous agents is performed on this basis.

However, underground structures requiring licensing, such as a final repository, require detailed numerical calculations to evaluate the stability and long-term integrity.. In this context, constitutive equations developed not only on the basis of rheological models, but also based on the effective micro-mechanical deformation processes, have increasingly won ground. This development can be followed very well in the six volumes of proceedings previously published on 'The Mechanical Behavior of Salt' (see box below). BGR researchers have developed special testing equipment for investigating rock properties and used it to perform numerous creep tests on salt samples to determine the effective micro-mechanism deformation laws. In-situ tests are used to supplement the laboratory tests. In the mid-1960s BGR thus founded an important field of research – salt mechanics – from the new field of rock mechanics and have played a decisive role in shaping it to this day.

Deformation mechanism maps were compiled based on the effective micro-mechanism processes (Frost & Ashby 1982) and were developed further by BGR scientists to suit their own investigation objectives (Albrecht & Hunsche 1980).

In conjunction with investigations on the development of the microstructure of deforming rock salt, which were aimed to confirm the micro-mechanism models, constitutive equations were developed by BGR based on the deformation mechanisms dominated by in dislocations in the NaCl crystal lattice. Substantial advances were achieved thanks to cooperation with various partners in other scientific institutions. This is reflected in the previously mentioned proceedings of the international conferences on 'The Mechanical Behavior of Salt'. In this context, the monograph by Cristescu & Hunsche (1998) is worth a special mention.

A preliminary **creep law for rock salt**, developed from laboratory results, was established by BGR at the end of the 1970s. This was the birth of **'salt mechanics'**. In 1981, a series of international conferences, 'The Mechanical Behavior of Salt', was founded on the initiative of professor Michael Langer (BGR) and professor Reginald Hardy, Jr. (Pennsylvania State University, USA). The sixth conference in this series took place in May 2007 with 150 delegates at BGR in Hanover.

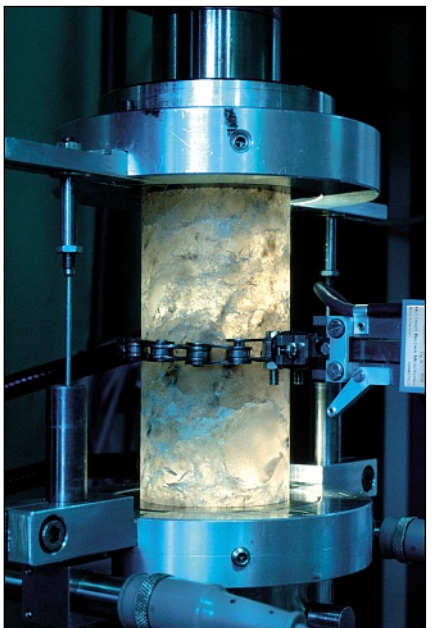
Delegates at the 'salt mechanics conference' at BGR Hanover in 1984 and 2007.

Underground structures were modelled for various rock salt formations using the constitutive equations developed by BGR – for example for evaluating the site of the Morsleben final repository for radioactive waste (see following article). The results confirm where the rock zones will remain stable in terms of stress state, anticipated deformations and the associated stress redistribution and, finally prove where the integrity of the geological barrier will generally not be effected.

However, the analyses also identified rock zones that do not satisfy the numerical demands placed on long-term stability. It became obvious from these results that not only the stress state needed to be identified, which according to laboratory results would be associated with dilatancy and eventually lead to a loss of barrier function (i.e. loss of integrity due to advancing dilatancy). Rather, it was necessary to expand the constitutive equations such that the temporal and spatial development of dilatancy could be modelled. The stage reached in developing a model for this complex problem was expanded and summarised in the joint Federal Ministry for Education and Research project '*Die Modellierung des mechanischen Verhaltens von Steinsalz – Vergleich aktueller Stoffgesetze und Vorgehensweisen*' (Modelling the Mechanical Behaviour of Rock Salt – A Comparison of Current Constitutive Equations and Procedures). The special value of this joint project lies in the comparison of constitutive equations and procedures from a total of six national institutions or working groups engaged in modelling using their respective constitutive equations.

Computer-aided numerical methods using the finite-element method have been employed for modelling the mechanical behaviour of rock salt since the beginning of the 1980s. One extraordinary challenge is that the results achieved during creep tests extending over months or years in the laboratory under comparatively high mechanical stresses and deformation rates need to be extrapolated to periods up to 1 million years for a final repository. Appropriate numerical codes realistically simulate rock mechanical processes (cavity excavation or backfilling) and thermomechanical interactions over very long periods of time. They allow BGR researchers to predict the long-term stability of a final repository. Today, these methods are based on real, three-dimensional geological models; coupled TMHC (thermo-hydraulic-mechanical-chemical) processes can increasingly be taken into consideration (see following article).

The keyword **TMHC** describes the more advanced demand on constitutive equations of modelling the interactions between thermal, mechanical, hydraulic and chemical influences. This highly ambitious problem was a special topic at the last of six international salt mechanics conferences, hosted in Hanover in May 2007. The stage reached as presented at the conference demonstrates the excellent spectrum of knowledge, but also the remaining challenges: they particularly include describing pore pressure impacts on the stress state during convergence of cavities, containing crushed salt for example, in the post-closure phase by means of constitutive equations. The same applies to self-healing in damaged rock salt in the near field of the underground structures in a final repository structure once the stress state has returned to a non-dilatant stress range.



The BGR core storage shed with cores totalling over 20 km long from exploratory boreholes such as in Gorleben or Konrad.

After the mid-1980s, granite increasingly became the focus of investigations as potential host rock for a final repository of radioactive waste, followed by work on argillaceous rocks from the mid-1990s, due to a change in political objectives in Germany. BGR also utilised and expanded its expertise and existing laboratory instrumentation to investigate these alternative host rocks. Site-independent, fundamental research and development projects (R&D projects), in particular those carried out in international cooperation with rock mechanics laboratories, are therefore now the main focus of interest, such as the current 'Clay Report' (see 'Clay Report' article).

Today, BGR owns one of the world's largest scientific testing laboratories (30 testing systems with approximately 65 testing stations) for determining the thermal, mechanical and hydraulic properties of host rock material. The constitutive equations developed by BGR help to improve the safety assessments of final repositories and underground structures in salt. BGR is thus in a position to simulate and correctly describe the numerous impacts and processes acting on rock salt and thus to provide an important contribution to the safe final disposal of pollutants in rock salt.

Crushed salt and bentonite before and after (in the dishes) compression in an oedometer test (above).

Opposite page left: Dynamic testing machine for investigating single-crack propagation in a rock salt specimen.
Right: Rock salt specimen under dynamic loading to determine volume change.

Specimen preparation, here sawing cores to length using a band saw.

Repository relevant properties of potential host rocks.

property	rock salt	clay / claystone	crystalline rock (e. g. granite)
thermal conductivity	high	low	medium
permeability	practically impermeable	very low to low	very low (unfractured) to permeable (fractured)
strength	medium	low to medium	high
deformation behaviour	visco-plastic (creep)	plastic to brittle	brittle
stability of cavities	self-supporting	artificial reinforcement required	high (unfractured) to low (strongly fractured)
in situ stress	lithostatically isotropic	anisotropic	anisotropic
dissolution behaviour	high	very low	very low
sorption behaviour	very low	very high	medium to high
heat resistance	high	low	high

Three-dimensional Geological and Geomechanical **Modelling** of the **Morsleben** Final Repository **(ERAM)**

It is aimed to utilise deep geological formations for the final disposal of radioactive wastes in Germany. Extensive geoscientific investigations, carried out by BGR with the aid of computer simulations, amongst other things, are required to guarantee the long-term stability of a final repository. Extensive geological and geomechanical investigations have been carried out in salt rock during the last three decades to prove the suitability of the host rock salt for the final disposal of radioactive wastes, for solution mining and for gas and oil storage in caverns. The geological barrier, as a component of the multi-barrier system, plays a particularly important role in the final disposal of radioactive wastes: the bearing capacity and geomechanical integrity of the salt rock, its geological and tectonic stability, and geochemical and hydrogeological processes must be analysed and evaluated to provide the necessary verifications for the final repository. Analysis requires a variety of steps, for example:

- Geological investigations to identify baseline data for two- and three-dimensional structural geologic models.
- Mine observations.
- Geotechnical in-situ measurements to identify the required host rock and overburden parameters.
- Geomechanical laboratory testing to determine the necessary material parameters and to develop suitable constitutive equations.
- Two- and three-dimensional geomechanical and, if necessary, thermomechanical or hydromechanical model calulations to investigate the stability of the final repository and the integrity of the salt barrier.

Finally, these are followed by the safety assessment, which takes all experimental and theoretical geoscientific investigation results into consideration.

Selected results of the geological and geomechanical investigations for the Morsleben final repository for radioactive wastes (ERAM) are presented below. Based on the development of a three-dimensional structural geologic model, three-dimensional geomechanical modelling is performed to numerically analyse the stability of old mining rooms and the integrity of the salt barrier.

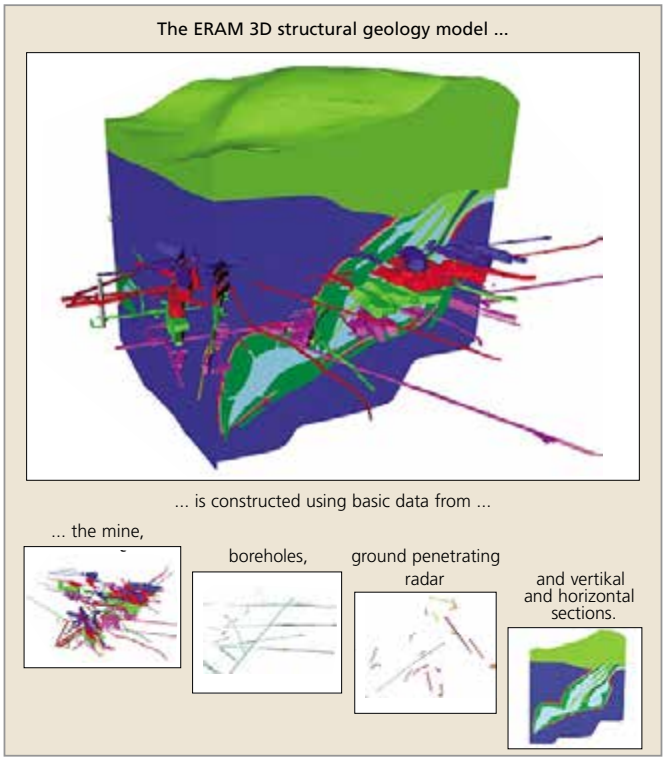
ERAM was established in the former Bartensleben potash and salt mine. The mine is divided into several parts, such as the southern, western and eastern part, where non-heat generating wastes are stored. The central part has a complex geological structure, represents the part with the highest degree of excavation, with numerous rooms on several levels, and is thus subject to high mechanical stresses.

A digital, 3-D structural geologic model for the northern central part of the Bartensleben mine (main trough) was compiled on the basis of the existing two-dimensional model.

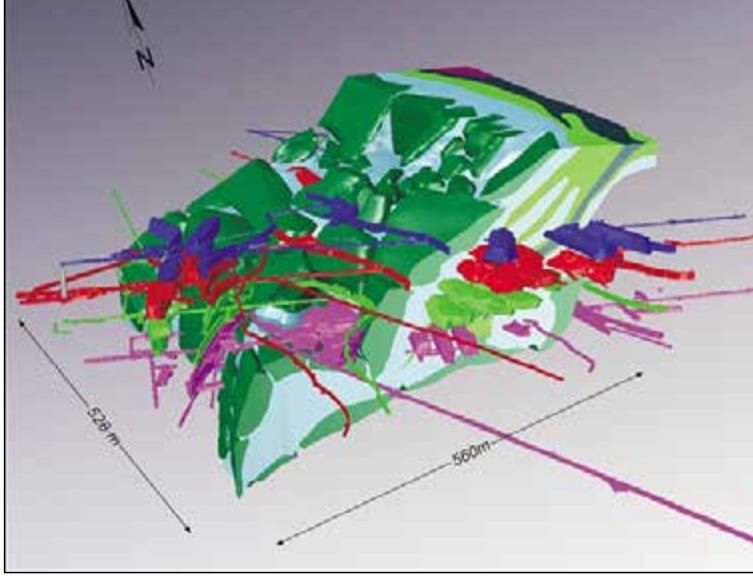
The aim of this work was to improve and expand visualisation and interpretation options for the existing mine data and to take into consideration the additional exposure data collected since compiling the 2-D geological-tectonic model (1997 – 2000). The model was developed with a view to geological monitoring of the backfill measures in the central part of the Bartensleben mine. New drifts were manufactured and a variety

of new boreholes drilled in preparation for the backfill measures. Optimal positioning is simplified and aided by detailed visualisation of the geological relationships in 3-D space. In addition, interpretation of microacoustic monitoring and assessment of GPR (ground penetrating radar) surveys performed parallel to drifting is substantially improved by the 3-D structural model.

A variety of basic data were utilised to create the 3-D model (see figure below). The 2-D geological-tectonic model served as the basis. Besides exploratory geological boreholes, the geological mine level maps, which are based on evaluations of geological drift mapping (scale 1:100), represent the most important data source. In addition, the GPR survey results and the 3-D mine cavity model were employed in support. All input data were examined for base data consistency in the openGEO™ construction tool, evaluated in 3-D space and visualised in the Gauß-Krüger coordinate system.



Base data for the 3-D structural geologic model of the central part of the Bartensleben mine (ERAM)



Part of the ERAM 3-D structural geologic model. Strata in the Leine Series (Hauptanhydrit in dark green, Linien to Buntessalz in pale blue, Anhydritmittelsalz in pale green, Schwadensalz to Tonmittelsalz in dark olive) and the Aller Series (violet) and the 3-D mine model are shown.

A 3-D structural geological model, in which every point is uniquely defined, was created by calibrating and interpreting the data in space. Rocks of the Late Permian (Zechstein) Staßfurt, Leine and Aller Series' were combined to a single structural unit, which are shown in the 3-D model as an independent geological body.

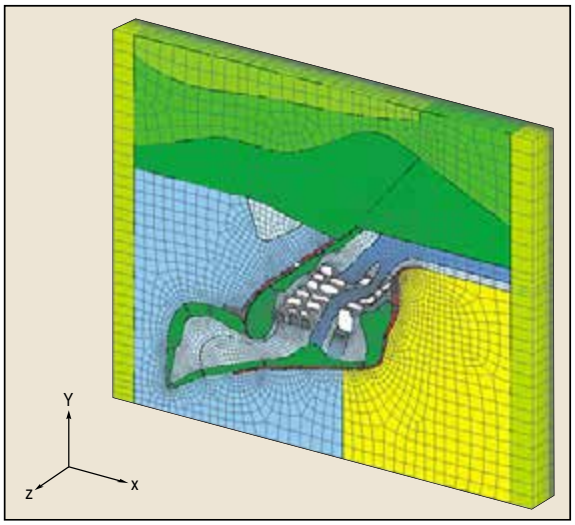
The 3-D structural model can be visualised and sections draw in conjunction with the mining surveyor's 3-D mine model. Because the resulting overall 3-D model is based on Gauß-Krüger coordinates, it is possible to exactly determine both spatial distances and volumes. What's more, additional visualisations can be generated for special purposes from the 3-D model, for example selected sections, virtual boreholes and any partial visualisations.

In combination with the 3-D mine model, the 3-D structural model of the central part of in the Bartensleben mine represents an important foundation for planning and other tasks, such as geomechanical modelling using finite-element methods (FEM) to asses the stability of the mine and the integrity of the salt barrier. The geomechanical model is developed for this purpose by idealising the geological structure and modelling the rock strata using different material behaviours in conjunction with the mine configuration. The geological model

comprises numerous, occasionally very thin, rock strata which do not require detailed geomechanical modelling. The geological structure is therefore condensed into homogeneous zones with uniform mechanical material properties and taken into consideration in the analysis using suitable constitutive equations.

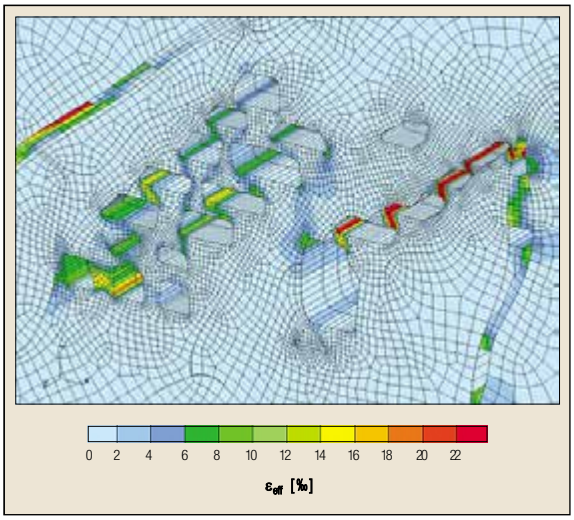
A characteristic 2-D section through the geological model is initially selected with regard to the three-dimensional problem to be investigated. The model is then extruded perpendicular to the geological section or parallel to the rooms to form a 3-D model. In the mine section considered here a mean room length of 120 m and a mean pillar width of 30 m can be assumed. By utilising the symmetry planes in the pillar and room area and modelling them using corresponding boundary conditions in the model, only half of the room lengths and half of the pillar widths need by taken into consideration in the three-dimensional rock mechanics model. This is followed by the discretisation of the numerical model, i.e. subdivision of the structure considered into finite elements. The figure at top right shows the entire three-dimensional FEM model with the dimensions 750 m high, 850 m wide and 75 m long. BGR carries out numerical analyses of the stability and barrier integrity of the central part of ERAM using this three-dimensional finite-element model. BGR uses the new JIFE (Java Interactive Finite Element Code by SRD, Berlin) program system, which facilitates analysis of very large, three-dimensional structures and numerical simulation of coupled thermohydraulic-mechanical-chemical (THMC) processes.

As an example, the adjacent figure shows calculated effective strains in the salt rock in the region of the roofs and pillars in the mine at the current time (2007). The effective strains, which reach especially high values in the roof areas between the rooms, are a measure of the rock deformations. They represent results that can be utilised to assess the mechanical stresses acting on load-bearing elements of the mine such as pillars and roofs, and for evaluating the geomechanical integrity of the salt barrier.



Three-dimensional finite-element-model of the southern central part in the Morsleben final repository for radioactive waste.

The geological and geotechnical investigations, which comprise geological modelling, geotechnical in-situ measurements, laboratory tests and geo-mechanical modelling, are incorporated in the overall safety evaluation for the final repository. They help ensure that a comprehensive, geoscientifically founded site characterisation is available as the basis for future licensing procedures.



Effective strains analysed using JIFE in the area of roofs and pillars in the mine at the current time (2007).

The BGR **„Clay Report“** – a **Media-Highlight**

During the last few decades the salt dome in Lower Saxony's Gorleben has been investigated as the only possible final repository site for high–level radioactive waste. It is currently being discussed in Germany whether the Gorleben site should be investigated further or other sites also be examined for suitability. With regard to the search for alternative sites, numerous articles in the press reporting the interim results of what is known as the BGR's 'Clay Report' led to heated debate. The report, compiled by BGR on behalf of the Federal Ministry of Economics and Technology (BMWi), identifies regions with argillaceous rocks worthy of investigation, as alternatives to the salt and granite host rocks previously studied in Germany. The aim of the report was to identify which rock formations would be suitable in case of new site studies, and their locations.

Interim results from the 'Clay Report' were published on the BGR website in April 2006. In August the *Neue Osnabrücker Zeitung* (NOZ) picked up these interim results and published an article with the title '*Lager für Atommüll in der Region*?' (Store for Atomic Waste in our Region?) on 24 August 2006. The subsequent media resonance, especially in local and national newspapers, was considerable. A total of 130 stories in the media on the 'Clay Report' with reference to BGR were recorded in August 2006 and more than 140 in September. The media echo was even greater compared to other BGR media highlights that year, such as the energy summit, the earthquake in northern Germany or nuclear weapons testing in North Korea. Why was that?

Waste disposal is not normally a particularly publicity-drawing topic. Who's interested in waste, anyway? In principle, this is no different for radioactive waste, but: high-level radioactive wastes emit dangerous radiation for a very long time and must therefore be carefully disposed of. This is why it is aimed to dispose of these wastes by isolating them from the biosphere in repositories in deep geological formations. The BGR's final repository experts have been researching the properties of potential host rocks such as salt, granite or clay for many years. However, for the experts, working on this topic also means performing scientific research against a background of socio-political decision-making. In Germany, public exchanges on this subject have been the source of conflict for decades. Scientists accept that safe disposal of radioactive waste in deep geological formations is possible. Technical implementation of a safe final repository is also possible according to current science and research. The 'peaks' displayed by final repository topics in BGR's media statistics make clear the significance of scientifically based facts and figures in general discussions of final repository topics in the population. The public nevertheless associate negative attributes with the topic of final disposal of radioactive waste.

Public survey results have shown that the overwhelming majority of citizens think that the waste should be finally disposed of as soon as possible. However, if they were asked if they agree to a final repository in their region, the overwhelming majority would disagree. This principle – known as NIMBY, or Not In My Backyard – describes the facility to recognise hazards, but to lay the burden of eradication on others. Citizens are well aware of the political problems involved in making decisions on the treatment of hazardous wastes, but are at the same time of the opinion that the lack of a decision on the problem proves that there is no safe path to disposal. While 45% of those asked thought

that underground disposal is the best long-term solution, 38% do not share this view (Eurobarometer 2005). The differences of opinion on this topic show that the expert's opinion that this is the best solution, do not yet appear to have reached public ears.

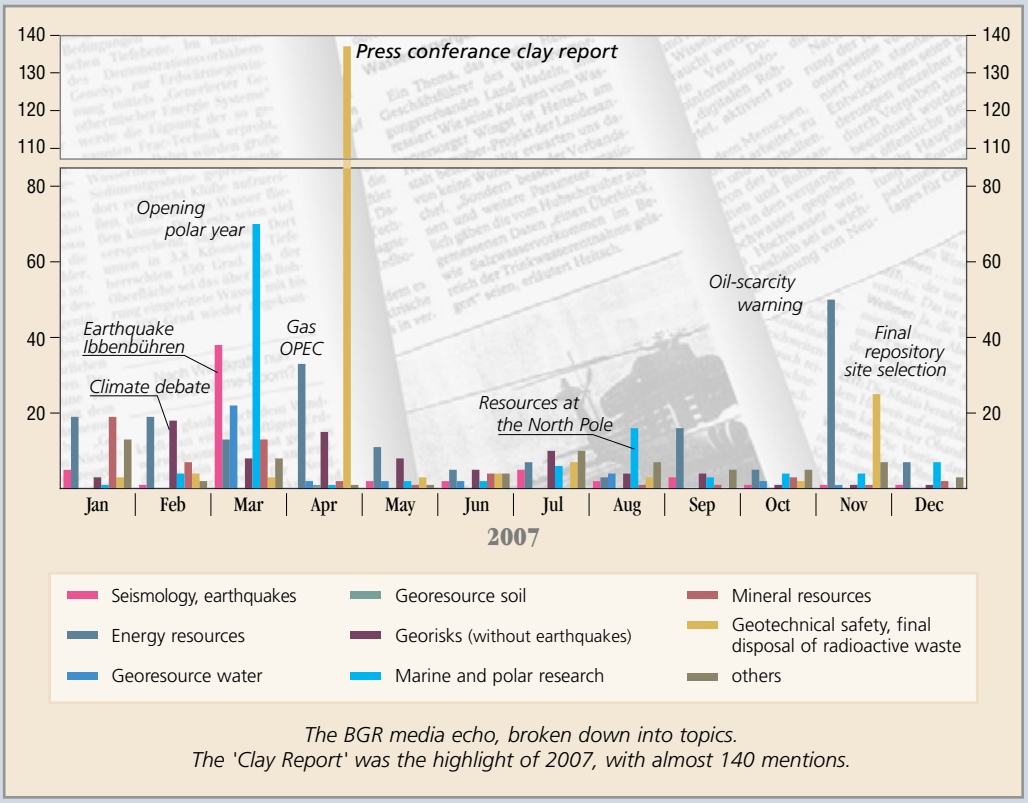
On the contrary – the fear and mistrust of citizens are often inflamed further by the media as a result of either a lack of, or incorrect, information. For example, in the *NOZ* newspaper article mentioned above, not only were potential alternative host rocks discussed, but also 'potential final repositories in the Osnabrück region'. It was also seen that after only a few days further articles were published in the north German press, radiating from the Osnabrück region. The 'Clay Report' was then picked up and published by the media in southern Germany after a further few days delay. In southern Germany the reactions of the interviewed local politicians, for example in Baden-Württemberg, were especially vehement:

- surprise – rejection – indignation – plans for 'rebellion';
- fear that regional tourism would suffer;
- 'The federal government has already invested billions of euros in investigating Gorleben';
- 'Continue following a course of phasing out nuclear energy';
- 'Delay tactics of the black-red coalition government in the final repository problem'.

It is obvious from the survey results and the reactions of local politicians that there is a measure of uncertainty, besides rejection, amongst the population, which can only be the result of insufficient information on the topic of final disposal. There is obviously a need for more information.

BGR media resonance indicated that final repositories were also a 'peak' topic in 2007 (see figure above). The occasion this time was a press conference on 18 April 2007 in the Federal Ministry of Economics and Technology in Berlin, where Federal Ministry of

Impressions from the press conference for publication of the 'Clay Report' on 18 April 2007 in Berlin.



The BGR media echo, broken down into topics.
The 'Clay Report' was the highlight of 2007, with almost 140 mentions.

Economics and Technology and BGR representatives presented the final 'Clay Report' to the public. Following this event, a total of 135 stories on the 'Mudstone Report' with reference to BGR were noted in regional and national newspapers, run by agencies and on the Internet.

BGR had been queried about film recordings in the run up to the event and numerous interviews were given after the press conference. BGR published an article on the 'Clay Report' on its website at the same time as the press conference. At more than 10,000 hits per day, access to the 'Final Repository' files section on 18 and 19 April 2007 were ten times higher than average, and still four times higher the following day. Overall, a total of 60 , 461 hits were recorded to the 'Final Repository' section and 3,425 different visitors registered: records for the 'Final Repository' section of the BGR website since its relaunch in November 2005. The resonance is even better when renowned national online newspapers adopt the topic. For example, 'SPIEGEL-ONLINE' published an Internet article on the 'Clay Report' on 18 April 2007, which included a download link to the BGR website.

The download option from the BGR website still exists at www.bgr.bund.de/DE/Themen/Geotechnik/Downloads/BGR__Tonstudie2007.html. Bound copies of the report are also provided upon request. An English translation of the 'Clay Report' is in preparation.

BGR public relations experience over the last five years has demonstrated that exciting, understandable information and assertive handling of the subject of final repositories evoke positive reactions and the interest of those concerned. Media, citizens and scientists increasingly use the Internet as an information source, as the Internet statistics for the BGR website show. BGR will strive to fill in any public information deficits with their public relations work and by carefully monitoring the media, and will thus contribute to objective discourse on the topic of final disposal. It provides first-hand, scientifically founded and understandable information on final disposal, for example for the 'Clay Report'.

The volcanoes Semeru and Bromo in Indonesia.

Geological Hazards

Geological **Hazards:** Overview

Catastrophic geological events such as the 2004 tsunami in the Indian Ocean raise global questions on the type and probability of such threats, and also on the vulnerability of particular regions/countries or societies to geological events posing hazard potential (geohazards). For the geosciences, as well as the exploration and utilisation of Earth's resources, risk analyses of geogenic hazard potentials represents the global field of action of the future. Geohazard analyses are integrated internationally in natural catastrophe management organisation types, where prevention, mitigation and rehabilitation/ reconstruction measures are implemented. Overall, the geosciences will thus acquire a new political dimension in terms of knowledge-based policy advice, both nationally and internationally. Taking into consideration the increasing requirement for national decision makers and the civil society affected to be adequately advised in the fields of provision of public services and catastrophe precautions, BGR has bundled its expertise in the field of geohazards into various thematic areas since the mid-1990s.

BGR's geoscientists focus on analysing the threats posed by geogenic hazards such as earthquakes, land subsidence, mass movement (mudflows, landslides), ground stability in earthquake zones, volcano monitoring and subrosion (subterranean disintegration of salt rocks forming regional/local sinkholes and dolines)

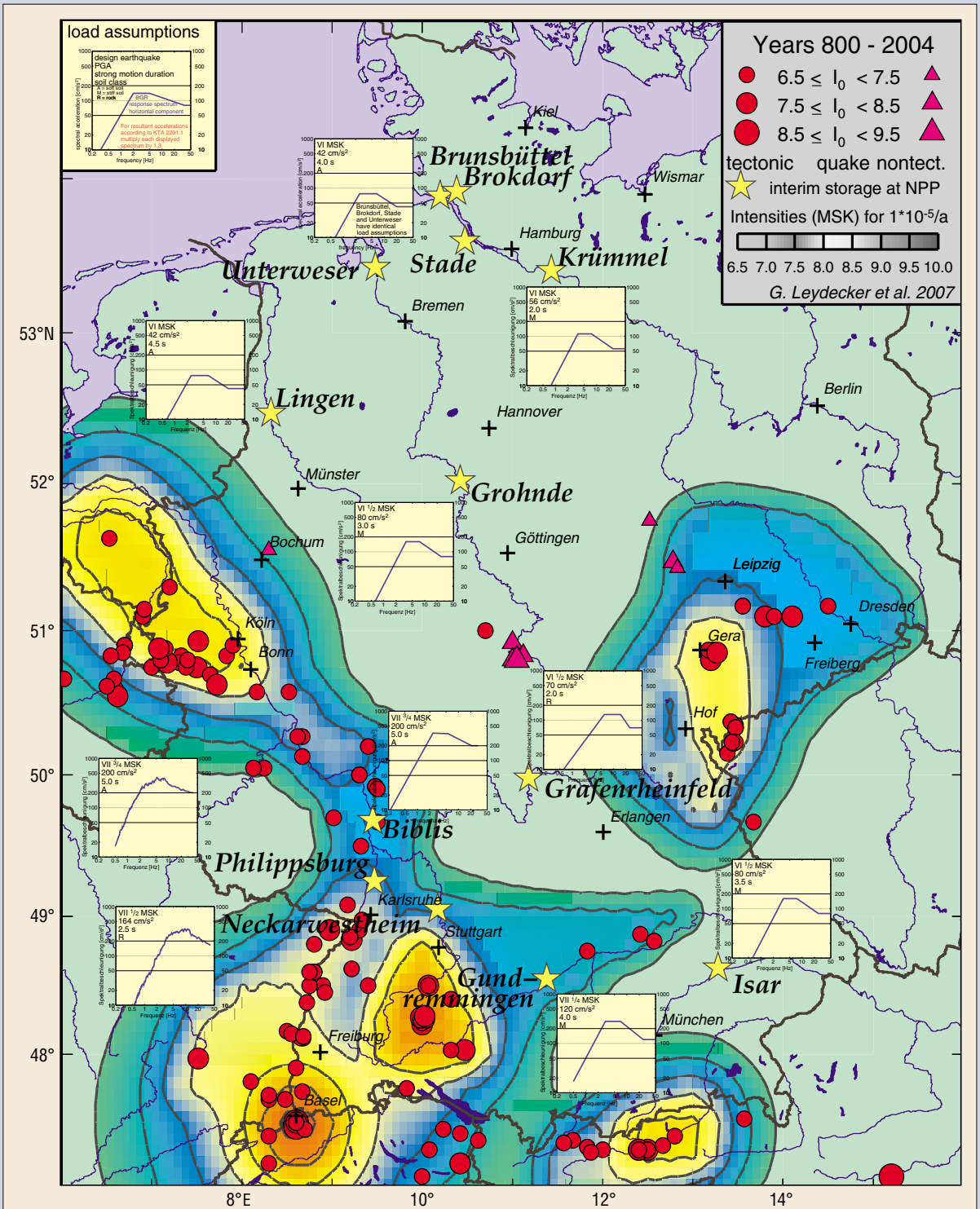
Earthquakes and Seismic Hazard Assessment

At BGR seismic hazard assessment of a site in Germany and compilation of the German earthquake catalogue, beginning with the year 800, are closely linked. In 1976 a research project to derive seismological criteria for site selection of nuclear facilities in the Federal Republic of Germany was approved. At the time the project was carried out it quickly became clear that without a digital earthquake catalogue including information from far of the past it would not be possible to produce statements on possible future earthquakes and their strength with any degree of certainty.

The saying 'he who does not know the past, cannot foresee the future' does not refer just to earthquake history, but also to geological evolution and (neo) tectonics. This is because all three are required to determine data concerning earthquakes of certain strengths with return periods from ten to a hundred thousand years, which is required for nuclear facilities. For large reservoir dams, design for a 2,500-year earthquake must be carried out and for a 475-year earthquake for normal buildings up to four storeys. BGR colleagues from the engineering geology and engineering seismology divisions were and are involved in compiling appropriate sets of safety standards for Germany and the EU.

Seismo-engineering activities required in preparing expert reports must be orientated to the respective national safety standards and to the status of science and technology. Initially, determination of the design earthquake could only be performed deterministically. This deterministic method assumes that past earthquakes within a certain periphery around the specific site and, dependent on its affiliation to a tectonic region, may recur at the site or in its vicinity in the future. The maximum shakability obtaining on the site must be estimated. Because of the temporal boundedness of each earthquake catalogue considerations must be employed to ascertain whether the maximum earthquakes observed to date can be also accepted as a future upper limit or, based on sound knowledge, whether the strength must be increased. Here the geological-tectonic situation of the periphery of the site naturally must be included in considerations.

Approximately 30 years ago computer technology was so advanced that initial comprehensive analysis applications were provided and distributed for probabilistic assessment of earthquake hazards, based on published theoretical principles. Using these applications, the annual probability of exceedance could be assigned to the deterministically determined design earthquake.



Map with the sites of interim storages for spent nuclear fuel at German nuclear power plants (yellow stars).

The seismo-engineering design parameters and the site-specific response spectra (horizontal component) determined by the BGR are plotted at each site into the small boxes. (from above: intensity of the design earthquake, peak ground acceleration, strong motion duration, subsoil or ground class.
The short cuts mean A = unconsolidated sediments, M = consolidated sediments, R = rock).

In the background of the map the damaging earthquakes since the year 800 (from epicentral intensity I_0 = VI ½) are represented and also first results of our probabilistic earthquake hazard map for a probability of exceedance of 10^{-5}/year.

The task of civil society here is to set the hazard safety level for technical plants and installations with science correctly designating the reliability and limits of its specifications and analyses.

Today both methods of determining the design earthquake are used in parallel and complementary to each other. The deterministic approach is directly accessible to plausibility considerations and thus helps us to better understand probabilistic results. In addition, the variation of an individual parameter during a probabilistic analysis serves to discover its direct effect on the result and to learn to judge it, for the same purpose. The strength of the design earthquake is finalized from all these examinations and considerations, including the tectonic conditions, Building loads are specified based on the design earthquake and taking the subsoil conditions at the site, such as rock and consolidated or unconsolidated sediments, into consideration. These loads are indicated as response spectra, spectral acceleration values and strong motion duration.

BGR seismo-engineering expert reports for different sites and hazard levels were compiled using the aforementioned basic principles and developed approaches. Scientific work for assessing earthquake hazards for regions and national territories were also carried out, for example for Germany, Bulgaria and Romania, as well as for regions of Ghana, always based on specifically compiled earthquake catalogues. For dams, nuclear power plants, final repositories for nuclear waste, and for all 14 interim storage sites for spent nuclear fuel at German nuclear power plants, site-specific expert reports were compiled to determine the seismo-engineering design parameters.

The accompanying figure summarises the results of almost all expert reports for the interim storage sites on a map (opposite page), together with the damaging earthquakes. The results of a general computation of seismic hazards for a probability of exceedance of 10^{-5}/year are also drawn. Such maps can be used for roughly estimating the seismic hazard; however, they can never replace a site-specific expert report.

Volcano Monitoring

Volcanoes are complex geological systems which erupt regularly, especially in the subduction zones of tectonic plates. They are the second most dangerous of all geological risks after earthquakes. For approximately ten years BGR has been investigating the processes active during eruptions and how risks can be reduced for people living in the vicinity of volcanoes.

BGR's scientific work in this field resulted from the fact that during the last few decades it has become increasingly necessary to monitor volcanoes because more people than ever are living in proximity to them, while the methodology of scientifically monitoring volcanoes has remained at the same level. The main failing being that there was no opportunity to use different scientific methods to obtain an overall picture of the active processes during an eruption. Enhanced understanding of the physical processes involved was not therefore possible.

Around 1995 BGR developed the concept of the 'Multi-Parameter Station' for volcano monitoring, which was subsequently used in two major projects: the Galeras Project and the Krakatoa Project.

Galeras-Project

Galeras is the most active volcano in Colombia and has a minimum age of one million years. In its past two major eruptions have occurred and almost

The city of Pasto in direct proximity to the Galeras volcano.

continuous small ones. Because of its activity history and its proximity to the city of Pasto with about 400,000 inhabitants, Galeras was included on the list of 'Decade volcanoes' in 1991. During its last eruption in 1993 nine people died, seven of them scientists working in the volcano's crater at the time of the eruption.

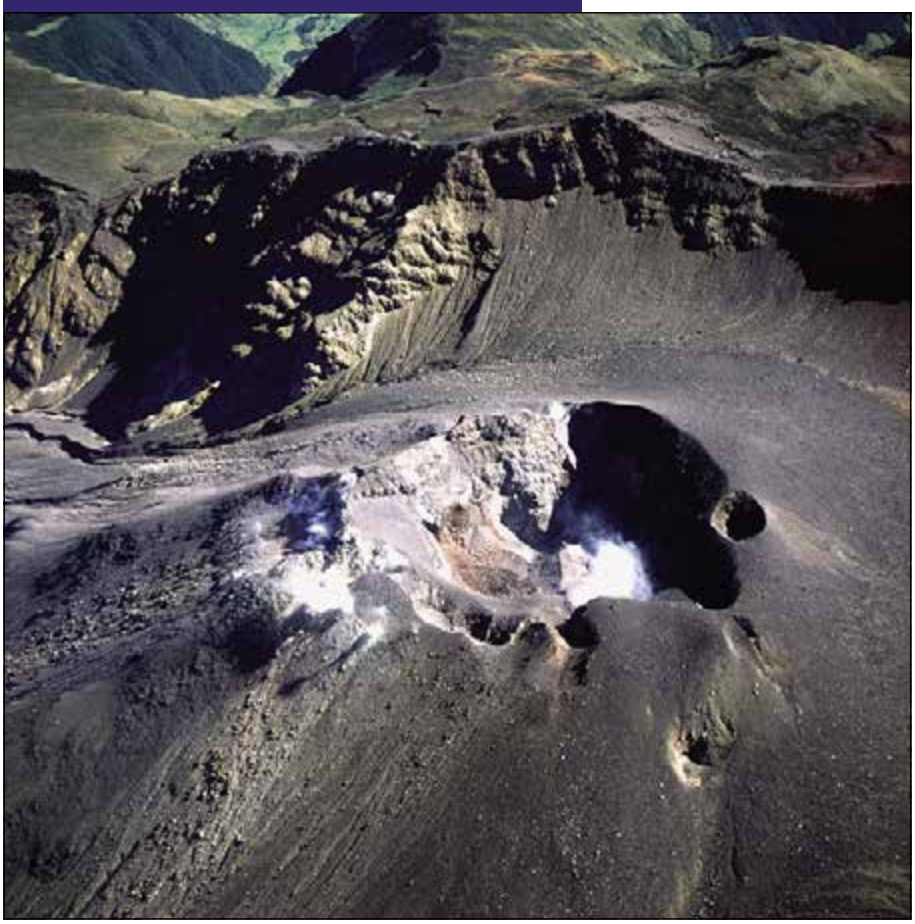
In 1997 in close cooperation with the geological survey of Colombia INGEOMINAS, BGR started the installation of the multi-parameter station. The station consisted of:

- several seismic broadband stations,
- one gas probing station,
- one station for electromagnetic measurements
- and one weather station.

It included regular flights over the volcano with a thermal camera.

Data was transmitted from the multi-parameter station into the observatory in Pasto by radio.

The signals of the Galeras recorded by the multi-parameter station showed that special seismic signals ('Tornillos') indicate the rise of magma inside the volcano. The composition of fumaroles gases begins to change several days before the eruption. Following the eruption, strong electric signals occur. After a break of more than ten years a new active phase of the volcano started in 2004 and is still continuing today. The last strong single eruption occurred in January 2008 and was the strongest since 1993.



View into the Caldera of the Galeras volcano. The discharge of gases demonstrates the activity of the volcano.

Krakatoa-Project

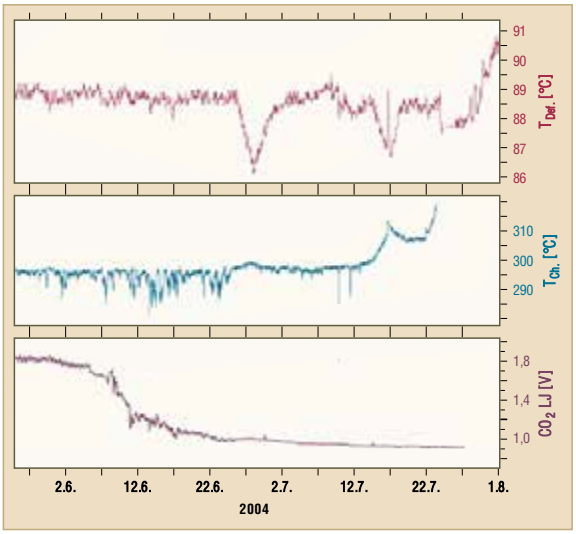
Krakatoa exploded in 1883 with an eruption which threw huge amounts of matter into the atmosphere. The eruption, including the effects of the tsunami, caused the deaths of more than 35,000 people. The volcano is still very active today, and is growing in height by four metres every year.

Within the geotechnologies project, funded by the BMBF, the Krakatoa volcano was selected by BGR in cooperation with the Geological Survey of Indonesia as a location for the installation of a multi-parameter station. The installation included broadband seismometers, measurements of deformation using GPS, a weather station, measurements of ground temperature, determination of the chemical composition of fumaroles gases, an electromagnetic station and observations of the volcano by video camera.

All the data are transferred via radio link from Krakatoa to an observatory at the mainland and from there to the main office in Bandung and to BGR in Germany. This is done via the satellite link system planned for tsunami monitoring and via the Internet.

Important features of the monitoring system are:

- worldwide data accessibility via radio link – satellite – Internet,
- automated data processing,
- analysis of the data using expert systems,
- standardized data access via web interface.



Changes of gas temperatures of the fumaroles Deformes (upper) and Chaves (centre), and change of carbon dioxide content of the fumarole LJ (lower) during June and July of 2004. Eruptions with ejection of ash occurred on 16 and 21 July 2004.

The system enables real time determination of the activity of the volcano at any time and therefore represents an important tool within the monitoring of Krakatoa for decision-makers in Indonesia. It makes an important contribution to the protection of the people of Indonesia against a foreseeable eruption of Krakatoa.

Installation of equipment at Krakatoa.

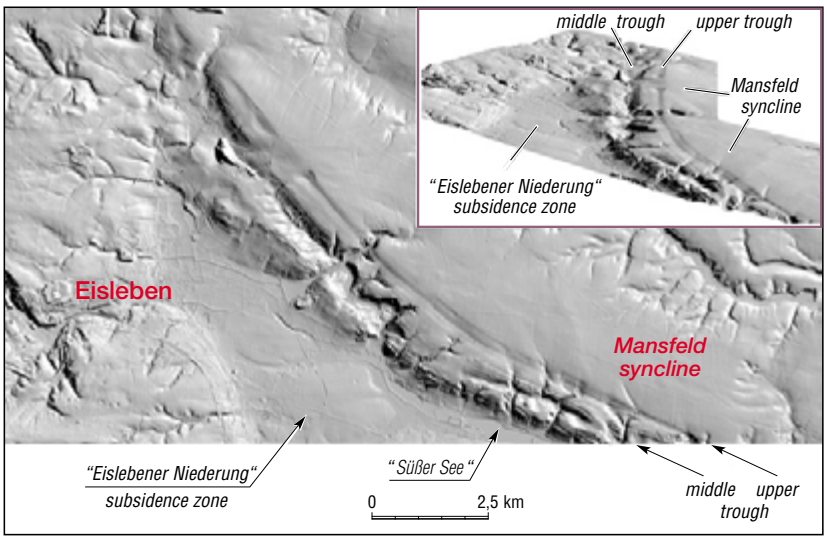
50 Years of Remote Sensing in Geohazard Research

Images, data and other information recorded by sensors in satellites and aircraft are utilised today in almost all fields of applied geosciences. Whether simple aerial photography or complex satellite sensors are involved, both profit from the generalising perspective given by the position of the recording device and thus provide information that often remains hidden to ground-based observers. In addition, the fact that remote sensing methods mean no access by foot or vehicle to hazardous areas is necessary, and therefore neither personnel nor equipment are put at risk, is also an important factor for the geohazard sector.

If we consider the remote sensing activities in the geohazard sector over the last 50 years, the first 30 years were characterised almost entirely by aerial and satellite images. These images, whose original medium of photographic film is today being increasingly replaced by light-sensitive semi-conductors, provide indispensable information on changes in terrain such as the formation of fissures and cracks, plant growth anomalies and other deviations from the norm in a given terrain, just as they did 50 years ago. In the geosciences, such information serves as an indicator of decompaction and destabilisation of the subsurface. Some examples include the slope stability evaluation work at the *Altenberg Pinge* (*Zentrales Geologisches Institut ZGI* Berlin 1980 to 1982), evaluation of subrosion-related subsidence in the Halberstadt-Westeregeln region (*ZGI* Berlin 1983 to 1985) or identifying collapse-prone zones above flooded potash mines in the Staßfurt region from the mid- to end 1990s. BGR work using conventional aerial and satellite images cover very wide thematic issues extending to monitoring glacier lakes in Nepal at the beginning of the 1990s.

From the first half of the 1990s onwards the existing image of traditional photograph-based remote sensing was altered by almost revolutionary technological developments. These include the introduction of airborne laser scanning (LiDAR) and differential SAR interferometry (D-InSAR) between 1990 and 1995 and persistent scatterer interferometry (PSI) post-2000. LiDAR uses a laser beam to scan the terrain and provides precise height data for every single point of terrain. The result is highest-resolution digital terrain models, which can reveal even the tiniest deviations from normal topography and thus signs of terrain nstabilities at the earliest stage, which are not yet discernable in the field. LiDAR data have been employed by BGR since the end of the 1990s.

Almost simultaneously, differential SAR interferometry provides another method that recognises horizontal and vertical terrain movements, even if the annual rates are mere centimetres or fractions of centimetres. These developments opened up completely new methods for remote sensing in the field of geohazards, because they finally allowed widespread terrain heave and subsidence, slope movements and crustal deformations to be recognised prior to earthquakes or risk-indicative changes in the volume of volcanoes.



Example of LiDAR applications: visualisation of a LiDAR-based terrain model as 'shaded relief' for the Eisleben region of Saxony-Anhalt, Germany; the *Eislebener Niederung* subsidence zone with the *Süsser See* and cracks and fissures in the transition zone to today's stable, former Mansfeld Syncline (well known as an extensional fracture zone) are clearly visible.

The introduction of persistent scatterer interferometry (PSI) in 2002 completed a further, important technological step in remote sensing. The PSI method distinguishes the smallest terrain movements, just as D-InSAR does. In contrast to D-InSAR, PSI can identify historical movements for discrete points on a terrain surface by evaluating series' of 20 to 100 radar data points. Thanks to its specific characteristics, PSI is primarily employed to monitor movements in urban spaces. PSI investigations with BGR participation were carried out in Berlin (heave within the city area), Staßfurt (mining subsidence), Hamburg (subsidence above salt domes) or in Semarang in Indonesia (dramatic subsidence within the town area).

One of the tasks of BGR's remote sensing section is to follow these developments and utilise them for the purposes of BGR. This is achieved either by creating the technical fundamentals for applying the developments or in the course of cooperation with national and European partners.

Geochemistry of Urban Spaces

At the beginning of the 21st century, urban spaces are the subject of national and international research programmes. Geochemistry, with its investigation and evaluation methods, represents an integral component of interdisciplinary research in this field. The national focus in the federal government's framework programme 'Research for Sustainability' (*Forschung für die Nachhaltigkeit*) is on a reduction of land use and in sustainable land management. Land use forms one of 21 indicators selected by the federal government as success criteria for sustainable development in Germany.

BGR's environmental geology and environmental geochemistry research programmes in urban areas and urban landscapes use extensive digital geochemical information and evaluation models to create the scientific baselines for updating land use and land management plans. The complex geochemical processes and influences in the various investigated media in urban spaces undergo differentiated evaluation in terms of baseline levels and contaminant inputs. Action recommendations for sustainable landscape and urban planning models are derived on the basis of multidisciplinary knowledge on contaminant distributions and fluxes, determination of background levels and the corresponding GIS-based maps. Methods for compiling regulations and standards for recording and geochemically characterising physical burdens at a national level and for sustainable hazard mitigation are developed. Information systems and models for making extensive estimates of geogenic hazard potentials are compiled and developed for this purpose.

Land use in towns and urban spaces, such as Staßfurt, with its anthropogenic and geogenic burdens, harmful alterations to the soil, mechanical instabilities and the formation of waterlogged zones and flooding as a result of mining, is of existential importance for retaining the functionality of the town as an urban system.

The investigation results provide the federal ministries, the state and regional administrations, and industry and politics with scientific knowledge and baseline data on urban sites as a decision making and action tool. The geochemistry of urban spaces was recommended as a research focus by EuroGeoSurvey for the coming years (Assessment of Urban Environmental Quality by Geochemical Methods), and recognised and confirmed as a component of the EuroGeoSurvey Geochemistry Working Group Strategy by the European geological surveys.

Cliff recession affecting the **Island Rügen:** A contribution to the behaviour of coastal landslide systems and geohazard assessment

Introduction

The famous Jasmund chalk cliffs on the island of Rügen (German federal state Mecklenburg-Western Pomerania), reach heights of more than 100 m above sea level. They are composed of soft, intensely folded and fractured, calcareous Cretaceous sediments, overlain by glacial Pleistocene sediments consisting of till with interbedded strata of boulders, clays and sands. Both units were comprehensively deformed by glacier action during the late Quaternary, which led to the alteration of stratigraphic relationships and strong deformation of the whole sediment sequence.

An ominous mass movement at Jasmund, island of Rügen.

The famous Wissower Klinken after a landslide in February 2005.

The Jasmund cliffs of are subject to the continuous abrasion of coastal sediments by wave action. This process has been reinforced since the last glaciation by massive landslides and cliff collapses which are governed by a complex and varied pattern of landward and seaward factors. Several events of this kind are known from the recent past, e.g. landslide near village Lohme with a volume of approx. 90,000 m³ in March 2005 (see figure on opposite page). The active cliff failures on the island of Rügen are natural phenomena shaping the unique landscape of the famous chalk cliff. However, these cliff failures pose a considerable (geo) risk, since they can cause damage and loss of the coastal infrastructure and threat health/life of thousands of visitors of the Jasmund National Park as well.

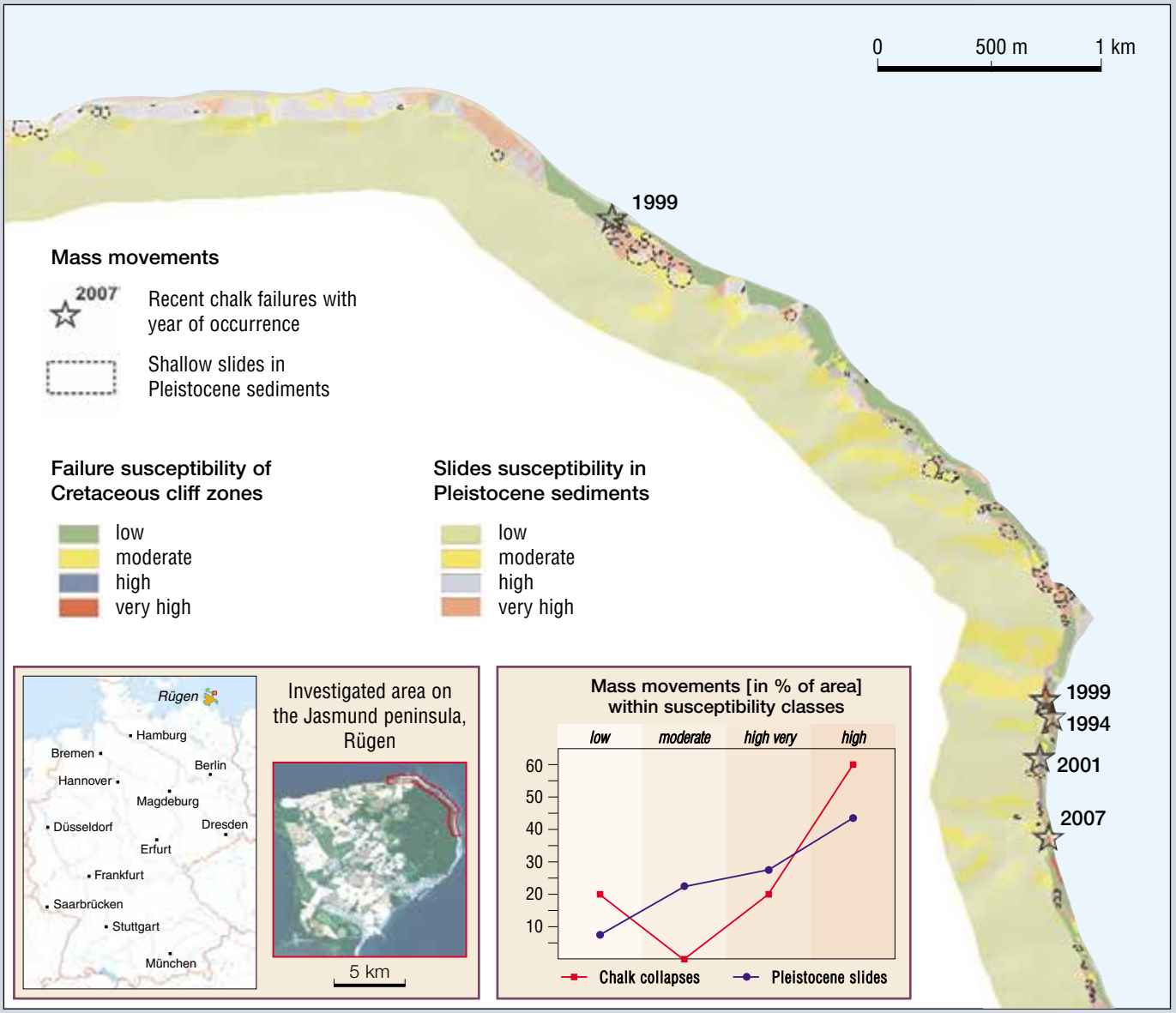
In a scientific-technical cooperation project BGR is assisting Mecklenburg-Western Pomerania's *Landesamt für Umwelt, Naturschutz und Geologie* in the analysis of the geological hazard potential generated by cliff instabilities in the northern section of Jasmund coastal cliffs. The project partners are also cooperating with the *Staatliches Amt für Umwelt und Natur/Nord* Rostock, the University of Tübingen and the University of Greifswald.

In particular, the project partners are investigating the localisation of possible future failures along the Jasmund coastline and choose critical localities for monitoring activities. For this purpose, the required geoscientific information is gathered using geological-geomorphological mapping, geotechnical field and laboratory investigations and remote sensing. As a result of extensive spatial process modelling, critical cliff localities can be identified and analysed in terms of increased failure susceptibility. This analysis provides the basis for subsequent monitoring of critical locations/ landslides at fixed time intervals using a terrestrial laser scanner in order to recognize and to quantify changes.

To perform susceptibility analyses concerning potential cliff instabilities in the Jasmund coastline region, different input data are required for the Cretaceous chalk sediments (locally known as "complexes") and the Pleistocene sediments (locally known as "stripes") as well. The data are processed with the aid of modern geoinformation technologies.

Utilizing digital terrain models (DTM) with a resolution of 10 m, detailed chalk cliff mapping has been carried out on Jasmund's cliffs. This included surveys of joints and bedding planes which are necessary to determine the kinematic possibility of future chalk cliff collapses. Therefore, the discontinuities of each chalk complex were recorded and statistically evaluated in order to characterize the fracture system regarding type, orientation, spacing and persistence.

Using the structural data gathered and a specially developed GIS software application it is possible to perform spatially distributed kinematic slope testing analyses according to different failure mechanism (for example sliding, wedge failure, toppling) for each chalk complex. By intersecting the results of kinematic analysis with the local topography, the type and number of possible failure types can be calculated on a grid cell basis, while the resolution of the analysis is defined by the DTM. The final result represents a relative measure of the degree of susceptibility to failure of individual cliff sections in relation to different failure mechanisms. The results can be visually summarised in a chalk collapse susceptibility map.



Landslide susceptibility map for chalk collapses and landslides in Pleistocenediments in a test area on Jasmund. The hazard zoning shown for both slide types corresponds well with the distribution of historic mass movements.

In order to evaluate the stability of the Pleistocene deposits, a complete landslide inventory of the working area was recorded to facilitate modelling of the landslide susceptibility in the Pleistocene stripes. Input parameter maps showing the distribution of topographic attributes (slope angle, distance to drainage systems, etc.), and subsurface and surface parameters (generally geological units, vegetation), which exert controls on the landslide susceptibility, were generated from the DTM, aerial photographs, field surveys and existing map material. The Pleistocene sediments were representatively sampled and investigated in the laboratory in order to derive important geotechnical parameters such as shear strength and hydraulic conductivities.

Using these different datasets it was possible to generate a composite landslide susceptibility map consisting of the chalk susceptibility map and the susceptibility map of the Pleistocene deposits. The resulting mass movement susceptibility map (left) thus displays both critical cliff chalk collapse zones and shallow landslides within the Pleistocene sediments, whereby the distribution of historical mass movements coincides very well with the identified susceptibility classes.

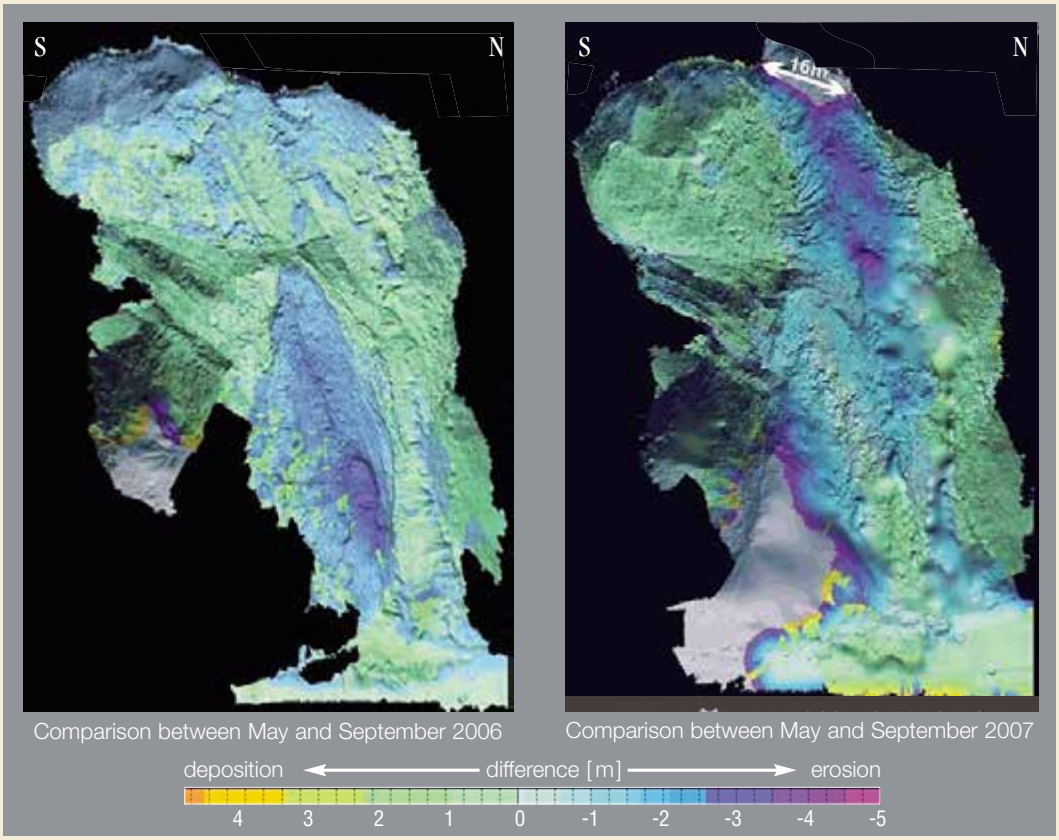
Monitoring unstable cliff zones with the terrestrial laser scanner

In the course of this project, BGR has also employed a terrestrial laser scanner (TLS) to perform long-term landslide monitoring at a selected unstable slope section affecting the Jasmund cliff. A terrestrial laser scanner is a ground-based LIDAR system ('light detection and ranging'), which enables high resolution imaging and surveying of all kinds of complex topographic surfaces. Biannual field surveys are performed in order to record the respective dimensions and surface of the landslide. The repeat surveys are then used to establish difference models for specific periods by overlaying successive surface models. These difference models provide instant visualisation of areas subject to temporal changes ("change detection") allow the analysis of failure processes and finally the quantification of mass wasting.

The intention is to derive forecasts of the future development of the landslide emphasizing the temporal extension and landward progression of the landslide and the mass transfer. The results of the studies support a better comprehension of the complex interplay of landward, seaward and meteorological controls on mass wasting and cliff stability and represent an important decision-making aid for sustainable planning of onshore coastal protection measures.

View of investigated slide north of the 'Wissower Klinken', looking west.

Imaging the slide using the terrestrial laser scanner in the foreground.



A landslide can be investigated using differential models compiled from satellite images taken at different times over an area north of the 'Wissower Klinken'. An idea of the scale is given at the top of the right image.

The differential model of two repeat surveys performed in May and September 2006 (above, left image) gives a visualisation of the surface changes of the monitored landslide in the specified period. It shows deep incision and channel erosion in the centre of the landslide due to superficial water runoff (blue colours) and in contrast depositional zones in green to orange colours.
On the other hand, a second differential model of the time interval between September 2006 and May 2007 (right image), displays upslope extension of pronounced channel erosion, leading to undercutting and failure of a 16 m x 7 m long section of the cliff edge. During the monitoring period between Mai 2006 and October 2008 an overall volume of approx. 6730 m³ was mobilised, and the landslide extension increased from an initial area of 2,111 m² to 2,289 m², therefore increasing about 178 m² in 2.5 years.

The results to date confirm pronounced mass wasting of the Pleistocene sediments in conjunction with landward slide propagation of the cliff edge. Given the prevailing velocity of landslide extension and assuming no change of the controlling factors in the future, the frequently used hiking trail at the top of the landslide has to be replaced in about 2 years time, in order to guarantee a safe passage of the tourists.

Summary and outlook

In the course of the project a methodology was developed to derive susceptibility zones for landslides on the Jasmund peninsula, island of Rügen in order to make spatial forecasts of future mass movements. The resulting maps serve as the basis for identifying unstable cliff sections and the determination of monitoring measures (visual surveillance, terrestrial and airborne laser scanning, field work).

During the course of the project the southern section of Jasmund cliff will be analysed regarding its landslide hazard potential, analogous to the northern section. Additional geotechnical, hydrogeological and remote-sensing information will be integrated to improve the existing models.

The data compiled during this project provide the agencies concerned with tangible information in terms of landslide hazard as a component of the onshore controls of cliff dynamics. This aspect was previously not or only insufficiently taken into account during the planning of coastal protection measures, which are generally implemented offshore.

"Mitigation of Geo Risks in Central America" Project

Due to their position close to an active continental margin, the population and infrastructure of Central American countries are exposed to hazards related to earthquakes, volcanism and tsunamis. Additionally, they are affected by annually recurring hurricane periods, which in most cases cross the continent from the Atlantic coast towards the west, achieving enormous precipitation volumes and wind velocities of more than 150 km/h, causing extensive windslashes and inundations.

The generally steep slopes mostly consist of porous, unstable volcanic rock, composed of poorly consolidated tuffs and ignimbrites, which tend to weather quickly. Many of them are in danger of failing under conditions of elevated pore water pressure due to intensive precipitation. Heavy rainfall or a low intensity earthquake can trigger slumps or mud flows with run-out distances of several kilometres.

Between 1960 and 2001 a total of 10 million people were affected by natural disasters in Central America, with 60,000 casualties and damage amounting to 17 billion US dollars.

Land use planning and disaster prevention must be adapted to mitigate the risk of lethal and expensive damage related to natural events. The authorities of some Central American countries – Nicaragua, Honduras, Guatemala and El Salvador – have

San Pedro Volcano, Guatemala.

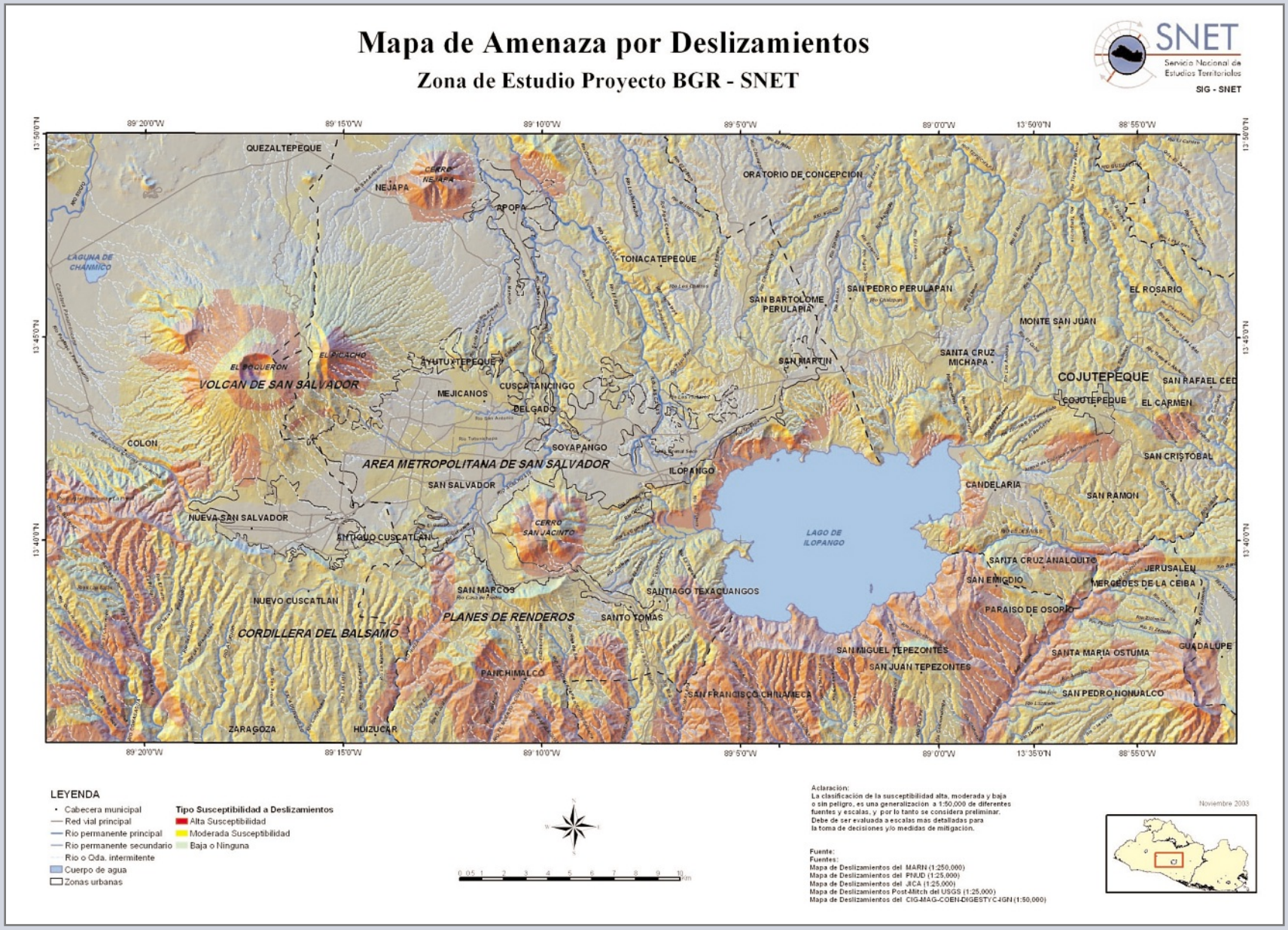
Landslide in Las Colinas, San Salvador.

only limited resources to carry out these tasks, a circumstance that makes them eligible for support based on Development Cooperation projects.

Commissioned by the German Ministry of Economic Cooperation and Development (BMZ), BGR is participating in the development of a regional, Internet-based geohazard information system. National geoscientific institutes and disaster prevention authorities in the partner countries, and the multinational 'Center for Prevention of Natural Hazards in Central America' (CEPREDENAC), share these efforts, acting as counterparts. The project is currently passing through a second phase, which was designed to foster regional and multinational cooperation and integration. The entire project was to take place over eight years (2002 to 2009).

The project comprises identifying a specific hazard magnitude per area and mapping elements at risk, followed by specific risk assessment and distribution of the results via an Internet portal.

The hazards are partly controlled by stable parameters such as soil composition, geology and slope inclination, which can be inferred from existing data (geological maps, Shuttle Radar Topography Mission). Other variable parameters – seismicity, precipitation and vegetation – are periodically monitored by the partner institutions by means of telemetric sensor stations or downloaded from operators of remote sensing systems (MODIS vegetation index, NOAA weather monitoring). These parameters are fed automatically into a geological information system (GIS) and serve as a basis for calculation of the specific hazard per unit of area, which is done by self-developed program scripts using well established but specifically adapted algorithms. For example, the method of Mora-Vahrson is employed for calculating the slope failure hazard (http://www.ineter.gob.ni/geofisica/desliza/estudios/Mora_Vahrson.pdf; in Spanish) – but it must be complemented by a stochastic inventory of landslides per geological unit and by a calculus of the area probably affected by corresponding runout avalanches.



This map of a part of El Salvador indicates areas of different landslide hazard levels (downscaled depiction)

During the further course of the project the population density per unit of area and the values of elements at risk will be derived from existing data in the partner countries and represented as vulnerability maps that allow risk estimates. The resulting spatial information (specific hazards and risk) shall serve as a basis for:

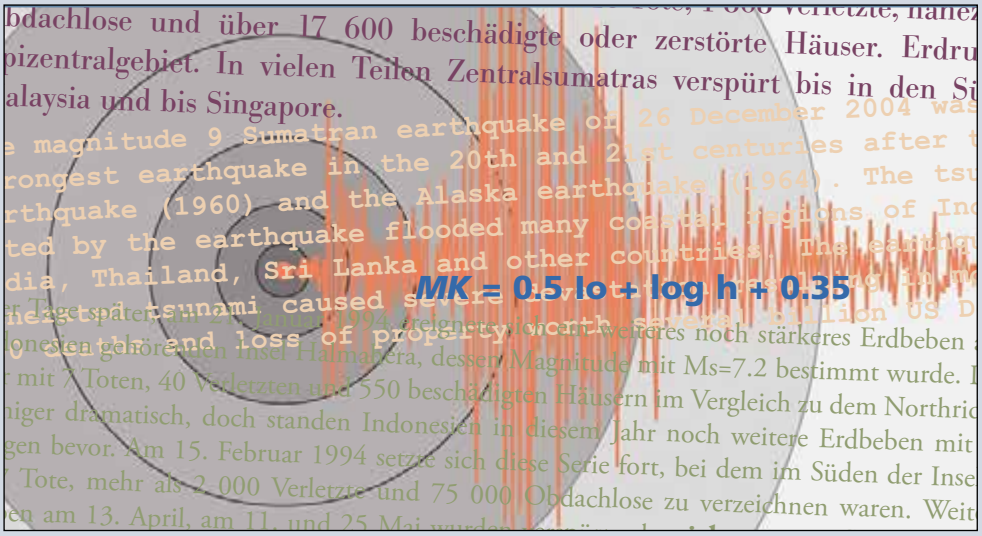
- Planning authorities who will be able to calculate potential risks for several land use alternatives and select the optimum variant.
- Delimiting areas of high hazard levels to keep them free from vulnerable infrastructure and structures.
- Facilitating the risk-based elaboration of alert and rescue procedures by disaster prevention organizations.
- Comprehensive citizen and investor information will enable them to modify their plans and actions taking into consideration existing and potential hazards to their lives, health and properties.

To assure widespread distribution of the results, they are presented online as processed GIS data with user manuals and downloadable maps through a publicly accessible web interface (http://www.georiesgos-ca.info/).

Seismometer.

Seismological Research I

Comprehensive Nuclear-Test-Ban Treaty



Seismic Monitoring and **Earthquake** Research at **BGR**

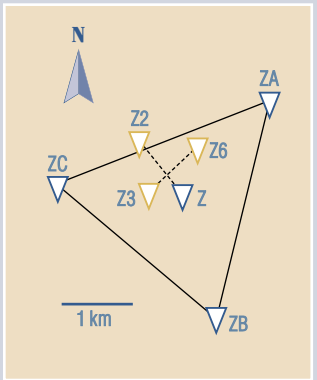
The initial step of BGR into the area of seismology was taken in 1970 when BGR signed a contract with the German Science Foundation (DFG) that guaranteed the scientific and economic existence of the Central Seismological Observatory. The idea of establishing this facility was driven by a consortium of directors from West German geophysical research institutes (FKPE). They recognized that seismological research and, in particular, in-depth investigations of the earth's interior, require a demanding and complex technical infrastructure which cannot be provided by university institutes alone. The challenging task of permanently operating a seismological array near the small town of Gräfenberg in the Franconian Jura region in south-west Germany proved this perception to be true. The Gräfenberg (GRF) array was originally set up by the US as a monitoring facility for seismic signals from underground nuclear explosions in spring 1963, and was offered to the West German federal government at no cost in May 1965. No university institute had the manpower or financial resources to ensure the operation and maintenance of this array. DFG and FKPE therefore began looking for a partner institution that promised to ensure long-term operation, maintenance and technical renewal of the array.

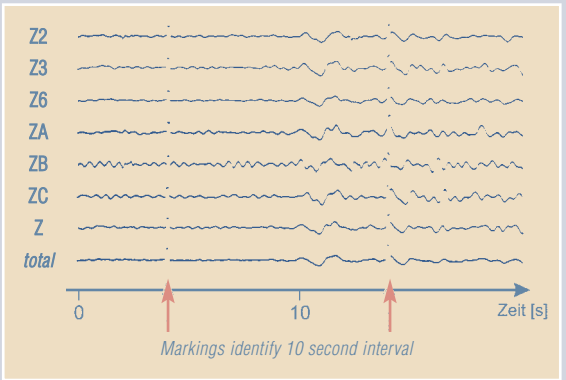
BGR, which was found to be the most appropriate partner in this regard, agreed in 1968 to engage in the setup of an earthquake observatory and to participate in seismological research. This initiative was justified by BGR's mission to act as a consultant to federal departments. This justification is still valid and can be related to the following principal BGR tasks: 'comment on questions from the federal government on underground nuclear weapons tests', 'provide geoscientific expertise for nuclear power station site selection', or 'give advice to the Ministry for Economical Cooperation on induced earthquakes in the context of dam structures'. Consequently, seismology and the Central Seismological Observatory have been firm components of BGR's wide-ranging responsibilities since 1970.

The seismological array, which was taken over from the US at that time, consisted of four elements. Even before BGR and DFG signed the cooperation contract, the technical concept and the station configuration was modified as shown in Figure 1. The ground motion picked up by the seismic sensors was transmitted via cable to a central facility and continuously recorded on photographic paper. The recording paper was automatically developed after one day. Afterwards the seismic traces were visually analyzed and arrival times of detected seismic signals written into a logbook. Subsequently this data was punched onto a paper strip and sent by telex to World Data Centre A in Boulder, Colorado.

Since then acquisition, transmission, recording and analysis of seismological data has remained, in principle, unchanged, although the work of seismologists today is facilitated to a great extent by computers and digital analysis procedures. Data, for example, are no longer recorded and archived on photographic paper, but digitally on hard disks. Irrespective of many technical advances, human experience in seismogram analysis and interpretation remains irreplaceable. Compared with present state-of-the-art science and technology, seismology, and particularly array-seismology, was in the early stages of its development at the beginning of the 1970s. The Gräfenberg (GRF) seismic array operation provided the basis for unprecedented developments in seismology in Germany in the following years. As the leading organization in this project, BGR cooperated closely with German geophysical institutes at universities and with its commitment paved the way for intensive and successful seismological research in Germany.

At this time, digital methods became increasingly important in the area of seismological measurement techniques. At the same time geophysical institutes at German universities were focusing on seismometry and developing broadband seismic sensors that enabled the recording of seismic signals in a wide frequency range. In 1974 BGR presented the first prototype of a modern digital seismometer station by combining three-component broadband sensors with high-gain digitizers. This combination marked the start of the era of digital broadband seismology. The idea to build up a seismometer array with stations of this type was a logical consequence. Such a facility, which acts as a seismological antenna, promised to reveal new information on the earth's structure and the focal mechanisms of earthquakes. Moreover, high-performance broadband seismic arrays were expected to improve the capability to detect and identify seismic signals from underground nuclear explosions conducted by nuclear weapon states. Primarily motivated by the latter BGR, in cooperation with DFG, installed such an array in the area of the Franconian Jura between 1975 and 1980. With a total of 13 stations, the first broadband array worldwide covers an area of about 100 km by 50 km as shown in the map on page 113. The concept of broadband array seismology opened up undiscovered areas for geoscience, when new scientific and





Top left: *GFS array data collection centre in a trailer.*
Left: *Benioff seismometer for recording horizontal ground motion.*
Top: *Configuration of the GRF four-element analog array.*
Top right: *Seismometer data originally recorded on film.*

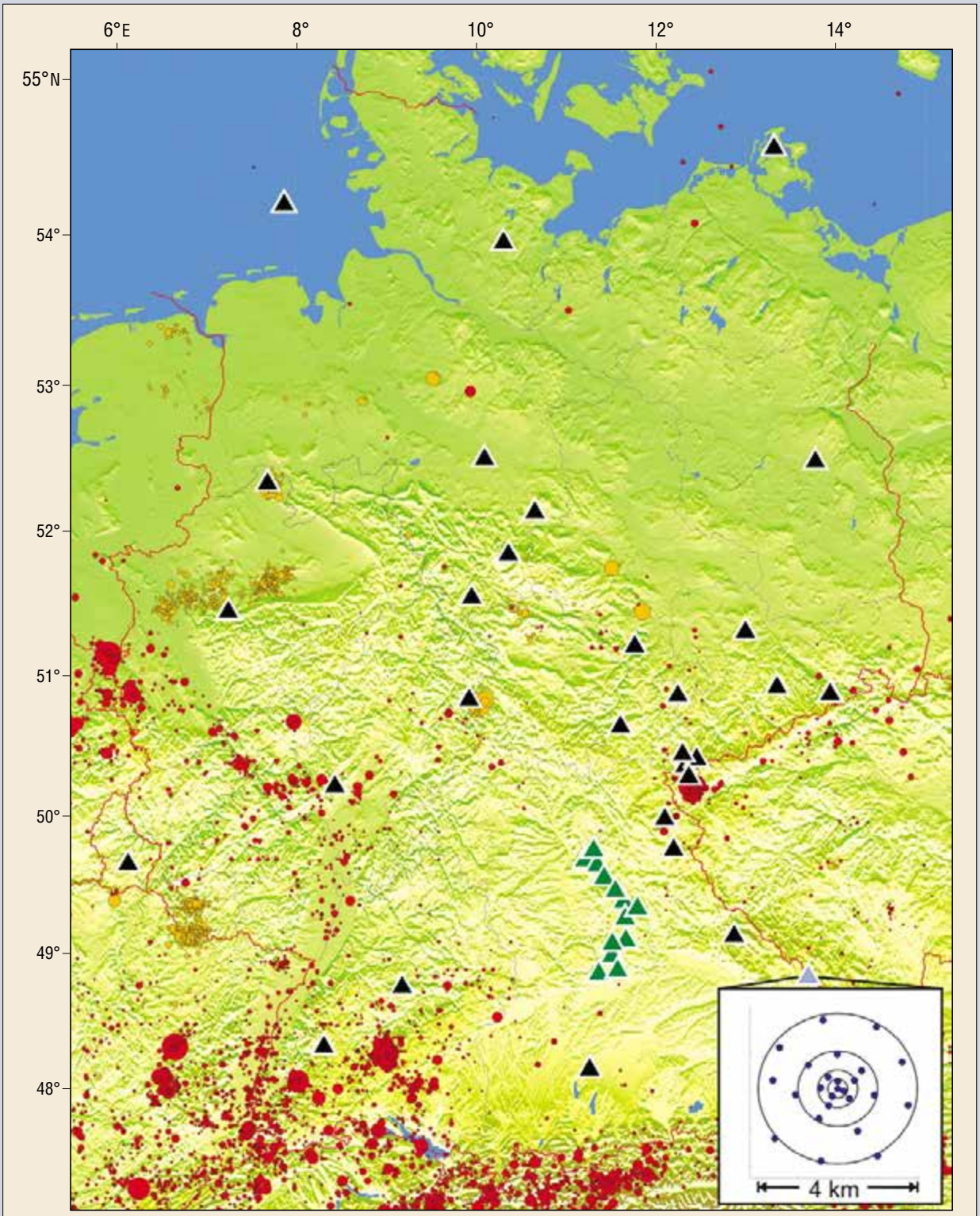
technical procedures became available providing new knowledge on earthquake sources, wave paths and the earth's structure.

The information gained from data provided by the GRF array initiated the wish to extend the array and to use high-quality broadband data from many broadband stations distributed across Germany to explore the earth's interior. Scientific expectations finally led to the establishment of the German Regional Seismic Network (GRSN). Under the leadership of BGR, which was responsible for the technical concept, the first of eight GRSN stations became operational in the Black Forest in January 1991. After Germany's unification, another four stations were installed in eastern Germany by 1994. Thanks to aspects of their technical design, all twelve GRSN stations made it possible for the project participants to directly access the stations for data retrieval. The principle of 'open seismometer stations' considerably aided the use of seismic waveform data and as a consequence this station concept was accepted by all users. In the follow-up to the initial GRSN setup phase, additional stations of this type have been installed by geophysical institutes at universities and by regional geological surveys in Germany. Today about 40 GRSN-type broadband seismometer stations are operational as shown in the map on the opposite page. They are intensively used for monitoring seismicity both in Germany and worldwide, as well as for a wide variety of scientific investigations.

A special role in this phase is played by a seismometer array in the Bavarian Forest near the Czech and Austrian borders, which consists of 25 array elements equipped with short period sensors distributed on five concentric rings with a maximum aperture of 4 km. With support from the US, this facility was installed during the cold war towards the end of the 1980s. Originally its aim was to detect, locate and identify underground nuclear weapons tests by Eastern block states. The array named GERESS (GERman Experimental Seismic System) became operational in 1991. Germany and the US agreed to transfer this highly sensitive seismic array to BGR at no cost after both countries had signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT). This happened in spring 1997 after CTBT had been signed by both countries in September 1996. Due to its capability to detect and locate weak seismic signals from distant events, GERESS was chosen to become one of a total of 50 primary seismometer stations for monitoring compliance with the CTBT. Due to the fact that BGR staff members had provided advice to the German Foreign Office during CTBT negotiations at the Conference on Disarmament in Geneva, BGR was consequently assigned to take over the functions of an NDC (National Data Centre) for Germany.

Its experience with arrays and related processing techniques turned out to be useful in an area in which BGR had so far no experience: infrasound. Because the CTBT not only bans nuclear tests underground and underwater, but also in the atmosphere, a worldwide distributed network of 60 infrasound arrays is currently being installed. BGR has been commissioned to take responsibility for the technical design, installation and operation of two infrasound arrays. IS26 in the Bavarian Forest was the first certified installation in the infrasound monitoring network. It became operational in 1999. IS27, the second German infrasound array, went into operation in 2003. This array is located in Antarctica, close to the German Neumayer research base. The array design is completely different from IS26 and takes the harsh environmental conditions in Antarctica into consideration. In particular, the characteristic response of this array was optimized with respect to recording infrasound signals under strong wind conditions. With both the infrasound arrays IS26 and IS27, and the GERESS seismic array, BGR contributes significantly to Germany's contractual CTBT obligations and is also breaking new ground for scientific research in the area of infrasound by making data from all these arrays freely available to the scientific community.

After setting up the GRF array and the GRSN, the next step to further developing seismology in Germany has not yet been made. As a general trend, arrays and multi-array technologies are becoming increasingly important in conjunction with early-warning systems. Exciting results in this context can be expected in the future from a new entity in BGR that was formed in May 2008 when the Central Seismological Observatory and the German National Data Centre were merged. The functions of this unit are best described by the acronym CESAM (CESAM – Centre for Seismo-Acoustic Monitoring)



Map of seismicity in Germany with magnitudes ranging from 2 to 6 in the period 1958 to 2008 (red and orange circles). The orange colour denotes events occurred in mining and gas extraction areas.

In addition, the distribution of the seismic broad-band stations is shown as triangles: GRSN (black), GRF array (green). The configuration of the short-period GERESS array (blue) is enlarged.

The Vogtland/NW Bohemia **Earthquake Swarm Region**

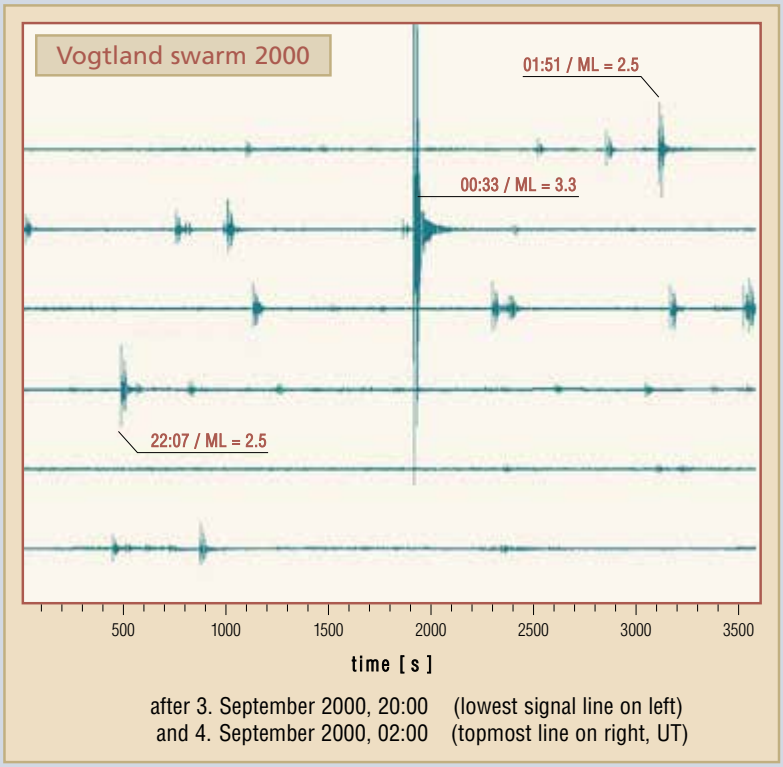
Since it hosts earthquake swarms in an intraplate region the Vogtland/NW Bohemia region, an area on the border between Germany and the Czech Republic, is one of the most prominent earthquake regions in central Europe. Seismic energy is usually released in earthquake sequences characterised by one distinct main shock and a series of aftershocks. Compared to these sequences swarms exhibit a huge number of single events of similar magnitude in a limited time interval of days to weeks without any dominant main shock (fig. on the opposite page). In terms of the number and magnitude of earthquakes, the Vogtland/NW Bohemia region is one of the most active earthquake regions in Germany, beside the Rhine Graben, the Lower Rhine Embayment and the Swabian Jura (fig. on page 113).

Earthquake swarms typically occur in volcanically active regions, with fluids assumed to be one possible cause. The term fluid comprises liquids as well as gases because their physical properties are similar. They govern rock properties such as shear and rupture behaviour. A characteristic feature of the Vogtland/NW Bohemia earthquake swarm region is its location in the interior of a continental plate close to the Eger Rift away from an active plate boundary. Further peculiarities of the Vogtland/NW Bohemia earthquake swarm region include extensive CO_2 degassing, deep crustal structures, quaternary volcanism, mineral springs, a steep gravity gradient and neotectonic crustal movements, for example. The sum of these spatially confined peculiarities makes the Vogtland/NW Bohemia one of the most challenging regions in Europe for integrated geoscientific research.

For the past 15 years investigation of the occurrence and cause of earthquake swarms in the Vogtland/NW Bohemia region has been a major BGR research topic. Its studies comprise investigations into the precise spatial distribution of the earthquakes and their relation to crustal structures as well as identifying the earthquake source mechanisms. These source mechanisms reflect the type and direction of displacements and the influence of fluids which contribute substantially to the initiation of earthquake swarms and their dynamics.

In the last decade several temporal seismic networks have been installed in the Vogtland/NW Bohemia region in and around the Eger Rift to observe and investigate the earthquake swarms. The last major swarm occurred recently between October and November 2008. It was observed with high precision on a dense network of stations. Overall, more than 10,000 distinct swarm earthquakes with magnitudes of up to 4.1 were recorded. Precise hypocentre determinations of the last swarms exhibit narrow spatial clustering, typical of earthquake swarms. The hypocentres situated beneath the village of Novy Kostel in NW Bohemia are arranged in a NNW-SSE striking planar structure. The strike direction of the plane coincides well with the strike of the Marianske Lazne fault zone and parallel oriented faults.

Detailed investigations of the source mechanisms mostly show a similar style of faulting. Inversions for the stress field on the basis of the calculated focal mechanisms yield a local stress regime which does not substantially differ from the overall stress field in Western Europe. Whereas the dislocations



Six hour recording of the vertical components of the Gräfenberg array (GRA1 Station (distance to centre: 120 km) with numerous swarm earthquakes from 2000 in the Vogtland/NW Bohemia region

of the seismic events seem to be controlled by the overall stress field, the triggering and episodic and avalanche-like course of the swarms seem to have local sources, such as the fluid dynamics.

The way fluids trigger earthquake swarms is expressed by the **focal mechanisms**: besides pure shear faulting, volumetric source components can be resolved which describe rock extension. In Vogtland/NW Bohemia the volumetric components are in the range of 0 to 30%. It is therefore assumed that they are reflecting extensional cracks originated by ascending fluids. The fluids may ascend towards the Earth's surface from partial melts at the depth of the crust-mantle boundary. They can be associated with crustal stress release in the form of earthquake swarms.

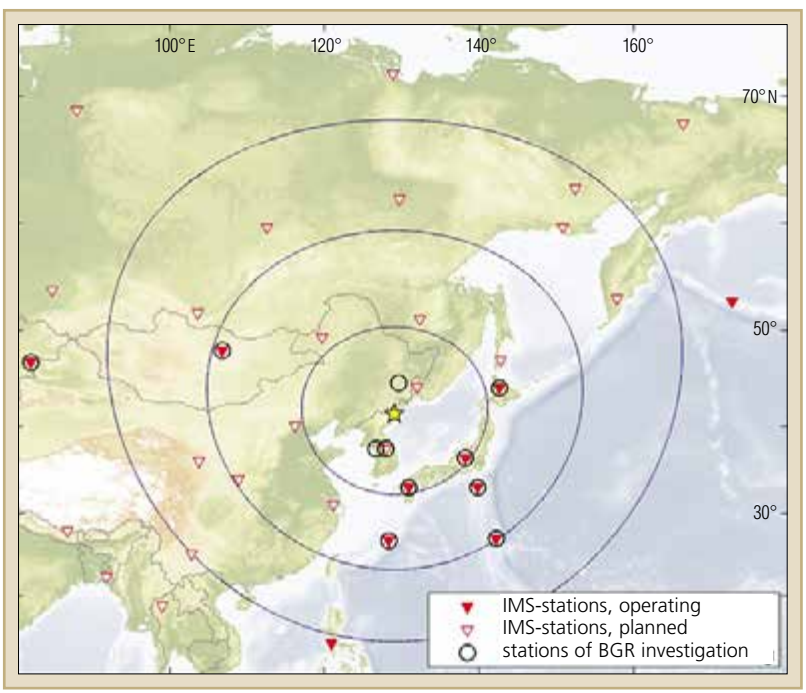
Additionally, in the course of scientific international projects, both temporary and permanent BGR stations have been used to resolve the lithospheric structures in Vogtland/NW Bohemia and the surrounding area. Analysis of teleseismic events estimating the receiver functions has revealed a crustal thickness of 26 to 28 km in the area of the Eger Rift, where the main seismicity takes place and the highest CO_2 degassing is observed. Furthermore, a comparison of swarm characteristics in Vogtland/NW Bohemia with two other earthquake swarm regions, the Rio Grande Rift (North America) and the Kenya Rift (Africa), shows that earthquake swarms typically occur in those places where major fault systems and rift structures cross.

Within the scope of these investigations and in close cooperation with colleagues from the Czech Republic, as well as other countries in Europe, BGR was able to contribute to a deeper understanding of the origins of earthquakes and especially of swarms. This leads to better estimates of the potential risk of earthquakes in rift systems and therefore to saving lives in those regions.

Verification of a **Nuclear Test** in North Korea

On 9 October 2006, at 10:35:29 local time, North Korea conducted a nuclear test in the province of North-Hangyong. This test had been announced by the North Korean government a couple of days previously and was confirmed by their officials after the test. Seismic signals of this test could be observed at the GERESS array in the Bavarian Forest, over a distance of 8,200 km. This nuclear explosion was the first real practical test for the international verification system of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

Although the IMS (International Monitoring System) was still under construction, with a lack of stations, especially in eastern Asia, the verification system was able to detect and locate this event with great precision using seismic stations. The epicentre was located in the Mantap Mountain region close to a tunnel entrance which had been in the focus of American surveillance satellites for many years and was therefore known as a possible nuclear test site. The magnitude of the explosion was determined by the IDC (International Data Centre) at 4.1,

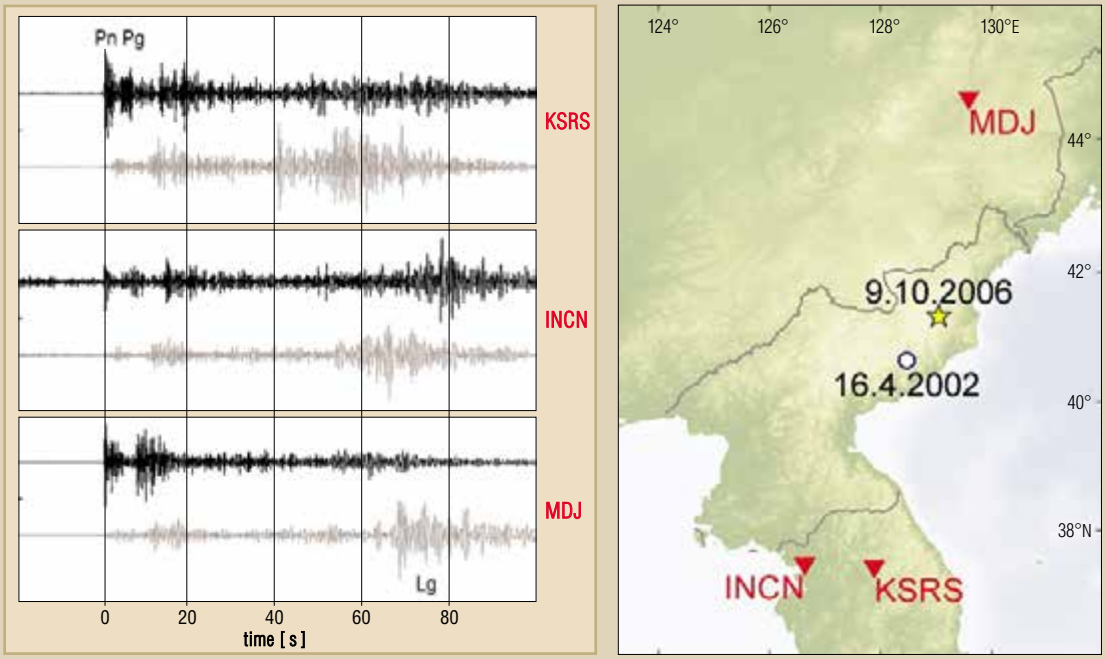


The IMS (International Monitoring System) seismic station network on 9 October 2006, which was barely developed in Eastern Asia at that time. The location of the North Korean nuclear test is marked with a yellow star and the blue circles show distances from 1000, 2000 and 3000 km to the epicentre.

corresponding to a yield ranging between 0.5 and 2 kilotons (kt) of conventional explosives. The variation in the yield estimates is caused by a lack of information on the environment at the test site, as well as the fact that no magnitude-yield relation exists for this region. However, these source parameters, which were determined by the IDC, were verified by independent analysis at BGR. Stations close to the source that were not exclusively part of the IMS were preferred (see figure on opposite page).

After detection and localisation of the event, it was necessary to first clarified that this event was an explosion and that, secondly, it was a nuclear test. Standard methods based on the comparing the event's signals with those of known earthquakes in the source region could be applied to clarify the first question. Amplitudes and spectral characteristics were analysed. However, it was difficult to find appropriate earthquakes for the comparison, because northern Hangyong province is a seismically inactive region. Only one earthquake was found recorded at the same stations. The figure below shows seismic signals from the nuclear test and the earthquake. Clear differences are seen with dominant primary onsets Pn and Pg for the explosion and a dominant Lg wave train later in the earthquake's seismograms. The spectral properties of the various onsets suggest that the 9 October event is an explosion. Moreover, numerical wave field simulations made by the BGR confirmed the explosive character of this event.

In general, seismic analyses are not suitable for identifying an event as a nuclear explosion since there are no differences in the seismic signals of chemical and nuclear explosions. The IMS therefore also has stations for measuring radioactive isotopes and noble gases in the atmosphere. These stations



Comparison of seismic registration of an atomic explosion (black, upper traces), dated 9 October 2006, to an earthquake (grey, below) of comparable strength dated 16 April 2002. Pn and Pg designate onset of primary compression waves, Lg indicates surface waves. The map shows the locations of the recording stations and the epicentres.

complete the monitoring network, identifying the 'smoking gun", whereas waveform technique stations detect, localise and characterise an event as an explosion. It was possible to identify the North Korean test as nuclear even though the station nearest to the test area was not in operation at that time. A station in Canada detected weak but well-defined indicators for radioactive Xenon isotopes caused by an underground nuclear explosion. Moreover, identification as a nuclear test was confirmed by mobile measurements in South Korea, carried out by the Swedish Defence Research Agency (FOI).

Overall, the 9 October nuclear test demonstrated that such events do not remain undetected by the CTBT verification system, and can be detected, localised and identified independently with a high degree of reliability whether they are announced or not. Difficulties during analyses of this nuclear test should be considered a warning to complete the monitoring network as a top priority, and to improve analysis methods for identifying explosions.

Burning grassland in Paraguay.

Climate change

Can **Geoscientists** Contribute to Understanding **Climate Change?**

Yes, because as geoscientists investigate planet Earth, one by-product of their activities is a multitude of observations and data, from which climate change throughout geologic time can be deduced. An impressive example from the early period of Geology is the discovery of the European ice-ages, which was derived from observing erratics and glacial striae on rock surfaces. However, even back then the geologists' climate theories met resistance from other science disciplines. The former all-round scholar Alexander von Humboldt recommended his colleague Agassiz to drop his theory of periodic ice ages and reengage in researching fossilized fishes: 'if you should do that you will provide geology with a greater service than with those general considerations (especially also very icy ones) on upheavals in the primitive world, which, as you surely know, will convince only those who call them into life.'

BGR can point to an almost 50-year history of involvement in sea floor exploration, the sediments of which represent a unique archive of past climatic evolution. Important results with reference to climate change during the last million years were achieved by the former Ocean Drilling Project (ODP) – now the 'Integrated Ocean Drilling Programme (IODP). BGR has contributed by coordinating the activities of German institutions within these programmes as well as through its own scientific involvement. In addition, marine research activities during BGR marine cruises with RV SONNE have resulted in various 'highlights'. For example, a pronounced correlation of the climatic history of the northern Indian Ocean and Greenland during the last 110,000 years was established with a high time resolution by isotope-geophysical investigations.

Mapping of Late-Palaeozoic glacial deposits or the discovery of Cretaceous fossilized wood detected during exploration of North Victoria Land/Antarctica by BGR polar scientists provided new information on the palaeoclimate of distant regions.

Publication of the book *'Klimafakten'* (Climate Facts) in 2000 was an attempt by BGR to explain the climatic history of Earth as deduced from a multitude of geoscientific observations. Various possible causes of current climate change were discussed. The book was widely praised by

geoscientists and positively received by the public, but also gained critical comments from groups developing various scenarios for future climate change based on numerical models. Irrespective of controversial public discussion, BGR will continue to critically engage in public debate of the potential anthropogenic contribution to climate change.

The current debate on climatic evolution aids research efforts to refine our understanding of the principal mechanisms causing climate change. BGR will continue to participate in these activities.

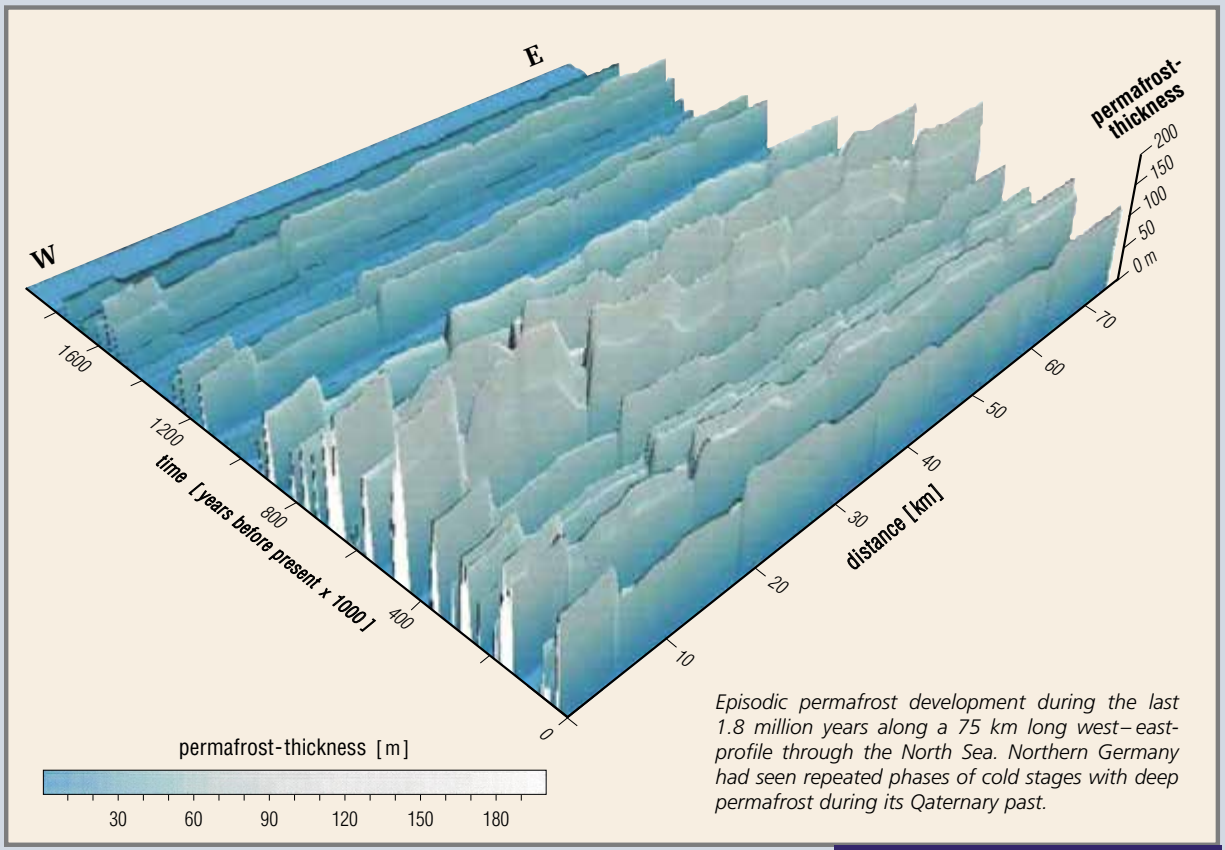
Does Arctic Permafrost Melt?

In conjunction with Laval University, Quebec, Canada, BGR has been continuously investigating phenomena involved in the slow decay of permafrost since 2000. Both institutions support a field site near the eastern shore of Hudson Bay near Umiujaq, where BGR equipment registers processes active during permafrost melting. One 'highlight' of these investigations is the observation of the considerable effect of groundwater movement within shallow permafrost. Near the melting point, permafrost becomes permeable to ground water, which means that considerable amounts of heat can be transported into the permafrost body resulting in accelerated melting. Massive land subsidence in the dm-range is the consequence.

The Fate of Arctic Permafrost in the 21st Century

Will Arctic permafrost completely decay in this century? BGR has investigated this premise after the appearance of such predictions in the literature. A numerical model produced by BGR on climatically driven permafrost decay demonstrates such predictions to be unfounded. Shallow permafrost will – depending on latitude – recede by several dm to about 15 m, the core of the permafrost body – in Canada several 100 m, in Russia up to 1.5 km thick – will be preserved even if unrealistically high climate warming in the order of 6°C to 8°C should occur in the period up to 2100.

BGR field site in permafrost: pipes (marked by red arrows) emplaced in 2000 have risen above the soil surface by about 75 cm – evidence of a rapid drop in the land level.



Episodic permafrost development during the last 1.8 million years along a 75 km long west–east-profile through the North Sea. Northern Germany had seen repeated phases of cold stages with deep permafrost during its Qaternary past.

Palaeo-Permafrost in Northern Germany?

Permafrost clearly existed during the last cold stages in Germany. Remnants of polygon patterns in topsoil have been discovered and linked to the former occurrence of permafrost. BGR has presented a first approach to reconstructing the thickness of former permafrost in northern Germany. Climate change during the last 120,000 years had previously been established based on palaeobotanic investigations of sediments. By parallelisation of this trend with the climate course derived from data from ODP borehole 659, which covers not only the last cold stage but the whole Quaternary period, the climate course of northern Germany was 'post-dicted'. These values were then used to reconstruct phases of permafrost development in northern Germany during the last 2.5 million years. The first episode of permafrost development occurred about 1.8 million years ago, followed at a later period by a multitude of permafrost phases with permafrost thickness of sometimes more than 150 m, interrupted by short warm phases such as the one in which we are currently living.

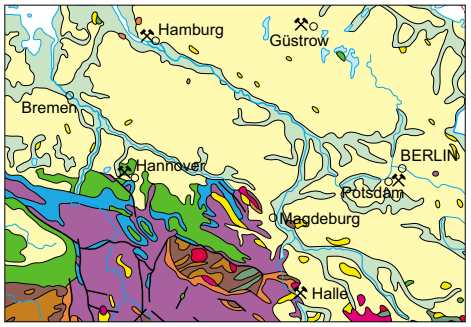
Monsoon Intensity and a Biological Pump in Offshore Sumatra

Algae grow and reproduce in the uppermost water layers and cause a reduction in CO_2 content in the uppermost water layers of up to 30%. Oceans and the atmosphere tend to establish a CO_2 equilibrium. Ocean water therefore tends to draw CO_2 out of the atmosphere. The organic material produced by photosynthesis will eventually sink to the ocean floor, together with the CO_2 fixed in it. This downward flux is called a 'biological pump'. Since investigations into sediment cores from the abyssal plains began 60 years ago, scientists have attempted to clarify the relationship between glacial cycles and bio-productivity in tropical oceans. Most research results point to increased marine production during glacial stages, controlled by the growth of ice shields in the northern hemisphere and a resultant increase in the strength of the trade winds.

Analysis of deep sea sediments, collected from 1,700 m water depth offshore of Sumatra, show that algae growth in these highly productive zones, as apparently in all equatorial waters, is controlled by the increase or decrease of monsoon intensity governed by the 23,000 year cycle of solar irradiance. Strong south-west monsoons have caused increased upwelling of nutrient-rich deep water in periods of enhanced solar irradiance, leading to a massive increase in algae production.

These examples taken from the geoscientific research of BGR illustrate the methodology on which BGR assessments are based, with regard to both the climatic past and also the probable future course of climate in the current century. BGR staff collect expert knowledge in this way, enabling them to actively participate in the ongoing climate debate. Advice for politicians and economists alike is presented on this basis, showing how optimal protection of both resources and climate can be achieved – since both aims represent the same side of the coin.

Interdisciplinary tasks



Geological Fundamentals

What do **Maps**, Thematic Geoscientific **Information Systems** and **Expeditions** Have in Common?

A geological map is the 'visual language of geologists' (Rudwick 1976). Maps are the perfect medium for visualising and distributing the results of geologically surveying a region, a country or a continent. Fifty years ago, field work was carried out 'on foot' and the maps were drawn and coloured by hand. Today, satellites, helicopters and ships are also employed in surveying. The acquired data are transferred to databases, specialist information systems, from which digital maps can be generated.

The progression from hand-drawn maps to digital methods, which BGR embraced from the outset, began in the mid 1970s. The first attempts were made on a computer working with punched strips and cards. In 1977 an expensive and still very large system was bought (ARISTO CD 400), which comprised an interactive workstation, a central computer and a precision photoplotter. The extremely rapid development of both hardware and software led to the introduction of computer-aided work-stations in 1992, equipped with ArcInfo software, which has since been continuously updated to the latest version. At the same time, databases were established, initially based on RDB, later ORACLE and now SQL Server.

The provision of geological baseline information on the geology of Germany at scales of 1 : 200 000 (GÜK 200) and 1 : 1 000 000 (GK 1000), and the geology of Europe at scales of 1 : 1 500 000 (IGK 1500) and 1 : 5 000 000 (IGME 5000), represent

important components of BGR's thematic geological information system. BGR provides Internet-based map applications ('web mapping') for the IGME 5000, which allow the user to access only the information they really need from our data, for example on the rocks of the Zugspitze massif or the North Sea. This type of availability will play an increasingly important role in the future and requires the continual optimisation of data usability and visualisation. BGR's cartography sets internationally recognised standards for geological maps.

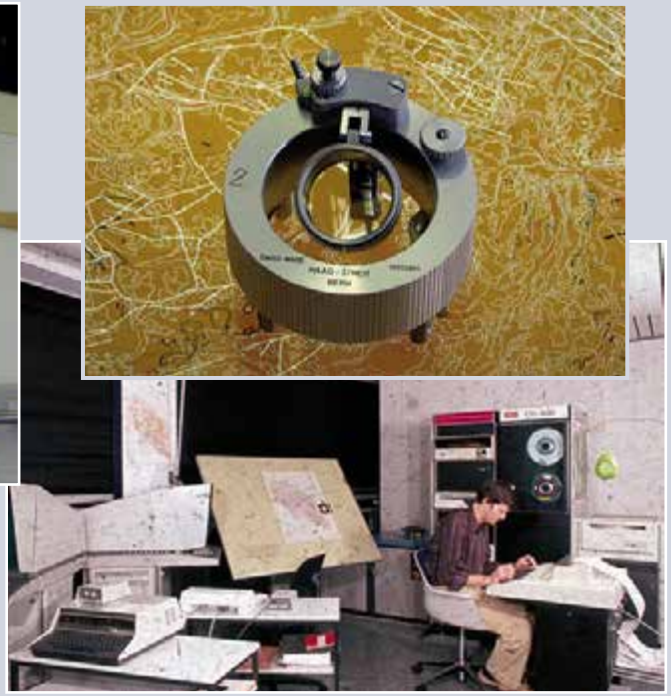
Geological maps, among other publications, are also compiled in the course of polar research. The data for these maps are collected on expeditions carried out regularly by BGR, since 1979 in the Antarctic and since 1992 in the Arctic, on behalf of the Federal Ministry of Economics and Technology. BGR specialises in researching the geodynamics of the Earth's crust in the Arctic and the Antarctic within the scope of the federal government's polar research programme. In this context, it also provides German universities with a reliable platform.

In 1979 the Federal Republic of Germany also entered the international Antarctic Treaty. BGR reacted to its obligations arising from the treaty by sending two large geoscientific expeditions in the southern hemisphere summer of 1979/1980: a land expedition to North Victoria Land and a marine geophysics survey to the Ross Sea. The first Antarctic expeditions made a crucial contribution to the Federal Republic of Germany being accepted into the circle of consultative countries in 1981 and thus acquiring an active voice in issues relating to the Antarctic Treaty.

The main aim of BGR's polar researchers and their partners from German and foreign research institutions is the study of the geological processes leading to the creation of the Gondwana supercontinent approximately 600 to 500 million years ago and to its break-up beginning 180 million years ago. The regional focus was and remains the Transantarctic Mountains in northern Victoria Land and the rift system in the neighbouring Ross Sea region, which was the target of a total of nine

Above: Typical analogue cartographer's station. Drawing pens, retouching scraper, ink pots and whetstone are grouped around the drawing film. Beside them lie the hand-coloured map and colouring pencils.

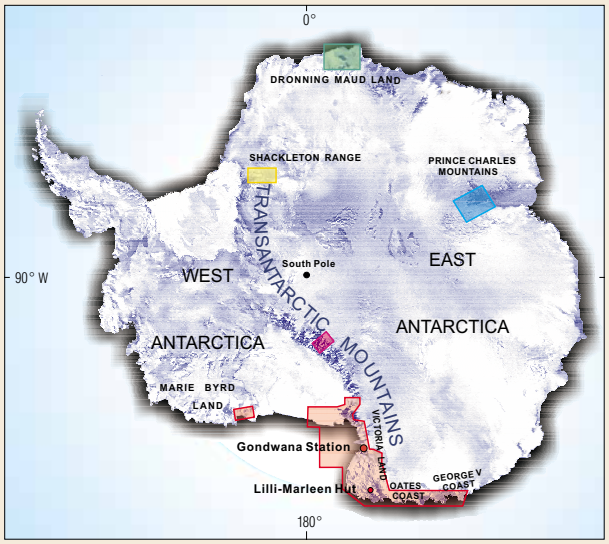
Right: Engraving was an alternative method. The originals were engraved on film or a glass plate. An opaque layer was applied to the carrier material, which was then removed again at the precise widths required using an engraving stylus. The negative created was copied together with other map elements using reprophotography to form the typescript.



This is what the first interactive cartographer's offices looked like at BGR in the end of the 1970s.

The Lillie-Marleen Hut provided a first permanent base camp for field work in the interior of North Victoria Land. It was declared an international site of historic interest in 2005 and was thus the first German 'historic monument' on the Antarctic continent.

Location of the BGR study areas in Antarctica



expedition	*year*	*cooperation partners*
GANOVEX I–IX, ASAP, GITARA I–XI, TAMARA	1979–2006	Australia, Italy, New Zealand, USA, Netherlands, England
GEISHA, EUROSHACK	1989–1994	England, Italy, Russia
GEOMAUD	1965–1966	Italy, Russia
PCMEGA	2001–2003	Australia, Russia
REVEAL / CTAM	2003–2004	USA

GANOVEX expeditions (German Antarctic North Victoria Land Expedition). Geophysical methods such as aeromagnetics, gravimetry or ice thickness radar are also employed on all land expeditions to acquire additional information on the structure of the crust in the neighbouring ice-covered areas, comprising around 97% of the Antarctic continent. Some of the measuring instruments required to withstand use in polar regions were specially developed by BGR.

Given that logistics costs continue to rise while the budget remains the same, international cooperation is indispensable in Antarctic research. Some of BGR's important cooperation partners include our 'station neighbours' at the Ross Sea, researchers from Italy and the USA. An expedition (PCMEGA 2002/2003) to the Lambert Glacier region in the East Antarctic, the largest glacier on Earth, and the flanking Prince Charles Mountains, was carried out together with Australian researchers. This followed in the footsteps of earlier research work in the East Antarctic, in Dronning Maud Land. BGR supported international drilling projects investigating the Ross Sea shelf (Cape Roberts Project 1998/1999, ANDRILL 2006/2007), which provided information on climatic history, besides data on the geological structure of the Antarctic continental margin.

International cooperation also plays a major role in compiling geoscientific maps of the polar regions. For example, in an ongoing German-Italian 1 : 250 000 scale geological map series of North Victoria Land, BGR has already published seven map

sheets. A number of anomaly maps of the Earth's magnetic field in North Victoria Land have resulted from cooperation with the USA. New geographic names related to BGR's Antarctic research (such as BGR Névé, GANOVEX Range) are now included in international topographic map sheets of North Victoria Land.

Onshore research work commenced in the Arctic at the beginning of the 1990s, after BGR had carried out extensive marine geophysics investigations between 1974 and 1977 while searching for new resources. An interdisciplinary, geoscientific programme called CASE (Circum-Arctic Structural Events) was developed, which aims to clarify the plate tectonic processes and associated structures before and during the ongoing opening of the Arctic Ocean. Estimates of the resource potential of the Arctic continental margins are then possible on this basis. In contrast to the Antarctic, the land regions around the Arctic Ocean are national sovereign territories, where research work is only possible in cooperation with the adjacent states. Nine additional expeditions have followed the first CASE expedition in 1992, accompanied by geophysical projects. The areas focused on include Spitsbergen, north Greenland, Canada's Ellesmere Island, including the nearby Nares Strait and Lincoln Sea, and northern Siberia. BGR investigations have contributed to the official geological map series of Spitsbergen (1 : 100 000) and of Canada's Ellesmere Island (1 : 250 000).

More 'virgin territory' – at least as far as mapping is concerned – is the German sector of the North Sea, although exploitation of its geopotential has increased considerably in recent years. The shallow shelf seas are increasingly utilised for laying pipelines and cables, building offshore wind turbines or even for extracting sand and gravel. But large areas of the German exclusive economic zone (EEZ) have been designated as nature conservation zones. In 2002, BGR therefore initiated a project to extensively map the shallow subsurface in the German sector of the North Sea to meet the ensuing demand for fundamental geoinformation (for example, structure of the uppermost 10s to 100s of metres of the sea floor, characteristics of the sea floor, etc.). In contrast to the onshore geological map series, which cover almost the entire land area, there had been no previous comparable geological mapping of the German North Sea summarising this

Location of BGR study areas in the Arctic

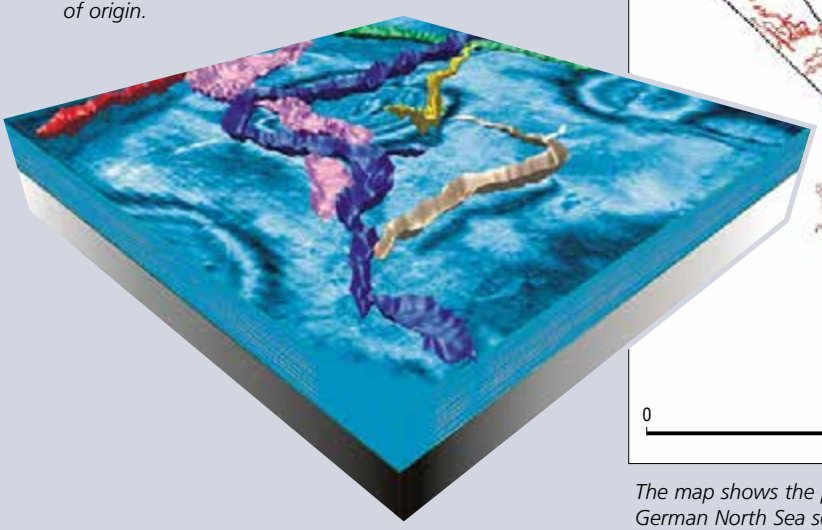
	expedition	*year*	*cooperation partners*
1	Ellesmere-Island CASE 4, 5, 6, 7, 8	1998 – 2001 2004	Canada
2	Lincoln-Sea PMAP-CASE, NOGRAM	1997 – 1998	Canada
3	Nares Strait I + II	2001 – 2003	Canada
4	Spitsbergen CASE 1, 9, 10	1992 – 2006 2007	Norway, England, France
5	North Greenland CASE 2	1994	Greenland, Denmark, England, France
6	Moms Rift, Sibiria CASE 3	1998	Russia
7	Polar Ural	2001 – 2003	Russia
8	Marine Seismic Laptev-Sea East Greenland	1993, `94, `97 1988	Russia

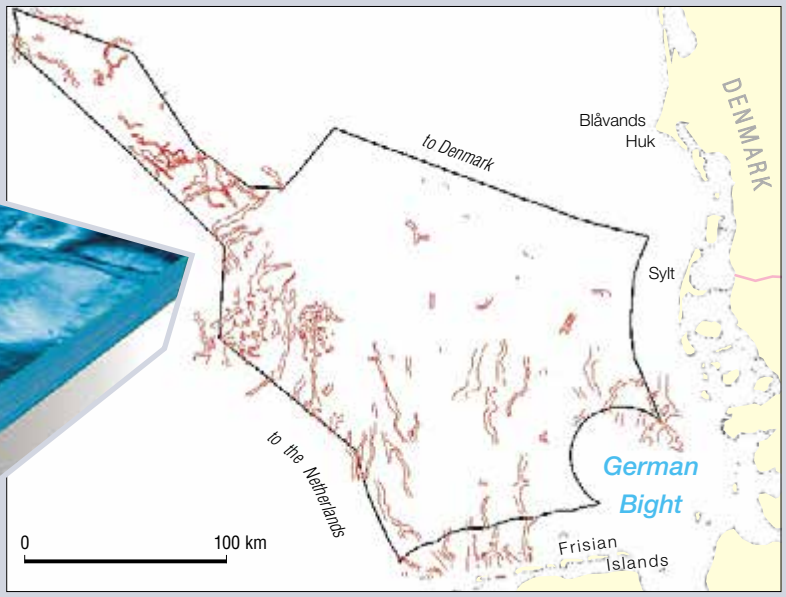
information. Besides the compilation of seismic data and drilling data from the hydrocarbons industry and scientific projects, we carry out our own seismic surveys and geological sampling during the various ship expeditions. In addition, a special airborne gravimetric survey was carried out in the summer of 2007, covering large areas of the German North Sea sector. All data are acquired digitally, evaluated and made available in a GIS/FIS system.

Here are some examples: compared to the previous situation, digital mapping of sub-glacial channel systems revealed by the seismic recordings resulted in a more precise picture of the course and occurrence of the former Quaternary glacial drainage systems, which are today completely filled. It is possible to visualise the exact geographic positions of the walls and the depths of the channel bases. In places, these channel systems are gouged up to 500 m deep into the subsurface. The channel systems, which have often been re-cut through several generations, may even be visualised in three dimensions in areas surveyed using 3D seismic techniques.

Interpreting seismic profiles and extensive mapping of reflectors also requires stratigraphic information, which allows the dating of individual seismic reflectors. Temporal information such as this can be derived from the investigation of microfossils (such as $CaCO_3$ nannoplankton and dinoflagellate cysts). Previously there has been only few or no detailed zoning in the southern North Sea, especially in the section above the mid-Miocene disconformity (the period from approximately 12 million years ago to today). It is now possible to tentatively date seismic horizons in this region thanks to the results of samples taken from borehole G-11-1.

Spatial model of subglacial valleys (3D seismics). This image has a side length of approx. 15 km. Some valleys overlap each other, indicating different dates of origin.





The map shows the precise location of the subglacial channels in the northern German North Sea sector, based on BGR's most recent measurements.

Systematic recording and dating of peat deposits, which often occur only a few meters below the seabed, allows reconstruction of the history of relative sea level rise since the end of the last glacial period around 20,000 years ago. The peat formed in coastal regions, when the groundwater level rose in line with the rising sea level caused by melting ice, and from this it is possible to map the history of sea level rise. Zones that have risen or fallen at different rates as a consequence of the isostatic rebound of the Earth's crust after the ice had melted can be identified.

A new project is the aerogeophysics helicopter survey of Germany to map the surface and subsurface down to the top one hundred metres (D-AERO). The first flight was in Vilshofen in 2007 with the Bavarian Environment Agency (*Bayerisches Landesamt für Umwelt*). It provided data on the spatial structure and characteristics of the subsurface. Further flights will be made in Germany in collaboration with other geological surveys or research institutions. Flights across the North Sea coast, in the Werra valley and in Bavaria were carried out in 2008. A common standard adopted for the duration of the entire 10 to 12 year project ensures that the data can be compiled to a map covering almost the entire country and transferred to the geophysics thematic information system in the Leibniz Institute for Applied Geosciences.

The BGR helicopter starting up, pre-flight and in action over the North Sea.

Environmental **Geodata –** the New **EU INSPIRE** Directive

On 15 May 2007 the new EU directive on the establishment of a European geodata infrastructure 'INSPIRE' (INfrastructure for SPatial InfoRmation in Europe) came into force. The aim of the directive is to simplify the international utilisation of environmentally relevant geodata in Europe. Standardised, internationally compatible and comparable spatial information shall be made available to EU policy makers, the economy and the public of the European Union. This processed information will be made available by Internet-based online services.

By **geodata** we mean data that can be allocated to a given spatial position (e.g. by geographic coordinates or eastings and northings) on the Earth's surface. Geodata are divided into spatial base data and spatial thematic data and are available digitally in area, line and point data formats.

Spatial base data are official baseline data that describe the landscape (topography), property boundaries and buildings, and are application-independent. Spatial thematic data include hematic data such as geology or soil data. They cannot be interpreted, or only with difficulty, without the spatial base data, because they are not oriented. One example of the combination of spatial base data with spatial thematic data is the geological map.

BGR deals exclusively with spatial thematic data. Because of the federal system of state responsibilities, BGR is responsible for generalised interstate maps (geology, hydrogeology, pedology and shallow resources).

The EU INSPIRE directive aims to make obligatory access to environmental information that is collected and processed in national institutions in EU countries, but which is often relatively unknown and inaccessible. Numerous technical details are not regulated in the INSPIRE directive itself, so complex procedures must be developed, in particular the compilation of standards for implementing the directive, in what are known as implementing rules.

In all, 34 topic groups must be coordinated and standardised in accordance with the implementing rules (these include data formats, definitions, classifications, hierarchies, thesauri and attributes of spatial data). The topic groups comprise information from numerous, very differing fields such as cadastral data, data on biotopes, land use, meteorology, and all kinds of conservation areas, but also include geoscientific topics such as geology, soil, natural hazard zones, energy and mineral resources.

BGR actively participates in writing the implementing rules within the data specifications drafting team, and also acts as a legally mandated organisation in reviewing, commenting on and modifying all draft directives. In this role, it actively includes and coordinates the German federal states via the soil information system steering group. Together with the state geological surveys, BGR thus contributes to legislation concerning spatial geoscientific data.

A parallel network of services must also be established to make the decentralised data available. In Germany the GDI-DE is responsible for this, with BGR merely acting as a consultant.

- GDI – Geodata Infrastructure: complex network for exchanging geodata, where geodata producers, service providers in the geo field and geodata users are linked by a physical data network, generally the Internet.
- GDI-DE – Geodata Infrastructure at the level of the Federal Republic of Germany: the federal government, state governments and local authorities participate under the auspices of the Federal Ministry of the Interior..

The directive must be implemented in national legislation by the respective EU member countries within two years. In Germany, this is carried out in line with the Federal Administrative Procedures Act, whereby a federal law and 16 identical state laws are compiled by a joint federal-state working group. The general management of the INSPIRE process and implementation within the federal government lies with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

BGR, and in all likelihood the state geological surveys, will be faced with new tasks when the directive is implemented as national law (probably end of 1st quarter, 2009): it is first necessary to make the metadata (data about data, i.e. data descriptions) available according to INSPIRE rules. In a further step, the thematic geoscientific data are processed and made available via special INSPIRE Internet geoportals.

According to the INSPIRE schedule, all INSPIRE geodata must be available to the public by 2019 at the latest. The data will permanently alter the geodata landscape in Germany and Europe: geodata will then be more transparent and accessible to the public, politics and the economy.

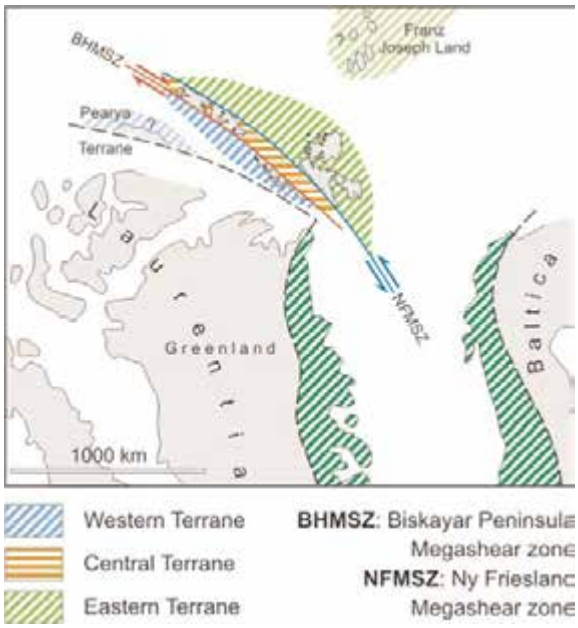
„CASE 10“ Arctic-Expedition to **Spitsbergen**

In the summer of 2007 the Federal Institute for Geosciences and Natural Resources (BGR) set off on the CASE 10 Arctic expedition. The target was the Svalbard archipelago, under Norwegian administration, where the northern region of the islands of Spitsbergen and Nordaustlandet were investigated. Fifteen years after the beginning of geological work in the onshore areas surrounding the Arctic Ocean during the ‘Circum-Arctic Structural Events’ (CASE) programme and the first expedition to Spitsbergen (1992), the Svalbard archipelago was once again the object of scientific interest.

Spitsbergen’s location in the Norwegian Sea.

The Arctic includes a unique plate tectonic constellation, in that an ocean basin is almost completely enclosed by continents. The CASE expeditions are attempting to unravel the ‘Arctic puzzle’ of continents and continent fragments that were created following the opening of the Arctic Ocean and the separation of Europe and America. The geological structure and history of the pieces of the puzzle must be known in detail in order to be able to compare and join them together again. To deepen their knowledge on the structure and history of the Svalbard basement, the scientists at BGR, the universities of Erlangen, Bremen and Idaho (USA), and the Store Norske Spitsbergen Grubekompani (SNSK Longyearbyen), carried out structural geology and petrographic investigations. Extraction of rock samples for dating and clarification of Svalbard’s uplift history round off the investigation programme.

Svalbard is probably composed of at least three crustal fragments (terranes: western, central and eastern terrane), which were joined along shear zones during a late phase of the Caledonian orogeny (see box on following page). The field work carried out during the CASE 10 expedition demonstrated that previous interpretations of the history of Spitsbergen’s Caledonian and pre-Caledonian basement needs to be completely rethought. The most important result is the discovery of two late-Caledonian “ductile” mega shear zones (see figure on following page): the Biskayar Peninsula Mega Shear Zone (BPMSZ) between the western and central terrane and the Ny-Friesland Mega Shear Zone (NFMSZ) between the central and the eastern terrane. Although “ductile” shear displacements were previously recognised in Ny-Friesland along the NFMSZ, the BPMSZ is a completely new structural element with a right-lateral sense of movement. With a width of at least six km it represents an important plate boundary, which probably joined the western and the central terranes during the late phase of the Caledonian Orogeny.



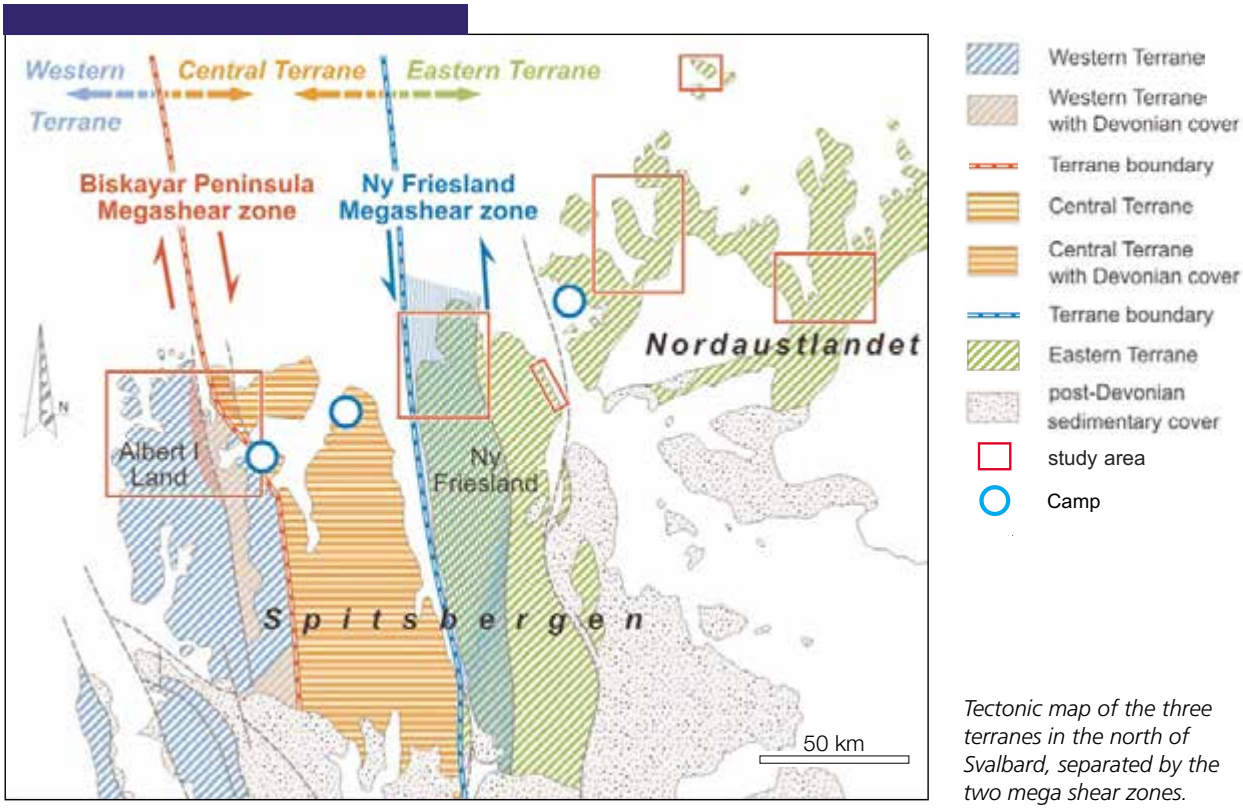
Reconstruction of the Svalbard terrane location at the time of the Caledonides.

Caledonian Orogeny (Caledonides)

The Caledonian Orogeny extended from the Cambrian to the Devonian (approximately 570 to 405 million years ago). The main folding episode, accompanied by metamorphism and granite intrusions, occurred in the late Silurian (around 420 million years ago).

Mountain building occurred following collision with the old continent of Baltica (now northern Europe) and Laurentia (now North America including Greenland), as well as smaller crustal fragments (e.g. the Svalbard terranes), which finally united to form the Old Red continent (also known as Laurussia).

Remains of the Caledonides can today be found in Svalbard, Scandinavia, Scotland, middle England, Ireland, east Greenland, Newfoundland and the North American Appalachians. **Caledonia** is the Latin name for Scotland.



Tectonic map of the three terranes in the north of Svalbard, separated by the two mega shear zones.

Seligerbreen glacier.

On the way to field work in the inflatable.

The kilometre-wide extent of the two shear zones (NFMSZ and BPMSZ) and the intensity of the shear displacements confirm that the two structures are in fact real plate or terrane boundaries. Although both mega shear zones strike approximately NNW-SSE and are oriented almost parallel, the BPMSZ is characterised by right-lateral displacements and the NFMSZ by opposite, left-lateral kinematics. One of the problems here is that the short time involved at the end of the Caledonian Orogeny leaves very little leeway for any reorientation of the plate tectonic constellation from a right-lateral to a left-lateral regime or vice versa.

Previous plate tectonic reconstructions of the Caledonides assumed that the western terrane was situated north of Greenland, the eastern terrane near east Greenland and the central terrane between them. However, the existence of a right-lateral shear zone between the western and the central terrane indicates that parts of Spitsbergen were not pushed to their present position from the south-west, as previously assumed, but – on the contrary – from the north-west and thus from the vicinity of what is known as the Pearya terrane at the northern boundary of the American continental plate. The origin of the eastern terrane (relative to the central terrane) almost certainly lies in the south-east; however, following the new investigations, correlation of the basement of the eastern terrane with east Greenland is now not as urgent.

The issues addressed by CASE 10 were continued in summer 2008 by the CASE 11 expedition to Ellesmere Island (Canadian Arctic). An approximately 150 km long and 40 km wide crustal fragment is exposed here. This is the Pearya terrane, which does not belong geologically to North America, but is probably closely associated with Spitsbergen. Thanks to the CASE 10 and CASE 11 expeditions, the geological history of these two regions, which today lie on two continents and are separated by an ocean, can be directly compared. The investigations and evaluation results for the rock samples collected will reveal whether the Canadian Pearya terrane can be correlated with any of the three Svalbard terranes.

The CASE investigations contribute to the intensification of knowledge on the geological structure of the still barely researched Arctic, with the aim of reconstructing the geological history of this region. This reconstruction is a requirement for forecasting the potential for crude oil and natural gas deposits in the large sedimentary basins, which are today located separately around the circum-Arctic shelf areas.

Field work in the Biskayar Mega Shear Zone region showing ductile deformation of rocks.

Ductile deformation in rocks in the Lerner Shear Zone.

Camp Kinnvika.

Having dinner at the end of a long day.




Geoscientific Cooperation

Geoscientific Cooperation

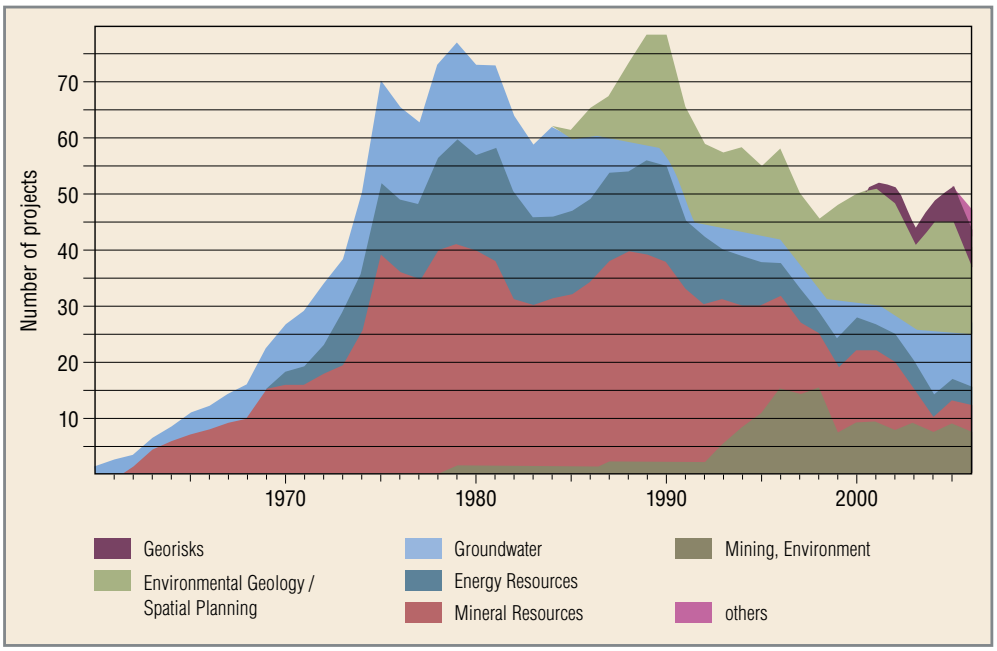
50 Years of BGR Means 50 Years of Technical Cooperation

Shortly after the former Geological Survey of the Federal Republic of Germany (today BGR) was established, BGR was entrusted with technical cooperation responsibilities in the field of geosciences. The aim was to provide partner countries with information, knowledge and instruments which would put them in a position to promote economic and social development within their own countries, without disregarding the fundamental consensus of sustainable development. A feedback mechanism between the 'researchers' and the 'partners' was cultivated, allowing the development of new products. They were tested for their applicability in development cooperation practise and the issues raised as a result returned to the 'science' side.

Although BGR initially focussed primarily on national interests in terms of resource supplies, this focus changed over the years. A clear relationship can be recognised, which was primarily a result of the overall political framework and the global events of the respective period, as can be seen in the diagram on the following page.

With increasing integration in the circle of the international community, the Federal Republic accepted more responsibilities for developing countries. Simultaneously, and in the course of the international discussion on 'finite resources' in the mid-1960s, the Federal Government transferred numerous projects aimed at recording and assessing mineral resources such as copper, gold, iron, manganese, etc., in particular, to BGR. This led to the work volume rapidly tripling in the 2nd half of the 1960s. Further peaks in work volume (1971–1981) included the years of the two oil crises.

The Federal Republic's obligation to increase expenditure for development cooperation to 0.7% GNP led to a further peak in geological-technical



Thematic distribution of BGR technical cooperation projects during the last 50 years

cooperation leading up to 1990. Budgetary restraints as a result of reunification then led to a gradual decrease in development expenditure to today's 0.3%, with direct repercussions on the number of technical cooperation projects executed by BGR.

Thematically, the topics addressed in the geological-technical cooperation sector were also subject to the processes of global change. While mineral and energy resources represented the central topics in the work of BGR in developing countries until the end of the 1980s, this changed in the 1990s in the course of the UN water decade and following the UN environmental summit in Rio de Janeiro in 1992, among other things. International natural disaster management (UN decade) tasks have formed a substantial component of BGR commitments in developing countries for a number of years.

During the first quarter of a century after World War II, BGR technical cooperation primarily consisted of exploration and evaluation of resource potentials, characterised by extensive field work. Since the 1990s, however, the type and topics of technical cooperation have changed dramatically. Since then, consulting services have moved to the fore, also as a consequence of the increasing independence of the partners in developing countries.

Many of the tasks and investigations formerly carried out by BGR are now independently performed by the partner countries. Today, BGR is requested to instruct on knowledge management, to contribute to building organisational structures and to facilitate participation for the partner countries in international knowledge dialogue and experience exchanges. Transboundary groundwater management or technical contributions to solving conflict potentials occurring as a result of resource overexploitation, for example, are governing factors. In addition, BGR is also a recognised partner of developing countries in the transfer of new technologies, interpretation instruments and methods.

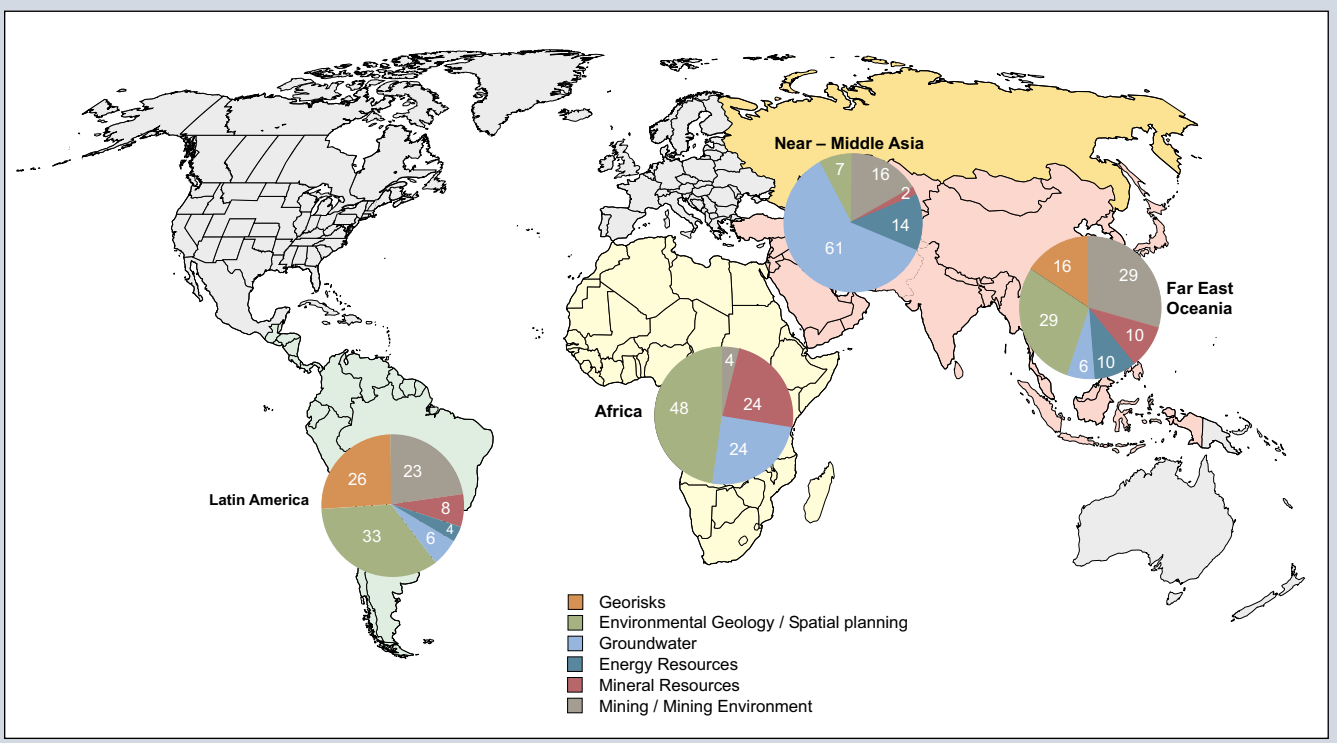
BGR has provided contributions to sustainable development with a total volume of more than 200 million euros equivalent in more than 130 developing countries in the course of technical cooperation over the last 50 years.

Technical consulting services, which are oriented towards reinforcing social justice, democracy and the rule of law, ecological sustainability, and efficiency and effectiveness in the partner countries, are provided in all four sustainable development sectors. BGR thus contributes to the Millennium Development Goals (MDG) in support of the Federal Government's international commitments.

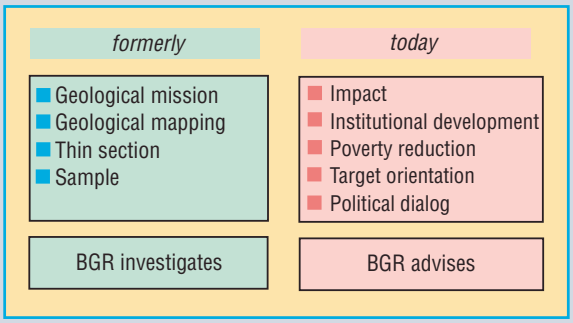
In the partner countries, BGR thus makes fundamental contributions to the development of a society that treats its resources responsibly, is environmentally conscious and socially just.

Economic development and employment are promoted, and poverty is reduced. In addition, resource management is transparent and civil society participates in regional development decisions.

In the past 50 years BGR projects were more or less uniformly distributed regionally over the continents of South America, Africa and Asia. The map below emphasises how the range of work reflects the natural geological conditions on the different continents. In Latin America the problems addressed primarily involved resources and groundwater. These two fields also formed the bulk of work in Africa. In the Middle East (Asia), water sector problems naturally dominated. In Asia, the spectrum of BGR mandates was more varied: here, mineral resources, water and georisks represented the majority of problems.



Regional distribution of BGR technical cooperation projects during the last 50 years.

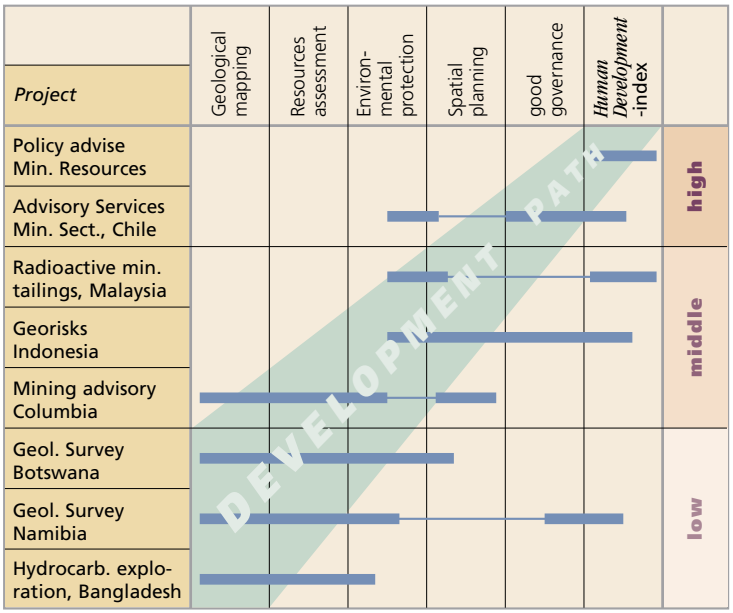


Change of scope of BRG-objectives in Technical Cooperation during the last 50 years

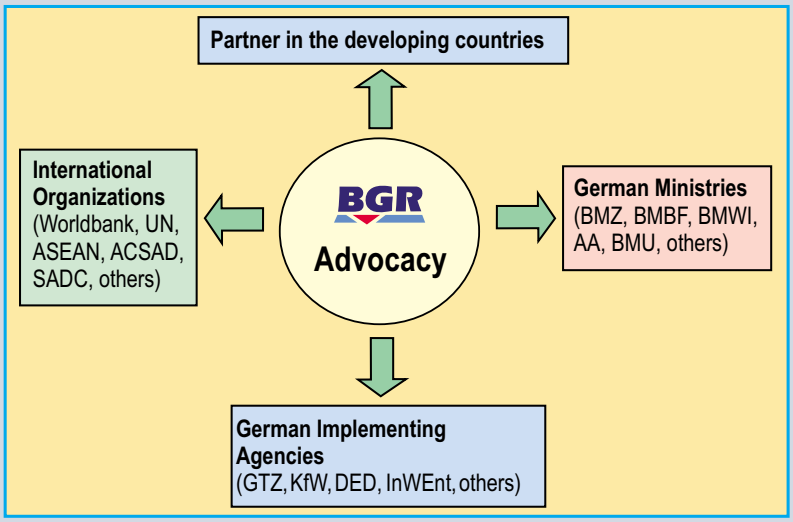
It can be seen from the figure above that BGR now performs tasks covering the complete geosector. This also includes a substantial component of management and policy advice for both our partners and our client, the Federal Ministry for Economic Cooperation and Development (*BMZ*).

As varied as the partner countries are in their development, so too are the consulting instruments adopted. The diagram below helps visualise this using selected examples.

Many of our partner countries are (still) relatively undeveloped, for example Bangladesh. BGR also advises countries with newly industrialised character (e.g. Chile). The societies involved expect answers from our cooperation partners to problems impacting them today. It has emerged that the demands placed on our partners can generally be described in the following sequence of added-values: geological exploration, resource assessment, resource protection, regional planning, participation and good governance. Depending on the level of development, the tasks involved move more and more towards regional and social policy decision-making. As a consequence, BGR also makes contributions to these topics. The diagram below shows the fields advised on in recent years in order to guide our partners along the geological 'development path'.



BGR technical cooperation projects contribute to the value chain of the partner countries.



BGR consulting clients in development cooperation.

The diagram above shows BGR's development cooperation clients.

Technical Cooperation with Developing Countries Today

The aim of German development policy is to improve living conditions, in particular of the poorer population in the partner countries. Four basic principles characterise work in the various fields and the focal points of German development policy:

- reducing poverty
- protecting the natural environment
- building peace and realising democracy
- promoting equitable forms of globalisation

Qualified advice to state-run institutions in the course of technical cooperation represents a core element of German development policy. It supports development processes and puts people and organisations in a position to improve their living conditions under their own power.

BGR's consulting and support services have also changed in line with the altered demands placed on its cooperation partners in developing countries. Following initial support for exploration and assessment of resource potentials, consulting services moved to the forefront during the 1990s. They include institution-building, capacity development and knowledge management and participation in international knowledge dialogue and experience exchanges.

Beside technical consulting services, BGR also provides development of sectoral concepts, and national and regional strategies for German development cooperation. BGR provides important networking functions at an international level and establishes contacts to international partners. The staff of the Federal Institute for Geosciences and Natural Resources, as the Federal Government's geoscientific experts, can rely on their specialised scientific knowledge and extensive experience in almost all fields of applied geology, including mining aspects. In addition, they also possess methodological consulting knowledge and can thus suitably convey and apply their specialised knowledge in the respective cultural context.

The focal points of the work lie in the areas of:

- sustainable management of groundwater and soil
- mineral and energy resources, such as carbon storage or geothermal energy
- mining consultations (mining auditing) and mining-environmental protection
- environmental and resource protection, geological principles of land-use and regional planning (e.g. for localising sites for landfill)
- georisks in a disaster management framework.

Conference on Transparency in the Resources Sector, **World Water Week** in Stockholm, United Nations Convention on the **Law** of the **Sea**

A Selection of BGR Sectoral Projects

Because many technical cooperation projects implemented in 2006/2007 are presented in the respective specialised chapters, three sectoral projects shall be described in more detail here. Two of the projects involve policy advice and are aimed at:

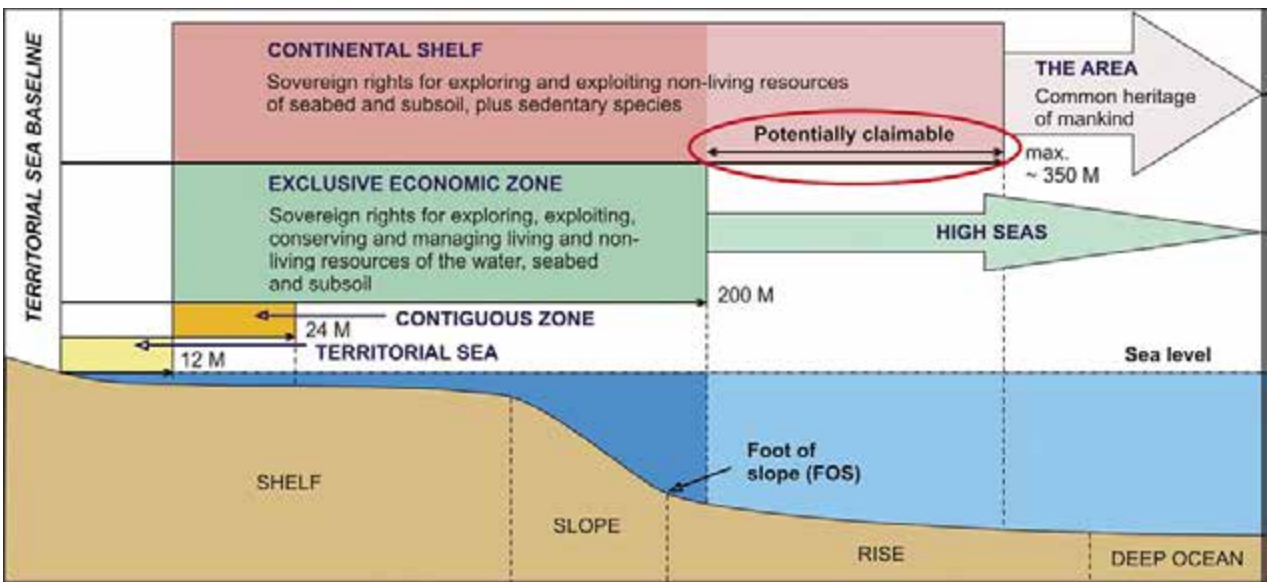
- resource and
- groundwater-/water-based dialogue both within German development cooperation circles and in international dialogue.
- The third project serves to implement the Law of the Sea Convention in selected developing countries.

(This relatively new approaches (for BGR) guarante(es) that policy concepts are compiled from the outset in harmony with geoscientific guidelines and that BGR's technical cooperation is embedded in international political processes. This is also clear from the following examples).

International Conference on Transparency in the Resources Sector: BGR supported the BMZ in its conceptualisation of the 2008 G8 conference on transparency in the resources sector. In this context, BGR ran a number of workshops on certification and transparency in the field of mineral resources trade chains**.** Here, BGR is closely integrated in a network including relevant national and international organisations (United Nations, World Bank, etc.).

Seminars at the World Water Week in Stockholm: BGR ran a number of events at the most important international forums for decision-makers in the water sector, which focussed attention on the relevance of the topic of transboundary groundwater. BGR cooperates with partners such as the African Ministerial Council on Water and various UN organisations on improving international cooperation in terms of mutual groundwater reserves.

In November 1994, following a 36 year preparation and ratification process, the United Nations Convention on the Law of the Sea (UNCLOS) came into force, creating a common, international maritime law which has now been ratified by more than 150 nations. Article 76 of the Sea Law Convention specifies that under certain hydrographical and/or geological conditions, coastal states may extend their continental shelf, and thus certain sovereign rights, seawards of the previous 200-sea mile boundary to approx. 350 sea miles. The resources in deep sea regions, which have previously been barely touched, often contain considerable economic potential. These resources may therefore play an important role in the economic development of the respective nations. An extension of the continental shelf can be applied for by the majority of nations at the UN Commission on the Limits of the Continental Shelf until May 2009. The aim of the 'Implementation of the Sea Law Convention (UNCLOS)' project is to support selected developing countries in their applications to extend their maritime sovereign rights. Training and CPD measures are carried out in the course of this project and support offered to individual countries in scientific and technical issues on request.



Schematic section from the shelf to the deep sea. The individual maritime zones as defined by the Convention on the Law of the Sea are colour-differentiated.

Technical Infrastructure

50 Years **Technical Infrastructure**

Our Office Through the **Eye of the Press**

– is the title of our first press review, compiled in 1958. It is designed as an album, into which press cuttings, photos and programmes were glued and in part lovingly complemented by drawings. There are three such albums in all, covering the period from 1958 to 1979. It is illuminating to flip through them as they reveal the importance of our office for the city of Hanover at that time.

The important topics of the 1960s to 1970s were heavily influenced by personnel issues. In particular, Presidents Martini and, later, Bender, were personalities with large public personas. In addition, the *Hannoversche Allgemeine Zeitung* regularly profiled Hanoverian scientists – including dozens of BGR staff. Even the emergency repatriation of a colleague with malaria from Malaysia was mentioned in the *Bild* newspaper – in today's global village this news wouldn't be worth peanuts. In terms of geoscientific topics, international resource research was right at the top of the journalist's agenda, but early marine and polar research was also eagerly reported.

The "child" portrayed in the albums grew and became adult. With the change of generations the previously loving press work began to lapse somewhat. Up until 1985 the newspaper cuttings are still correctly sorted and stored in a folder, but the press reflections of the late 1980s and the entire 1990s are practically not documented at all. A few articles on the opening of the Berlin office in 1990 and, three years later, on the protest of the Berlin colleagues over their 'expulsion' from the traditional building of the former *Königlich-Preußische Geologische Landesanstalt* (Royal Prussian State Geological Office) in Invalidenstraße, are the only exceptions.

It is not until 1998 that more comprehensive press reviews reappeared in report format. Finally, a new era of press and public relations work was heralded by the 'EXPO 2000' in Hanover and the 'Year of the Geosciences' in 2002. Since then, BGR's media presence has substantially grown, reaching a new, preliminary heyday in 2006.

Link: Aktuelle Pressemitteilungen (www.bgr.bund.de/presse)

Did you know …

- That in August 1968 the entire BGR management had to leave the International Geological Congress (IGC) in Prague prematurely, because the Soviet Army had invaded the city?
- That in 1968/69 BGR helped to save the temple of Abu Simbel from flooding caused by the Aswan dam and to move it to higher ground?
- That in 1980 a member of staff was fired without notice, because she secretly put tranquilisers in the tea of two colleagues?
- That BGR expert reports not only appear in reports to the ministry of economics, but have also found their way into 'Mickey Mouse', 'Who wants to be a millionaire?' and other TV programmes?

50 Years
of Publications in Geozentrum Hannover

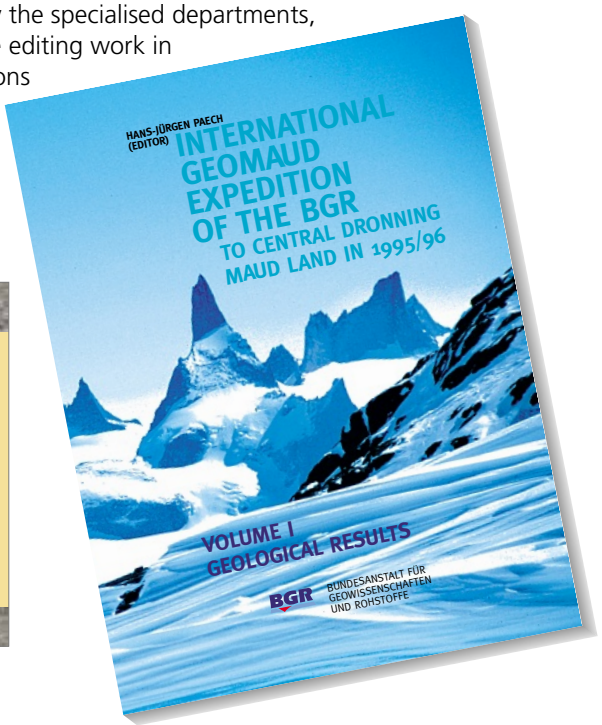
Manufacturing and distributing the results of the work of scientific staff in a suitable format was certainly always one of the original tasks of today's Federal Institute for Geosciences and Natural Resources and its predecessor organisations.

The Publications Section has changed its name several times over the past half century and, as a result of our rapidly changing times, integrated related responsibilities. The original core task has remained: professional management of manuscripts from authors generally within Geozentrum Hannover – from initial acceptance to publication in the various publication series'.

The *Geologisches Jahrbuch* has probably now become the quintessence of the 'editing' field and, in addition, is also a figurehead for the scientific expertise of BGR staff. The equivalent of an enormous book was published annually (increasingly in several volumes) up to and including 1971. In line with the increasing range of duties and the necessity of publishing their results associated with this, its mammoth coverage was taken into consideration from 1972 onwards and the *Geologisches Jahrbuch* divided first into six, then later into eight fields, arranged according to geoscientific perspectives. Since then, scientific essays have been irregularly published as self-contained works in Series' A to F, supplemented since 1996 by Series' G and H.

A number of publication series' have formed within this topical ordering, consisting of independent parts, which are either mutually supporting or complement each other. These include Series H of the *Geologisches Jahrbuch*, '*Bewertungskriterien für Industrieminerale, Steine und Erden*' (Evaluation Criteria for Industrial Minerals, Non-Metals) in 13 parts, 11 issues on polar expeditions in Series' B and E, as well as the '*Das Maastricht in Nordwestdeutschland*' (The Maastrichtian of North-West Germany) (11 issues in Series A).

Other publishing platforms were also established (see the 'Energy Resources' section). The biennial report has also always reached its final format by compiling the text contributions and figures submitted by the specialised departments, including the editing work in the Publications Section.



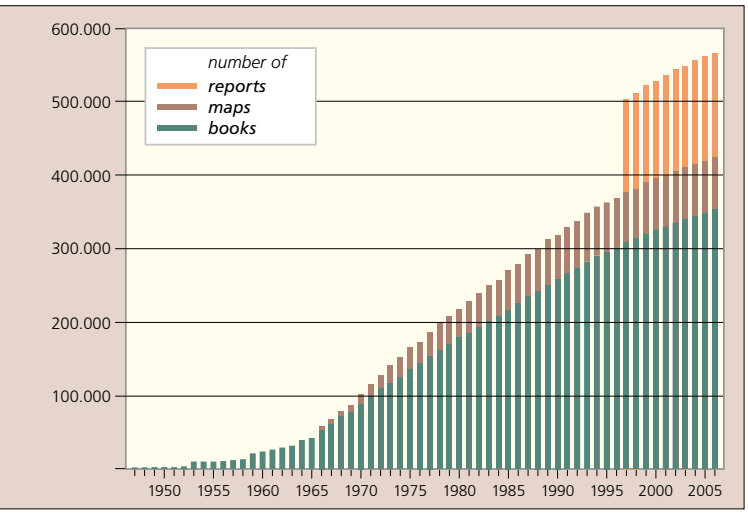
50 Years Library in Geozentrum Hannover

The origins of the library in Geozentrum Hanover reach way back into the 19th century. It first flowered as part of the Prussian State Geological Office in Berlin, until losing almost its complete stock during the Second World War. Reconstruction in Hanover made it into one of the leading geoscientific libraries in Germany. It now comprises almost 600,000 books, journal volumes, maps and reports – its stocks are thus some of the most comprehensive in the world. All media are listed in a catalogue, the Online Public Access Catalogue (OPAC), accessible on the Internet. With a total of approximately 1 million records, it is the world's largest free catalogue for geoscientific literature.

The Internet has drastically changed the library's duties. Previously, collecting and maintaining scientific knowledge were the primary objectives and the library, as the guardian of these treasures, determined the time and place of use. Access to its works was provided by extensive paper catalogues, the full usefulness of which often remained hidden.

In the age of modern search engines the library is expected to provide its services at any time and almost anywhere, regardless of the education of its users. The Geozentrum's library takes these demands seriously. Its users can search the catalogue for both formal criteria and criteria pertaining to content; a thesaurus, which is constantly expanded, is also available. It also increasingly links the references to full online texts and systematically expands its role as a specialised information centre. It will follow its objective of systematically collecting and permanently maintaining scientific knowledge in any format and thereby secure access to many, often unique, works

Link: Bibliothek www.geozentrum-hannover.de/bibliothek-archiv
Link: OPAC http://bms01.nlfb.bgr.de:8080/aDISWeb



From **Punched Cards** to **Virtual Reality**

Information technology (IT) has certainly led to the most radical changes in work processes during the past 50 years. Where at first only a few people worked in departments with IT support, today there is barely a single workplace without IT.

In BGR, this process began with decentralised laboratory computers, computers for literature documentation, and for mid- and large-scale numerical analyses. These computers ran programs written by staff and used punched cards – third-party programs were not available. Data processing technology expanded to cover more and more fields, until finally a central IT Section was created in 1980. The feeble decentralised computers in the individual departments were replaced by a centralised Siemens computer system, installed in an air-conditioned room. Display devices were installed in a central office and connected to the central computer via a V24 cable with a maximum capacity of 9,600 bit/s. In 1985 a new computing centre was installed to meet professional demands in the newly built Annex F. Computers manufactured by DIGITAL (generally VAX) were almost exclusively used as the new central computers.

Besides addressing scientific questions, all workplaces in the house were now provided with the centrally installed DIGITAL office information system ALL-IN-1, which provided word processing, email, appointments management and a filing system. The first PCs arrived in 1990. They replaced the alpha-numerical display devices for central applications and at the same time allowed the use of standard software for almost every scientific problem. The external offices were connected and connection capacities continuously improved, so that Internet access in Hanover now has a data transfer rate of 100 Mbit/s, Berlin and Clausthal-Zellerfeld 20 Mbit/s each and Grubenhagen and Meppen 2 Mbit/s each. Access to other networks such as the intranet of the *Informatikzentrum Niedersachsen*, the *Informationsverbund der Bundesverwaltung* (IVBV), the *Informationsverbund Berlin-Bonn* (IVBB), *Bundesverwaltungsnetz* (BVN) and the extranet of the Federal Ministry of Economics and Technology is also possible. Every workplace computer is connected internally to the central servers with a data transfer rate of 1 GBit/s.

Every IT workplace has access to powerful hardware and software to solve scientific problems. Stereoscopic projection even allows the first virtual reality applications to be run.

Presentation of a geological 3D model in the BGR media room for the German 3sat TV channel 'hitec' science series.

View into collection hall of the Berlin branch of BGR in Spandau.

History of the **Geo** scientific Collections

Who collects stones in the flat northern countryside of Germany – a region which is dominated by sand, clay and loam? Where do they come from?

Kings began to collect stones because they had a bias for beautiful and decorative materials. The first systematic collecting is associated with the foundation of the Royal Minerals Cabinet of the Montan Academy in Berlin in 1770. This passionate collecting evolved into scientific collecting and reflected resource prospecting in Prussia at that time. Only a few samples have been preserved from that period.

Up until 1945 the collections had been presented in the courtyard of the historical building in Invalidenstraße.

The actual stock in the collection came from the geological mapping of Prussia and Germany and the natural resource prospecting. Mapping began with the foundation of the Royal Prussian Geological Survey in Berlin in 1873; the Hanover office was established in 1934. Geological mapping is carried out by geologists who explore their district (10 x 10 km) from spring to autumn, documenting the character and stratification of the rocks and collecting typical and beautiful, as well as more problematical, samples. The samples are investigated, identified determined and/or given to the collections.

Collecting also happens in connection with the exploration of mineral deposits or regions at home and abroad, and in connection with the scientific investigation of specific rocks and fossil groups. Findings from temporary exposures, such as building the underground railway system, have augmented our archive of the Earth's history. The BGR collections are stored in Berlin and Hanover in more than 1,600 cabinets. Besides minerals, rocks, salts, coals, macro- and microfossils, they also contain drill cores, thin and polished sections and typical products made from specific raw materials.

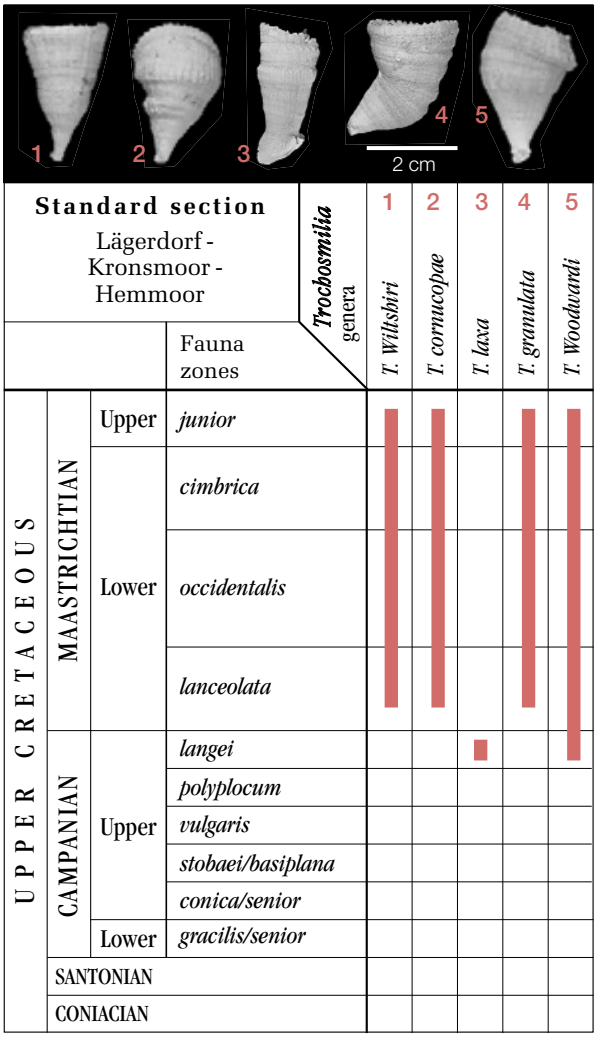
Link: Die geowissenschaftlichen Sammlungen
www.bgr.bund.de/sammlungen

Pioneering palaeontology: small fossils from Rügen Island, which are mentioned in the book of 1846 (Geozentrum library). This small part of von Hagenow's estate is presented on the Internet as a collection object representing the III/08 quarter.

Developments in **Rock Dating** and **Facies** Identification

Rock dating and facies identification using fossils, known as palaeontology, was exclusively for applied purposes in the early days. This was also the case at BGR, where it was an independent department accountable only to the President. It investigated the fossil content of rocks and samples from the regions explored by BGR within Germany and around the world, with the aim of addressing economical issues. For BGR's international activities, palaeontology was primarily utilised in hydrocarbon exploration for crude oil and natural gas and the search for important industrial resources. This was the case in Jordan, for example, where extensive phosphate and oil shale deposits, and other resources (quartz sand, gypsum, marble, salt), were discovered in the 1960s. As the correspondence of the day between Hanover and the 'mission' in Jordan reveals, due to the large number of samples sent from Jordan, there was great pressure on employees in Hanover, not to mention annoyance in Jordan, when the urgently anticipated results did not arrive on schedule.

Palaeontology played an important part in the basic geological map series and generalised maps created at the time – in fact BGR's '*Geologie von Jordanien*' (Geology of Jordan) still enjoys a first-rate reputation in the Kingdom of Jordan. Because reliable dating and strata correlations using fossils contributed to the clarification of geological relationships and thus to successful deposit exploration. Micropalaeontology played a central role in stratigraphic divisions, just as it did in the crude oil industry, because microfossils enabled strata to be better dated and more reliably correlated. Outstanding, well equipped laboratories were therefore established at BGR for all important microfossil groups, where several hundred thousand samples have since been micropalaeontologically prepared, investigated and documented in reports. Today, the scanning electron microscope laboratory is a shining light in the succession of palaeontology laboratories. In 2004 it was equipped with the third generation of one of the most modern and powerful devices for microfossil work.



With the aid of biological knowledge regarding the respective genus and its environmental conditions, fossils found in quarries and mines, or taken from rock samples and boreholes drilled specially for dating, provide valuable age information. In addition, comparison to key sections provides knowledge on the lithological rock sequence.

One example of this identification method is shown above with a narrower width and supplemented by the coral images. It is taken from 'Die Gattungen Parasmilia und Trochosmilia (Scleractinia) aus der Schreibkreide Norddeutschlands' by Jürgen Guerrero Kommritz and Gero Hillmer in Geologisches Jahrbuch A 157.

In the 1970s, (vertebrate) macropalaeontology was reduced by a decision of the institute management, partly because the results obtained were too 'palaeontological' and relevant to only a small number of people, and partly because better dating methods for younger strata were found, for example isotope dating. Numerous 'macro-colleagues' found it necessary to refocus both within palaeontology, by learning about new microfossil groups, and outside, by transferring to operative tasks in BGR management. Macro-palaeontology (of trilobites, brachiopods, cephalopods) was later completely abandoned in BGR and NLfB (Geological Survey of Lower Saxony).

Micropalaeontology emerged strengthened from this critical, and for palaeontology absolutely existential, phase of BGR reorientation, because it ventured into 'unknown territory', working on boreholes for the crude oil industry (DEMINEX), its own research boreholes and boreholes for international research (DSDP, ODP, IODP). It gained acceptance with new specialists and new focuses common in industry, such as carbonate microfossils (foraminifera, ostracods, coccoliths), microfossils with organic walls (pollen, spores, dinocysts) and special groups (bolboforms, conodonts, diatomea), which can reliably differentiate continental and marine sedimentation zones, especially in previously uninvestigated regions.

The close scientific cooperation between BGR and NLfB palaeontologists has always been constructive and beneficial. They were organised into 'mirrored departments' and mutually complemented each other's work when the required specialists were available in the other organisational unit. For many years they formed a micropalaeontological centre of synergy and excellence – although they were sometimes competitive – which was unique in Germany's scientific community.

From the 1990s to the present day, micropalaeontology has 'lost weight', especially in terms of personnel, and has been completely integrated into BGR project structures. Micropalaeontology is therefore strongly aligned with the scientific infrastructure in the Geozentrum, which is available to everybody in the Geozentrum, with structural geology investigations of the deeper subsurface and with the tasks involved with securing marine resources. Since 2007 palaeontology has also been called 'stratigraphy' – in accordance with how it is actually used.

Geosciences for Society

Science provides a service to society, it is not just self-admiration in an ivory tower. This applies especially when it is funded by taxes from the public purse. Geosciences are both exciting and indispensable for the responsible management of our planet: we want society to have its share.

Beside our core task of advising the federal government and industry on questions relating to geo-scientific and natural resources, we have taken up the cause of providing comprehensive information to the public.

We want the public to appreciate the impact our work has on their daily lives, and the topics we work on to guarantee a foundation for good and stable living conditions for future generations.

Public Relations

This is where public relations comes into play as a mediator between scientists and laypeople: we communicate with the media, publish information brochures and provide ‘hands-on geosciences’ at fairs and other events.
BGR staff have passed on their expert knowledge to the public and science colleagues on many occasions during the past:

- We present our work and our products regularly at national and international fairs and conferences.
- BGR regularly informs the media about new research results.
- We organise biannual science festivals in our grounds for the interested public,, to demonstrate what the ‘geo-neighbours’ do all day.

- Every year on Pupil's Future Day we invite pupils to visit the Geozentrum and take them on a journey into the fascinating world of geosciences.
- We send 'geo-ambassadors' to schools and to presentation events, where they talk about their work, both at home in Germany and on all the world's continents.
- We regularly participate in 'Geoday Hanover', an ongoing professional development event for teaching staff.
- And, of course, we utilise modern media such as the Internet.

Internet

In October 1995, BGR, NLfB (now LBEG) and GGA introduced their first joint website, which represented the Geozentrum on the Internet until its complete reorganisation in May 1998. In 2002 the websites of the three institutions separated and 'www.bgr.de' became independent: since October 2005 BGR's address has been http://www.bgr.bund.de.

The aim is to present the scientific results of the work we carry out to the general public. Staff use the medium of the Internet, with more than 2,000 pages of text and illustrated with more than 5,000 illustrations and figures, both to present their work and responsibilities, and to inform the public about new products, services, publications or events. A total of 44 BGR editors and Internet coordinators work on information from 22 departmental topic editors, quickly, efficiently and targeted to specific groups.

Comprehensive and topical presentation of the project work carried out by BGR is particularly important. An international event calendar including in-house presentations, as well as situations vacant and invitations to tender, round off the website. More than 600 downloadable files provide the user with facts and figures, for example in the Annual Report on Reserves, Resources and Availability of Energy Resources. Reference is often made to the products available in our eShop. Applications used by the different departments to present their work interactively to outside users are integrated in the website.

At the upper navigation levels the website is available bilingually in both German and English; at the lower levels, project results are presented in a further language such as Spanish or French, etc., depending on the region involved. Subsites with their own domains may be established for large, autonomous projects with a variety of cooperation partners, (for example: http://www.whymap.org).

The BGR website has been compiled and managed since October 2005 using the Government Site Builder (GSB) content management system. GSB was developed as the basic CMS component for websites under federal administration as a result of the E-Government initiative BundOnline 2005. Using a standard solution adapted by BGR to their requirements, it takes standards and architectures for E-Government applications (SAGA), design specifications of the federal government's online style guide and the requirements of barrier-free information technology in accordance with the BITV regulations into consideration. External hosting is provided by the *Bundesstelle für Informationstechnik* (BIT) (Federal Office for Information Technology) in the *Bundesverwaltungsamt* (Federal Administration Agency) in Cologne.

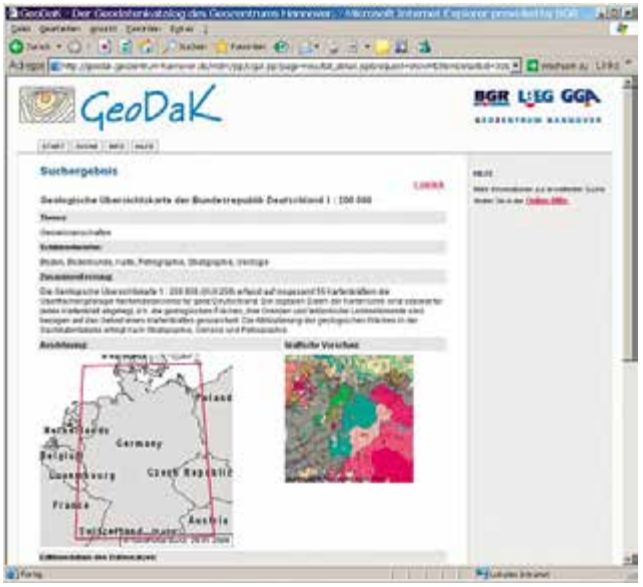
The figure of 30,000 average monthly visitors (in 1995 there were 200!) and 1,500,000 file accesses demonstrates that the information made available is welcomed by users worldwide.

Internet IT-Applications

However, the Internet does not only offers texts, images and multimedia elements, it can also be a platform for databases and IT applications. Many departments not only want to put their reports on paper, thereby making them accessible to an exclusive user group, they also want to make them available – as far as possible – to the general public. For this reason, over the past few years IT applications have been increasingly programmed to allow the departments to present their results to external users interactively.

The task of the technical infrastructure is to provide tools and technical solutions to support the application developers. For example, general specifications such as safety aspects, approved script languages and tips on user-friendliness have been published in a 'Web Application Development Manual'. BGR's 'design stamp' was developed into a corporate design and is used to indicate BGR applications. Each respective department is responsible for the technical implementation and correctness.

Personal support by a central helpdesk and formal quality assurance of the applications provide a solid foundation in the departments for presenting their scope of tasks via interactive IT applications.



The GeoDAK geodata catalogue provides information on the BGR data inventory:
http://geodak.geozentrum-hannover.de/mdm/jsp/cigal.jsp?page=simplesearch.jsp

The 1 : 5,000,000 scale International Geological Map of Europe and Adjacent Areas is available at
http://www.bgr.de/app/igme5000/igme_frames.php

Many results are literally 'worth the money'; they are also available for purchase: the Internet as a 'market place' for the sale of digital products.

eShop and the Sale of Digital-Products

BGR acquires spatial data in all fields of the geosciences from its own projects, technical cooperation with other countries and cooperation with the state geological surveys in the Federal Republic of Germany. These digital geodata inventories serve as the basis for planning for users in industry, public administrations and science.

The BGR website allows data inventories to be researched, but does not allow them to be ordered directly, so an electronic shop (eShop) offering BGR and LBEG products was designed and opened in 2004 as part of the Bund-Online 2005 project.

The eShop (www.geoshop-hannover.de) is operated jointly with an external company. The products are created in BGR departments and provided, with the product information, to an external service provider who operates the eShop. The service provider supplies the customers with the required products by delivering and invoicing them on our behalf.

The GeoDaK metadata catalogue of Hanover's Geozentrum serves as the basis for the eShop product catalogue. When updating the product catalogue, XML export files containing the product specifications are generated and sent to the service provider, who then updates the corresponding information in the product catalogue.

The varying formats in which the geological information are presented are well received by customers, because the data are available quickly and economically. For example, based on exemptions defined by the federal and Lower Saxony ministries of economics, Internet moderate fees of approximately € 50 maximum including VAT are allowed. In addition, there are minor retrieval fees, which are taken up by the external eShop operator.

Public awareness of geoscientific issues has altered drastically in recent decades. Today, even the public consults technical authorities in private matters. Technical advances and external demands have thus contributed to integrating an infrastructure field, such as the technical infrastructure employed in the external presentation of BGR.

Use of New **Satellite Methods** for Monitoring **Land Subsidence** on Java, Indonesia

Testing new methods, the results of which are used by BGR in many ways represents one element of technical infrastructure. A topical example is presented here, executed jointly with Indonesian and European partners.

Background

If the term 'georisk' is mentioned in connection with Indonesia, it is mostly in conjunction with natural disasters such as earthquakes, landslides, volcanic eruptions, flooding or tsunamis. Another, often underestimated and chiefly man-made, hazard potential is widespread land subsidence. Land subsidence, sometimes dramatic in extent, impacts the environment of millions of people, especially in coastal megacities of south-east Asia. The causes of land subsidence are manifold.

In south-east Asia's coastal regions, uncontrolled exploitation of groundwater generally leads to drying of the clay layers separating the aquifer levels, primarily consisting of sands and gravels. The clays shrink as a result of dewatering, leading to subsidence of the overlying sediments. Annual subsidence rates of 10 cm and more are not uncommon in some of Indonesia's coastal regions.

The consequences for the regions impacted by land subsidence are often disastrous. Residential areas and industrial installations suffer widespread destruction. Maintaining community infrastructure such as railways, streets, utilities and buildings demands enormous and continous remediation efforts, binding substantial sums from the public budget.

Large-scale detection and assessement of land subsidence in Semarang in the north of Java, with a population of 2 million, forms a component of the project 'Good Local Governance – Management of Georisks'. The project is part of the technical cooperation between Germany and Indonesia and supports national authorities in evaluating and assessing geological hazards, and aims at developing political and social conscience. Geological advice on risk reduction allows recommendations for the authorities in towns and villages to be derived, aimed at protecting the local population. The BGR project partner is the Geological Agency in Bandung.

Due to its lowland character, flooding occurs seasonally in the city of Semarang. As a consequence of the land subsidence, several parts of Semarang are permanently submerged by the sea resulting in an additional vulnerability to tidal inundations. The disastrous floods in northern Java in February 2007 come to mind in this context. In an attempt to prevent at least residential areas from sinking below the groundwater table, paths and roads are regularly filled using earth and waste. This is also done in the interiors of dwellings to keep them dry. Enormous economic losses are caused by the widespread sinking of industrial installations and traffic infrastructure.

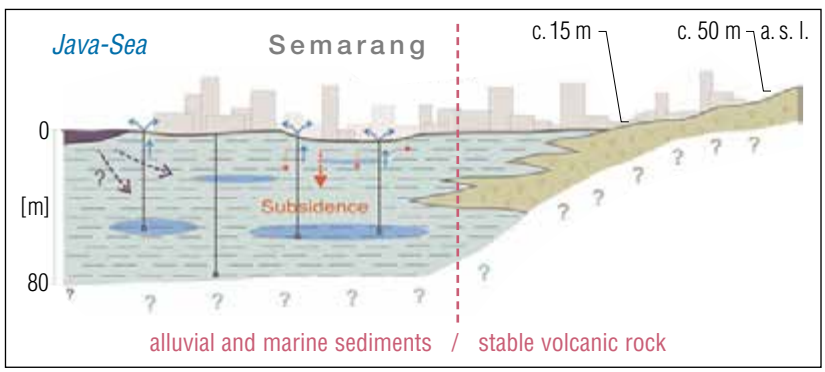
A simplified geological section, derived from the hydrogeological map of the Indonesian Directorate of Geology (1988 issue), demonstrates the general situation. The land subsidence is concentrated in in the north where alluvial and marine deposits including sands, gravels and silt are distributed. In contrast, the volcanic breccias and tuffs of the

Photos 1 to 5 demonstrate the dramatic extent of land subsidence and document the desperate attempts to combat it with the simplest means – filling with soil, debris and even waste.

Photos 6 and 7 show the disastrous effects of land subsidence on the infrastructure.

Quaternary Damar Formation following towards the Ungaran volcano in the south are considered to be stable. However, slope movements associated with clayey layers are possible here.

Stopping or slowing down land subsidence, and mitigating the consequences require effective urban development measures, including establishing measures for controlled use of groundwater resources. Reliable information on the scale of land subsidence is also necessary to enlighten groundwater users, planners and political decision-makers in the region and thus for improved regional planning.



Simplified geological section through Semarang.

The previous subsidence maps for Semarang are based on conventional surveying data from only a few benchmarks in the city area. The maps are therefore highly generalised and imprecise in their details. Continuation of ground-based measurements has now been terminated due to the complex conditions in the city area.

Satellite-based Subsidence Measurements

Because of the urgent requirement for reliable data on ground movements, alternative methods of subsidence measurement have been explored. In this case, BGR benefitted from its experience gained as a partner of the Terrafirma-Project. Terrafirma is one of ten services being supported by the European Space Agency's (ESA) Global Monitoring for Environment and Security (GMES) Service Element Programme. Terrafirma is based upon the remote sensing technique of Persistent Scatterer Interferometry, which has the power to map millimetric ground motion phenomena from space (www.terrafirma.eu.com).

The **PSI method** utilizes SAR data series' from the ERS-1, ERS-2 or Envisat satellites, recorded over a defined observation period, to detect the smallest movements in the ground surface. Persistent 'reflectors' of the radar radiation transmitted by the satellites are identified. The reflectors are called'persistent scatterers', which must be recognisable as such on every single SAR scene in the entire set of data. Usually, building corners, metallic structures and other objects that reflect the incident radar signals back to the satellite because of their character and orientation, act as persistent scatterers.

BGR evaluated and assessed PSI products derived for seversal German Terrafirma test sites from a user perspective. For the Semarang project, BGR utilises experience gained in the Terrafirma project and thus guarantees that technical cooperation tasks are solved using the most modern technologies for earth observation.

Thirty-five ERS and Envisat SAR scenes recorded during 2002 and 2006 were processed and evaluated for Semarang using the PSI technique (SAR: Synthethic Aperture Radar). A total of 46,912 persistent scatterers were identified. By evaluating phase information it was possible to determine ground motion rates for every single scatterer. Because the interferometric phase reacts very sensitively to ground movement, very small motion rates can be detected, even when they are in the range of a few millimetres per year, often fractions of this.

PSI processing of the Semarang SAR data was performed by the Spanish company Altamira Information (www.altamira-information.com) on behalf of BGR. Altamira belongs to a group of PSI service providers working in the GMES/ Terrafirma initiative. Because subsidence rates in excess of 10 cm are known from Semarang, new approaches were attempted to record these 'hot spots', which were previously undetectable in standard PSI applications.

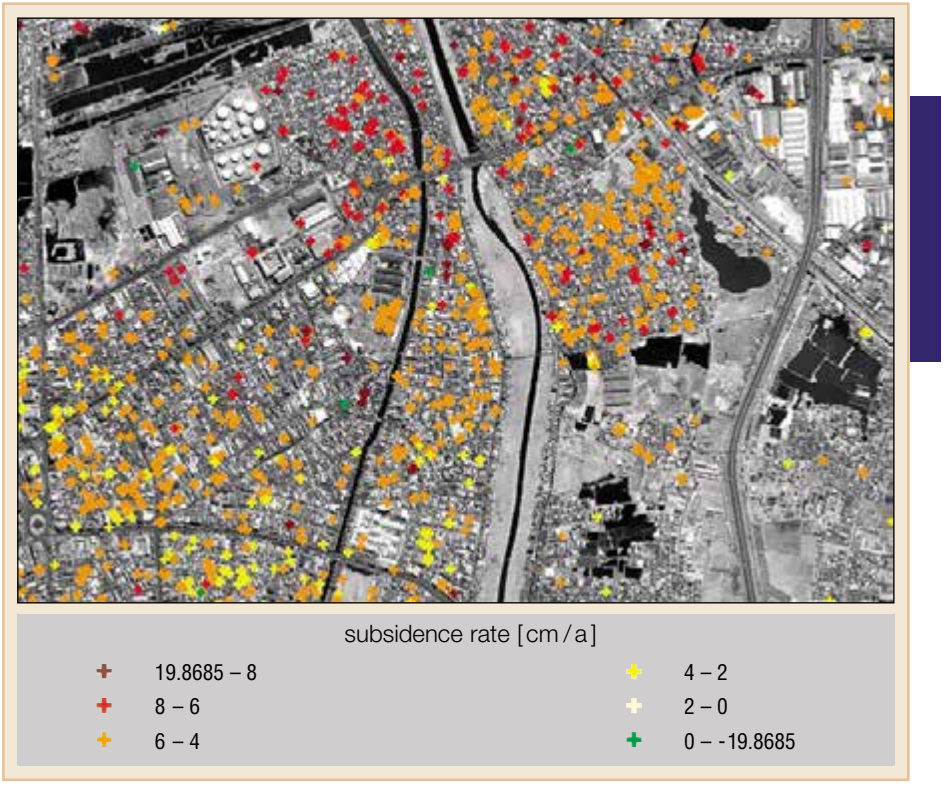
In order to assess the situation in Semarang, the PSI-drerived ground motion rates were presented in map format. Map derivation formed the content of training courses in Germany and Indonesia attended by personnel from the Indonesian project partner. The maps were made available to the authorities, politicians and industry, in order to make urban planning more efficient and to contribute to reducing risks.

Landsat 7 satellite image with classified land subsidence rates.

The visualisation of classified ground motion rates for all identified 'persistent scatterers', overlain on a Landsat 7 satellite image, clearly reflects the situation. The boundary between the stable volcanic rocks in the south (green), and the north of Semarang, almost completely impacted by subsidence, can be clearly discerned (light brown to red) in the movement pattern. Dark red points represent land subsidence with annual rates of 8 cm and more, the yellow and orange points represent movements between –2 cm and –6 cm per year. Motion spots within the generally stable region are probably the result of slope instabilities. Preliminary examinations on the ground support this assumption. Indications of widespread subsidence at the foothill of the Ungaran volcano (up to 1 cm per year) are tentatively explained by movements resulting from the weight of the volcano edifice on the older marine deposits – in conjunction with ring faults.

By zooming into the image, individual persistent scatterers, which reflect the incident radar radiation, can be precisely identified. This is easily recognisable in the extreme enlargement of the high-resolution IKONOS satellite image, for example on the side wall of a mosque.

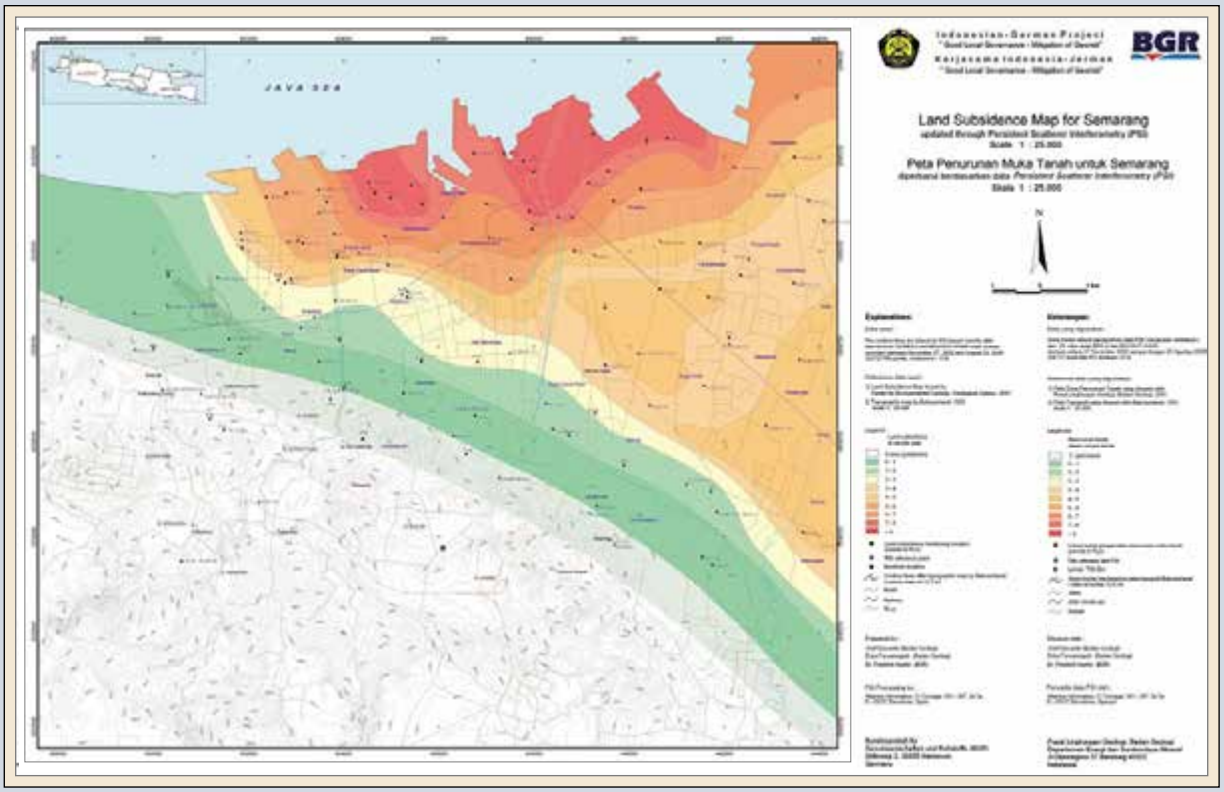
IKONOS Pan satellite image enlargement with classified motion rates (Includes material ©2002, Space Imaging LLC. All rights reserved).



IKONOS MSS satellite image with classified motion rates
(Includes material ©2002, Space Imaging LLC. All rights reserved).

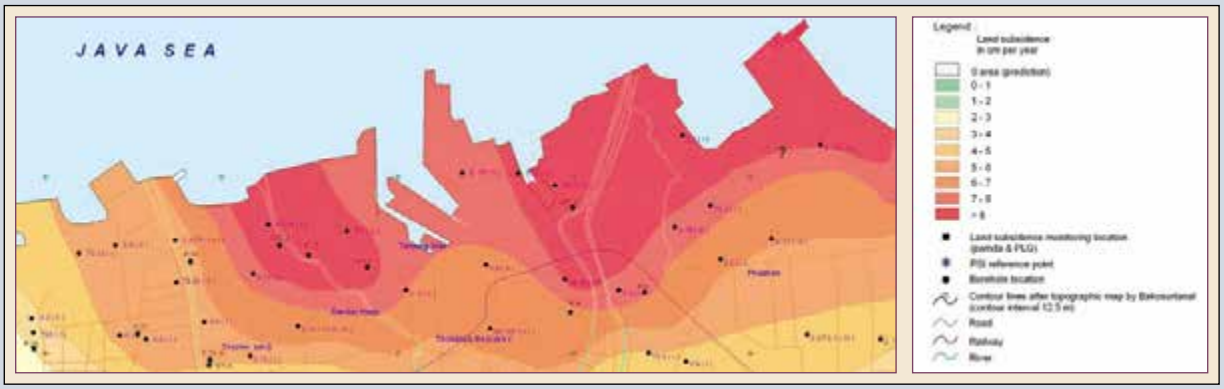
Assessing the whole area of PSI data coverage, individual areas of Semarang can be evaluated in terms of stability. It can be clearly seen that the industrial and harbour areas in the north are particularly severely affected by land subsidence, characterized by annual rates of 8 cm and more (see above figure). The same applies to the residential areas housing the poor population, which is in the immediate vicinity (see photographic documentation on page 160).

Overall, data collected from space using most advanced methods of Earth observation provide a completely new perspective on the large-scale movement behaviour of a large region, in a way previously not possible using ground-based methods. In the case of Semarang, the final result of the project is a significantly improved subsidence map, based on 46,912 PSI data points, compared to the previous map derived from only 29 survey points.



Above: The preliminary final result of the project is the Semarang subsidence map at 1 : 25 000 scale. The original dimensions of the much reduced overall image shown here are 120 x 90 cm.

Below: A part of the map and a section of the legend are shown enlarged for better reading.



BGR grounds and buildings between 1960 and 2007.

Appendix

BGR from 1958 until 2008,

its precursor organisations ...

Reichsamt für Bodenforschung

1960

Bundesanstalt für Bodenforschung

1965

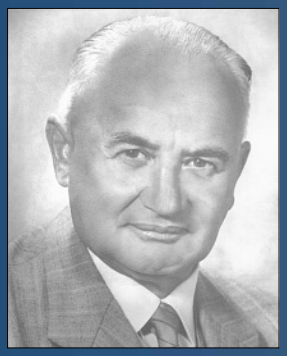
1970

1975

1980

Bundesanstalt für Geowissenschaften und Rohstoffe

17.1.1975



ALFRED BENTZ

✸ 1897
✝ 1964

HANS-JOACHIM MARTINI

✸ 5. 1. 1908
✝ 22. 10. 1969

GERHARD RICHTER-BERNBURG

✸ 22. 2. 1907
✝ 8. 3. 1990

EBERHARD MACHENS

✸ 1929

MACHENS, as the brother-in-law of the economics minister, was appointed president in 1972 to the accompaniment of staff protests. After only a few days in office he offered his resignation, which was accepted.

ULRICH ENGELMANN was then appointed as a state commissioner by the Ministry for Economic Affairs to deal with the interests of the BfB (now BGR) from January 1973 until February 1974.

... and presidents

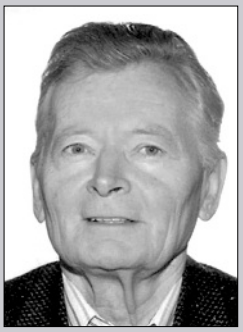
1985

1990

1995

2000

2005



Friedrich Bender

✷ 1924

✝ 2008

Bernhard Stribrny

✷ 1952

Martin Kürsten

✷ 12. 10. 1931

temporary president from 2006 until 2007

Alfred Hollerbach

✷ 1942

Friedrich-Wilhelm Wellmer

✷ 23. 6. 1940

Hans-Joachim Kümpel

✷ 1950

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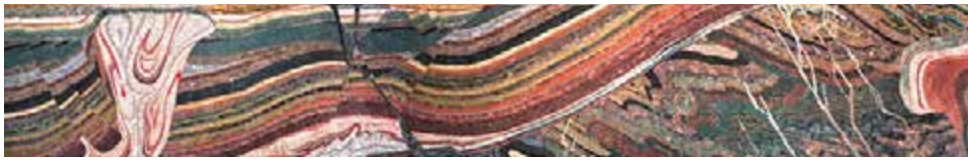

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