

BGR Report

Federal Institute for Geosciences and Natural Resources

September 2014



Information gaps in the Arctic Ocean

Geoscientific expeditions focus on resource potential of the Arctic

Imprint

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This BGR Report presents projects that BGR was working on in 2013 and looks ahead to future projects.

Editorial



*Prof. Dr.
Hans-Joachim
Kümpel*

President
of the Federal Institute for
Geosciences and Natural
Resources

Dear Readers,

With this BGR Report, we once again take you on a journey to the fascinating world of geosciences and our projects.

Last year, for instance, a team of BGR scientists working on the PANORAMA project started to explore the raw material potential in Arctic seas. Currently, some of our scientists are conducting research in the Indian Ocean into the potential of polymetallic sulfides, which contain elements needed in high-tech applications such as computers or wind turbines. In this year's BGR Report, you will also learn interesting facts about the groundwater situation in a number of African countries and about the development of soil maps.

This BGR Report has four sections: the Projects section looks back at 2013; the Outlook section describes a number of major working programmes we are planning to start in the next few months; in the People and Projects section individual scientists are interviewed for an in-depth and personal look at their projects; and the Spectrum section rounds off this year's BGR Report with a look at additional highlights.

You may be interested to know that the BGR Report is also available in PDF format, either on CD-ROM or as a free download from our website at www.bgr.bund.de.

I hope you will find it an interesting read!

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“Planet Earth represents the basis for all our lives
– its resources are limited.”

This is why BGR is committed to protecting the Earth’s biosphere and promoting
the sustainable use of natural resources.

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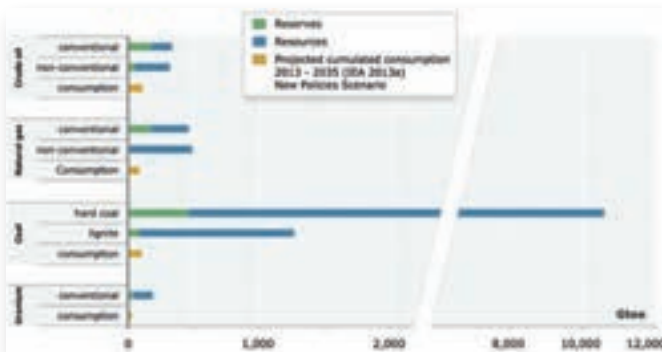
Energy Study – the same, but different

Fossil fuels still on the agenda

Natural gas, coal, oil and nuclear fuels are the topics of BGR's Energy Study, published for the 17th time in 2013. Given its long tradition and great success, this annual study will in future be published as a series in its own right.

What geological stocks of energy resources are there? Where are there still oil reserves? How are the com-

modity markets developing? The 17th BGR Energy Study addresses these and many other issues.



▲ Supply situation for non-renewable energy resources at the end of 2012.

modity markets developing? The 17th BGR Energy Study addresses these and many other issues.

The Federal Institute's raw material experts have been compiling data on fossil fuels since 1976, though initially at irregular intervals. Since 2004, the Energy Study has been published annually. "Given its long

tradition and great success we will from now on be publishing the Energy Study as a series in its own right with sequential numbering," says Dr. Harald Andrulleit, energy resources expert at BGR. The study contains important information, compiled by BGR for the German Federal Ministry for Economic Affairs and Energy and for German industry. Even though the German federal government is planning to increasingly rely on renewable energies, Germany will in fact continue to depend on fossil fuels for many years to come. For the Energy Study, BGR experts led

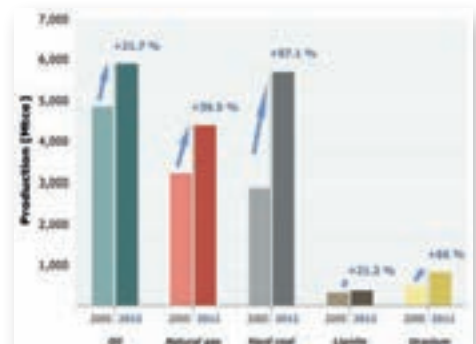
by Andrulleit are continuously analysing scientific publications and reports from industry and government agencies. Data collected by BGR are also included in the study. The latest Energy Study has two special topics: shale gas deposits in Europe and oil and gas resource potentials in the Arctic. In addition, the scientists explain the concepts by which they distinguish conventional and unconventional resources.

Main conclusion: from a geological perspective, there are still large global reserves of all energy resources – with the exception of conventional oil of which experts expect production to peak in the foreseeable future.

www.bgr.bund.de/energiestudie2013_en

Contact: **Dr. Harald Andrulleit**

▼ Comparison of global production figures for fossil fuels in 2000 and 2012.



Securing the Supply of Raw Materials

NiKo: Oil and gas from shales – potential resources for Germany

A recipe for oil

BGR scientists study formation of hydrocarbons

Making oil is really very simple. This is what you do: take some organic matter, such as microscopic algae, spread them in fine-grained mud and heat the mixture to between 65 and 120°C. Then pressurise the mixture and wait a few million years. At some point, part of the algal material will transform into long-chain hydrocarbons – and there you have your black gold!

The scientists simulate subsurface conditions in high-pressure reactors. One of their aims is to establish what part sulphur compounds play in the formation of oil and natural gas. In nature, gases containing sulphur are often formed together with hydrocarbons. The scientists are hoping to determine under what conditions a geological stratum has a high potential for oil or gas formation.

trapped, for instance, underneath a salt dome.

But sometimes oil or gas remains trapped in the source rock. Experts refer to such resources as shale oil and shale gas or unconventional reservoirs. BGR scientists are now studying the way in which hydrocarbons are gradually released from the source rock under natural conditions, which compounds are lost and how quickly. For their investigations, they have linked a high-pressure vessel directly with an analysis instrument. The aim of these tests is to assess more re-



▲ Gas chromatograph (left) to analyse the release of hydrocarbons from source rock under subsurface conditions, directly linked to a high-pressure reactor (right).



▲ Gold cells can be used to analyse the role of organic sulphur-containing compounds in the formation of gas.

But it is not always as simple as that. In some rock types, all of the above criteria are met, but no oil will form. In other places, the process is much quicker than normal. In the NiKo project, BGR scientists and engineers want to find out the reasons for that.

Trapped in the source rock

The team are also studying under what conditions oil will migrate in the subsurface. Hydrocarbons are formed in the so-called source rock, which is in many cases largely composed of clay minerals. From there, they often migrate across long distances – until they are

liably if an unconventional source rock contains economically viable amounts of oil or natural gas.

Contact:

Dr. Christian Ostertag-Henning

Securing the Supply of Raw Materials

Exploration of manganese nodules in the German licensing area

Deep-sea harvesting

BGR scientists explore German licensing area in Pacific Ocean

Manganese nodules are widely considered to be a mineral resource of the future. BGR scientists have found several resource-rich areas in the German licensing area. In addition, biologists have surveyed the biodiversity on the seabed.

BGR experts have discovered about a million tons of copper, nickel and cobalt – hidden in structures called manganese nodules on the Pacific seabed. During an expedition to the German licensing area in summer 2013, a team of scientists led by Dr. Carsten Rühlemann discovered one particularly promising area. Explorations of the 2,000-square-kilometre site have indicated that it contains around 30 million tons of manganese nodules. The industrial metals copper, nickel and cobalt, which are of econom-

ic interest, make up some three percent of the nodule mass.

“There are at least ten more zones of interest that have a dense covering of manganese nodules over a wide area,” says Rühlemann. The aim is to explore these nodule fields by 2021. In 2006, Germany signed an agreement with the International Seabed Authority, permitting exploration of the 75,000-square-kilometre licensing area over a period of 15 years.

Under the agreement, BGR has also undertaken to determine the potential environmental impacts of manganese nodule mining. This is why the expedition team includes biologists, some of them experts from the German Centre for Marine Biodiversity Research (DZMB) at the Senckenberg Institute in Wilhelmshaven. These scientists are studying biodiversity in the nodule fields. “First findings have shown that some animal species are widespread. So there appear to be no barriers that would stop recolonisation after the possible future mining of manganese nodules,” says Annika Janssen of DZMB. What this means is that if the manganese nodules were to be mined in future, the animals would probably recolonise the area once mining was completed.

Contact: **Dr. Carsten Rühlemann,**
Dr. Michael Wiedicke-Hombach



▲ Box corer sample with manganese nodules.

◀ Deployment of an acoustic current meter in the Pacific between Mexico and Hawaii.

Mineral resources of the future

BGR scientists analyse mining waste in Chile for rare metals

Chile is the world's largest producer of copper. With an annual output of 5.7 million tons it covers a third of global demand. In copper mining, vast amounts of earth are moved, of which about 95 percent are dumped as processing waste (tailings) after the copper has been recovered. It is estimated that Chile currently produces at least 370 million tons of such tailings material every year. Over the past 30 years, a total 6.8 billion tons have thus accumulated mainly in the form of dried sludge. The tailings are now in high demand and attracting considerable research as they may contain not only residual amounts of copper but also other rare metals.

Strategic metals in tailings

This previously neglected mineral re-

source potential is now at the focus of a research project led by the German Mineral Resources Agency (DERA), a BGR sub-department. The project is conducted in collaboration with partners in Chile. Together with CAMCHAL, the German-Chilean Industrial Chamber of Commerce and Industry in Santiago de Chile, the Chilean mining association SONAMI, the Chilean National Mining Corporation ENAMI, and the Chilean Geological Survey SERNAGEOMIN, BGR scientists Dr. Malte Drobe and Dr. Herwig Marbler are studying the economic viability of recovering strategic and rare metals such as molybdenum, zinc, rhenium or gold from Chilean copper mine tailings.

Of the approximately 1,000 existing copper tailing deposits, the team is

planning to select about ten representative sites for detailed investigation. Currently, the scientists are evaluating available data and analysing samples taken during the first field campaign in October 2013.

Partners in the mineral resources sector

Chile and Germany have been working together closely in the mining sector since early 2013. In January 2013, the two governments inked a mineral resources partnership. At CAMCHAL in Santiago de Chile the Competence Centre Mining & Mineral Resources was already launched in early 2013. This centre has since been representing the interests of German businesses who are currently active in the Chilean mining industry or are interested in such an involvement. DERA and CAMCHAL organise the annual Forum for Mining and Raw Materials, which will serve as an exchange platform for projects with German participation. Both geological services SERNAGEOMIN and BGR have confirmed their intention to collaborate closely in future in the areas mining and raw materials.



Source: DERA

▲ Sampling at a copper tailings deposit owned by ENAMI, at Copiapó, Atacama province, Northern Chile.

Contact: **Dr Herwig Marbler**

Due diligence for businesses

BGR supports businesses in responsible sourcing of minerals

The importance of transparency in the exploitation of mineral resources is increasing worldwide. More and more governments require businesses to disclose their mineral supply chains. BGR provides up-to-date information on requirements.

For many businesses, 31 May 2014 is a critical date. For the first time, businesses listed on the US stock exchange have to disclose whether their products contain so-called conflict minerals from the Democratic Republic of the Congo or its neighbouring countries. The basis for this rule is the Dodd-Frank Act, a US law for the regulation of financial markets. With

minerals from the Democratic Republic of the Congo or its neighbouring countries. The basis for this rule is the Dodd-Frank Act, a US law for the regulation of financial markets. With



▲ Tin mine in Rwanda.

it, the US government aims to stop armed groups continuing to acquire funding through the mining of and trade in tin, tantalum and tungsten ores, or gold.

This also affects German businesses. Many suppliers to the automotive industry and tool and electronics manufacturers now have to disclose their supply chains. “That is often a difficult task,” says BGR expert Dr. Gudrun Franken. “Every circuit board contains resources that might originate from the conflict region; and the same applies, for instance, to tin in laptop displays.”

BGR is a member of an OECD working group that has drawn up guidance for the responsible sourcing of mineral resources from conflict regions. At numerous events, Gudrun Franken and her colleagues are publicising the latest requirements and ongoing initiatives.



◆ Cassiterite mining in Rwanda.



Contact: **Dr. Gudrun Franken**

Securing the Supply of Raw Materials

Deposit potential of metals of strategic economic importance

Jurassic legacy

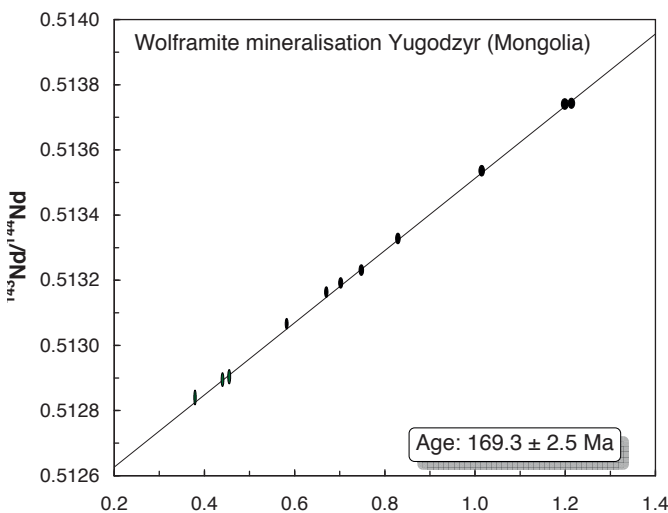
Scientists determine age of high-tech metals

Tungsten and the rare earth elements (REE) are of strategic importance for industry. BGR is using isotopic age dating in the search for new deposits in Mongolia and South Africa.

Several times in geological history, magma got stuck in the Earth's crust on its way up underneath present-day Mongolia. As they cooled down, the molten rocks released hot water from which unusual minerals formed, containing, for instance, the metal tungsten. But it remains a mystery why this element accumulated more in some deposits than in others. This is a question that Dr. Friedhelm Henjes-Kunst from BGR and other geoscientists are seeking to answer in the project Metals of Strategic Im-

portance by determining precisely the age of the tungsten-containing minerals.

They are applying the samarium-neodymium dating method, which is based on the radioactive decay of the samarium-147 isotope to neodymium-143. "If you know which processes are responsible for the formation of deposits, you can look for new deposits in specific places," says Dr. Henjes-Kunst. Valuable metals frequently accumulate in the crust only



▲ Graph showing the age dating of a wolframite mineralisation in the Yugodzyr deposit in Mongolia using the samarium-neodymium dating method. The age of the sample is 169.3 million years (Ma).

million years, placing it in the middle of the Jurassic period.

The BGR team is also studying the accumulation of rare earth elements in a rock complex in northeast South Africa. Their studies show that the concentration levels in some rocks



▲ Geoscientists from BGR and from CGS Pretoria during field work on the Schiel Complex in northeast South Africa.

within the complex are similar to those found in large Chinese deposits. Using age dating, the BGR scientists are now planning to find out when exactly the deposits were formed and whether they formed contemporaneously with rock complexes rich in rare earth elements found in other parts of South Africa.

in brief periods of geological history. Isotopic dating can help in identifying promising rock units.

BGR scientists have dated the Yugodzyr deposit, a large tungsten deposit in Mongolia, to an age of 169.3

Contact:

Dr. Friedhelm Henjes-Kunst

Securing the Supply of Raw Materials

German federal government incentive for exploration of natural resources

Focus on critical resources

The German Federal Ministry for Economic Affairs and Energy has launched an incentive to improve Germany's supply of critical resources. The German Mineral Resources Agency (DERA), part of BGR, has been commissioned to provide expert support and is inviting applications.



Source: S.-U. Schulz (DERA)

▲ Underground exploration of wolframite-bearing quartz veins in Bolivia.

In Saxony, the search is on again for mineral resources: in the western part of the Ore Mountains, Saxony, Minerals & Exploration AG are exploring the Pöhla-Globenstein tin and tungsten deposit, while, at Marienberg-Süd, Umbono Capital Projects GmbH are searching for indium, a metal of major economic importance.

Both projects are receiving funding from the German Federal Ministry for Economic Affairs and Energy (BMWi). A total of 4.7 million euros have already been made available by the ministry for these two projects in Germany and four other projects in Mozambique, Sri Lanka, Bolivia and Spain. The funding is provided under the Exploration Support Programme that the federal government hopes will improve the



Source: S.-U. Schulz (DERA)

▲ Wolframite concentrate produced in small-scale mining, Bolivia.

supply of critical resources to industry. The scheme's funding totals 25 million euros, 7.5 million in 2013 and again in 2014, and 10 million in 2015.

Critical resources include 14 metals and industrial minerals, such as antimony, cobalt, fluorite, gallium, germanium, indium, platinum-group metals (PGM), rare earth elements, tantalum and tungsten. The projects funded in 2013 involved exploratory work above and below the surface, and feasibility studies.

DERA has been commissioned by the BMWi to provide expert support for the programme and handle applications. The project proposals are assessed according to formal and technical criteria based on international standards. The final decision on the proposals is made by the BMWi, who also provides the funding.

Contact: **Siyamend Al Barazi**

Underground biotechnology

Bacteria and other microorganisms can help extract hydrocarbons from the ground

Microbes are normally undesirable intruders in oil reservoirs. These single-cell organisms transform hydrocarbons into tar-like heavy fuel oil, often producing hydrogen sulphide, a toxic and corrosive gas, in the process. In pipelines and other equipment, they form biofilms that corrode the metal or block pipes.

But there are many useful microorganisms below the surface, which so-called MEOR (Microbially Enhanced Oil Recovery) strategies aim to exploit. The idea is that these microbes will help increase oil produc-

tion. Because currently only about a third of the oil in a reservoir can be recovered. In future, microbes could help to extract the residual oil, which is trapped in tiny pores in the rock and is therefore inaccessible.

Useful microbes

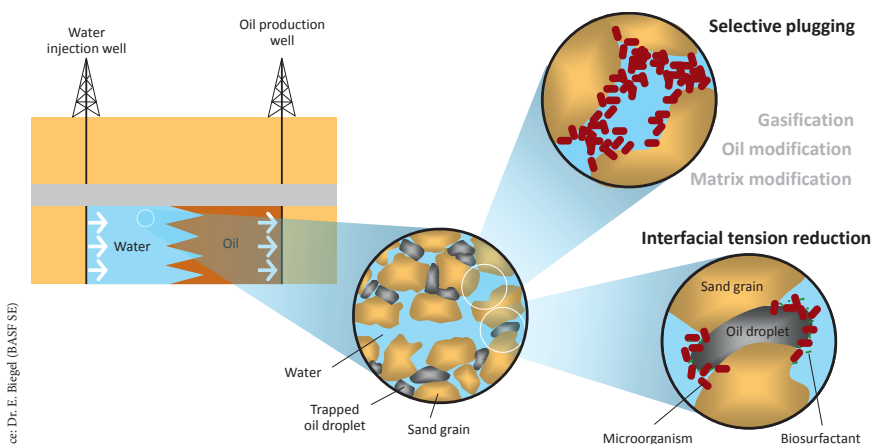
BGR scientists led by Dr. Martin Krüger are working to achieve this goal. “There is considerable potential for the use of microorganisms in conventionally depleted reservoirs,” says Krüger. The microbiologist and his colleagues are considering several strategies. In one approach, the mi-

crobes would convert oil or coal that is difficult to extract to methane gas, directly in the reservoir. This would increase pressure in the oil deposit, and methane is also easier to extract.

Another option would be to cause the microbes to produce surfactants, soap-like substances, which could remove the residual oil from the rock. In a third approach, certain microbes would be stimulated to form biofilms or produce some sort of thickening agent. This would seal the empty areas of a deposit. If water is then pumped into the reservoir, it will primarily flow into the unsealed areas, flushing out more oil.

Project in China

As part of the BGR project, Martin Krüger and his colleagues are currently studying microorganisms in a reservoir in China, south of Beijing. Initially, they are planning to find out what microbes occur in the deposit and what metabolites they secrete. They are also studying what substances improve the solubility of oil. Krüger is sure that “these MEOR processes can provide additional environmentally friendly energy resources.”



Source: Dr. E. Bregel (BASF SE)

▲ Ways of using microorganisms to enhance oil production.

Contact: **Dr. Martin Krüger**

Securing the Supply of Raw Materials

INDEX: Indian Ocean – exploration of polymetallic sulphides by BGR

Where metals bubble up from the seabed

INDEX 2013 expedition finds new ore fields

In autumn 2013, BGR scientists were searching for metal-rich deposits, so-called massive sulphides, in the Indian Ocean. The aim of their work was to submit an application for an exploration licence to the International Seabed Authority.



Source: T. Schubert

▲ Research vessel Sonne during the expedition in the Indian Ocean.

The INDEX 2013 project took the research vessel Sonne on one of its last journeys. In the Indian Ocean, southeast of Madagascar, a BGR team discovered another previously unknown inactive hydrothermal field with considerable massive sulphide deposits on the seabed. These ores contain copper, zinc and lead,

and even precious and trace metals such as gold, silver, tellurium, gallium and selenium. "The findings to date have been so encouraging that we applied to the International Seabed Authority (ISA) for an exploration licence back in late 2013," says Dr. Ralf Freitag, marine geologist at BGR. The scientists found the cop-

per ores to have a silicic-acid coating, which partly protects them from submarine weathering. "The ores we have found suggest that there may be significant deposits below the sea," reports Freitag.



▲ Lowering the box corer from the vessel for use on the seabed.

Another highlight of this expedition: the scientists recorded a temperature of 418°C at one active hydrothermal vent – one of the highest ever measured on the seabed. "We assume that more metals are precipitated from these hot hydrothermal solutions than in other sulphide fields," says expedition leader Dr. Ulrich Schwarz-Schampera. And indeed, ROV Kiel 6000 collected copper-rich and zinc-rich samples near the vent.

Contact:

Dr. Ulrich Schwarz-Schampera

North Sea on the web

A mouseclick takes you 5,000 metres below the seabed

At the end of the project Geoscientific Potentials of the German North Sea (GPDN) a new web portal went live. This provides information on the geological subsurface of the North Sea – from the seabed down to several thousand metres below it.

It presents the North Sea as it has never been seen before: complex fault zones twist their way between light-coloured salt structures, geological strata of various colours are stacked on top of each other. The GPDN web portal presents numerous 3D models that show the

They give a 3D image of the subsurface off the German coast.

BGR scientists in collaboration with colleagues from the State Authority for Mining, Energy and Geology (LBEG) and the Federal Maritime and Hydro-

graphic Agency (BSH) compiled the necessary data over a period of five years.

As part of the collaborative project Geoscientific Potentials of the German North Sea, they carried out eight expeditions and

prepared archive data for use on the web portal. For the deeper subsurface in the northwestern corner of the German exclusive economic zone, the so-called "Entenschnabel" (Duck's Bill), the



▲ The map server of the GPDN project provides simple GIS functions. The image shows the sediment distribution map according to Folk.

first ever comprehensive and clearly illustrated picture of the complex geology of the German parts of the shelf sea. Additional maps can be accessed via the website and a special map server.



▲ Logo of the GPDN project.

experts developed a new interpretation of the geological structures. Other major topics were sediment distribution, ground conditions and resource and storage potentials.



▲ Visitors to the GPDN website can access the various project products from the homepage.

The project aims to contribute to the sustainable development of the North Sea economic area. It provides the scientific basis for maritime spatial planning and helps to better coordinate the different stakeholders' interests.

www.gpdn.de (Language: German)

Contact: **Dr. Lutz Reinhardt**

Securing the Supply of Raw Materials

Adviser to the International Seabed Authority

Guardian of our heritage

The exploitation of mineral resources in international waters requires a permit from the International Seabed Authority. An expert from BGR is deputy chair of a commission that advises this autonomous institution in legal and technical matters.

In the middle of the Pacific Ocean, there is a no man's land half the size of Europe, called the Clarion-Clipper-ton zone. This area is of great interest to many countries and international businesses, because the seabed there is covered with black manganese nodules containing commercially significant metals such as cobalt, copper and nickel.



▲ Logo of the International Seabed Authority.

The mining rights to this deep-sea treasure are regulated by the Jamaica-based International Seabed Authority (ISA), set up in 1994, with the entry into force of the United Nations' Law of the Sea Convention. To date, 166 nations have signed the treaty. ISA is the official guardian of parts of the seabed that are defined as the "common heritage of mankind". That includes all mar-



▲ Head office of the International Seabed Authority on Jamaica.

itime zones outside the boundaries of coastal states' sovereign rights. Environmental protection is a major priority in all issues relating to deep sea mining.

Source: ISA

ISA's Legal and Technical Commission (LTC) develops binding licensing rules to ensure the responsible use of resources in international waters. As Vice Chairman of the LTC, BGR geophysicist Dr. Christian Reichert attends LTC meetings twice a year. The 25 experts on the Commission – legal professionals, geoscientists and biologists – assess licensing applications from countries for exploration or mining of specific mineral resources, draw up new regulations, and review the reports submitted by licensees.

In 2012, the LTC was asked to define regulations for the mining of manganese nodules in the Clarion-Clipper-ton zone. Since then, it has been working on a basic study that is currently at the review stage. The aim is to complete the regulatory framework by 2016.

ISA has ruled that exploration is currently permitted in about one third of the vast manganese nodule belt, and mining activities are strictly forbidden in another third. This latter area is now the world's largest marine protected area.



▲ Many areas of the seabed are home to a wide range of animal species.

www.isa.org/jm/en/home

Contact: **Dr. Christian Reichert**

Securing the Supply of Raw Materials

Risk assessment for metal resources

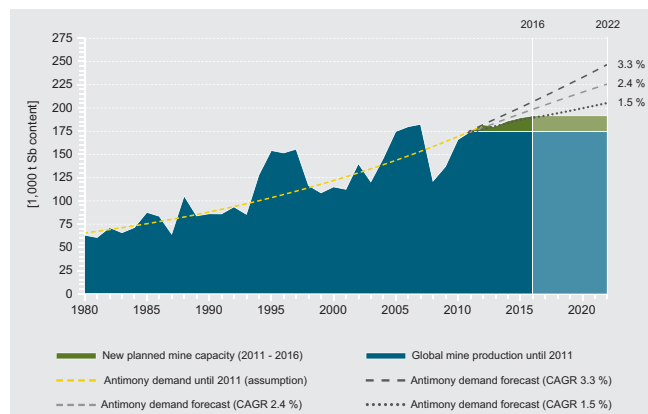
Risky business

German Mineral Resources Agency monitors market situation for critical resources

As an industrialised country, Germany needs natural resources to produce goods. The German Mineral Resources Agency (DERA) advises German industry on potential risks relating to resource prices and supply.

Disruption of production in a Chinese mine may very well have unpredictable consequences for German businesses – if the mine produces the metalloid antimony, for instance, which is mainly used in flame retardants and lead alloys. If China as the main exporter reduces exports, prices may rise around the globe. Between 2003 and 2013, for instance, the price of antimony increased by a factor of ten.

Other natural resources are also at times subject to strong price fluctuations, usually for economic or political reasons. In 2006, BGR responded to these challenges by developing a risk assessment model for natural resources. DERA, which was set up in 2010, is continuously enhancing this model. A team led by Maren Liedtke, Ulrike Dorner and Michael Schmidt studies, for instance, existing trade obstacles such as export restrictions, market



▲ Forecast scenarios for the trends of antimony supply and demand up to 2016.

Source: DERA

power through country and industry concentration, or the development of the supply side through exploration or mining projects.

Based on indicators such as these, the scientists are currently developing different commodity risk analyses for German industry. Qualitative market analyses and a quantitative model form the basis for assessment. Using time series data analysis, the major factors in-



▲ Antimony is a major component in the production of flame retardants.

fluencing supply security are investigated. Commodity risk analysis offers an assessment of the current

market situation and scenarios for the supply situation for individual resources.

In their coalition agreement of November 2013, the German political parties CDU, CSU and SPD

specified that critical resources should be monitored and that German industry should receive information about their availability at regular intervals. DERA's commodity risk reports represent an important contribution in this respect.

Contact: **Maren Liedtke**

Information gaps in the Arctic Ocean

BGR explores energy resource potential in the Arctic

The seabed of the northern Barents Sea and the waters around Greenland are virtually unexplored in geological terms. With its PANORAMA project, BGR is now taking a closer look at this region, to assess its resource potential.

Many raw material experts expect to find large, previously undiscovered oil and gas reservoirs in the Arctic. The US Geological Survey (USGS) estimates that about a quarter of as

yet undetected deposits are located north of the Arctic Circle, the largest share below the seabed of the Arctic Ocean.

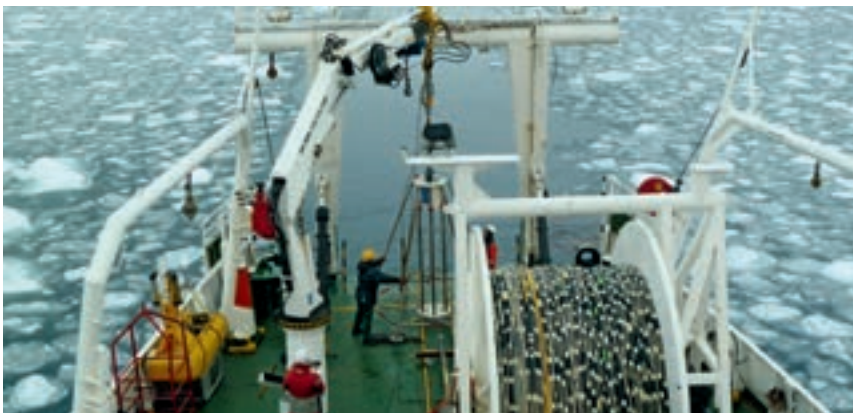
However, the reliability of these estimates is unclear. "Information about the resource potential is based on statistical calculations," says BGR expert Dr. Kai Berglar. Since the Arctic Ocean is almost permanently covered by ice, very few geological data are available for many areas.

With its PANORAMA project, BGR aims to expand the scope of knowledge in this field. Berglar and his colleagues are planning to carry out geophysical and geological exploration work on the seabed of the northern North Atlantic and the northern Barents Sea. They are primarily interested in tracing the depositional history of the seabed sediments since the opening of the Arctic Ocean around 55 million years ago.

The programme is scheduled to last six years. During the first expedition in August 2013, BGR scientists together with colleagues from the University of Oslo explored the northern Barents Sea. On board the Italian research vessel OGS Explora, they advanced into regions that until recently had been permanently covered by ice. With the data they have acquired, the scientists will be able to model the deep Earth's crust at the transition from the continental shelf to the Arctic Ocean.



▲ Monitoring data recordings.



▲ Tough working conditions close to the pack-ice limit.

www.bgr.bund.de/PANORAMA_en

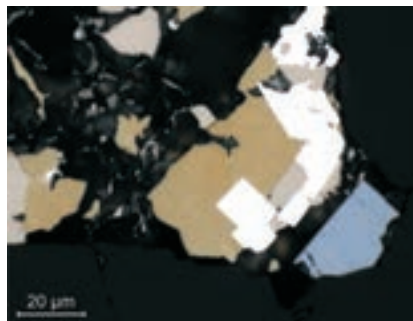
Contact: **Dr. Kai Berglar**

Pay dirt: useful raw materials below our feet

BGR scientists develop processing methods for weathered platinum ores

Seventy percent of global platinum metals are found in South Africa. But a large proportions of the ores are weathered and, therefore, the ores are uneconomic at present. BGR scientists are working to enhance mining and processing methods.

In South Africa, many treasures lie hidden in the ground – gold and diamonds, for instance. But north of Johannesburg, valuable precious metals are literally below our feet. An enormous, ancient rock body, the Bushveld Complex, contains the largest deposits worldwide of the platinum-group elements (PGE) – ruthenium, rhodium, palladium, osmium, iridium and platinum. However, the top layer of this precious metal deposit are weathered and the contained PGE cannot be extracted by conventional metallurgical methods. According to BGR scientists Malte Junge and Dr. Thomas Oberthür, the reddish-brown soil could become an important source of PGE in the near future.



▲ Ore microscopy image of platinum-group minerals (platinum-iron alloy: white; laurite: bluish) and sulphides (chalcopyrite: yellow; pentlandite: cream-coloured) in a chromitite ore from the Karee Mine in South Africa.



▲ Open-cast mine at the Platreef, South Africa. The weathered platinum ores near the surface are clearly recognisable by their brown colouring.

Mining weathered platinum ores is currently not economically viable, as traditional processing methods yield only a small output. In the BGR project Oxidised Platinum Ores, Junge and Oberthür are developing new

methods specifically for these oxidised ores. For this purpose, they are studying how the PGE are chemically bound in different minerals. Orig-

inal, pristine ores are already very complex, because the PGE occur in different forms within them – as different platinum-group minerals and bound in sulphides. During weathering, the precious metals are redistributed and then locked in various compounds.

For this project, on which several German universities are collaborating, the scientists have analysed samples from the Bushveld Complex at different stages of weathering. They are also studying the solubility of PGE in experiments. On behalf of BGR, scientists at Jacobs University Bremen are investigating new chemical approaches for releasing PGE from the rock. They have already achieved high recovery rates of more than 70 percent.

Contact: **Dr. Thomas Oberthür**

Planning data for Yaoundé

BGR heads interdisciplinary pilot project in Cameroon

Yaoundé, the capital of Cameroon in West Africa, has a problem with water. BGR scientists in collaboration with colleagues from Cameroon and Bonn have analysed in which parts of the city the water supply is particularly critical. Relying on samples, laboratory tests and surveys, they were able to correlate groundwater quality with population health.

It rains a lot in Yaoundé. Dark clouds frequently obscure the skies over this metropolis in the centre of Cameroon. On average, 1,600 millimetres of rainfall are record-



▲ The map shows sites where groundwater samples were taken and households surveyed (coloured dots) in the five districts of Yaoundé: Messa Carrière, Ekoudou, Madagascar, Biyem-Assi/Obili and Ngoa Ekelé. The survey provides additional information about the different housing and living conditions.

ed annually, almost three times as much as in Germany. Yaoundé is located only three degrees north of the Equator and surrounded by tropical rainforest. Its two wet seasons together last seven months.

But the public water supply system is inadequate nonetheless. “It can currently provide only about a third of the required volume of drinking water,” says Dr. Robert Kringel of BGR. Most of the population has to rely on groundwater, which is often polluted.

Difficult location

These problems with water result from the city’s location, but also from inadequate urban planning and a lack of investment, says Kringel: “Yaoundé was originally built on a watershed, at precisely the highest point between two large rivers. In terms of water supply, that’s a rather unfortunate choice of location.” Yaoundé is located about 250 kilometres from the Gulf of Guinea. The German colonial administration had founded the settlement in the late 19th century as a research station and base for its ivory trade. After the First World War, Yaoundé became the capital of French Cameroons. While both the city and

its population grew rapidly, urban planning was not able to keep the pace. “Infrastructure developments fell by the wayside. The water production and treatment systems and the sewerage system were never adequately expanded,” explains GIS expert Dr. Markus Toloczyki from BGR.

Cameroonian scientists have been carrying out regular water surveys since the late 1990s. Cameroon’s National Institute of Statistics (NIS) is now planning to set up a geographical information system (GIS) that will capture all important environmental data. The aim is to establish the use of digital thematic maps in environmental work. To this end, NIS launched a pilot project involving experts from BGR, the universities of Bonn and Yaoundé, and representatives from government agencies and ministries. The project is receiving funding from the German Federal Ministry for Economic Cooperation and Development.

Extensive data collection

In spring and summer 2012, the German-Cameroonian team of scientists collected the necessary data in several field campaigns. They took 54 groundwater samples and surveyed 1,136 households, asking detailed questions about their habits: what water did they use, how often did the supply fail, how did they dispose of wastewater and household rubbish, how often did diarrhoea and other diseases caused by polluted water occur. The scientists also tested 500 young children for malaria and anaemia.

groundwater pollution was particularly high. "Contamination with nitrogen and salt from urine and wastewater rapidly increases with the flow direction of the groundwater," says Kringel. The water drawn from – usually hand-dug – wells comes from a weathering layer that can be up to 20 metres thick. Given the lack of a central sewerage system, this upper aquifer is in some places highly contaminated due to seepage from latrines. Bacteria, viruses, nitrogen compounds such as ammonium and the harmful

in particular pollute the groundwater in Yaoundé. If suitable toilets were in place that permitted collection of the urine and separation of the nitrogen, the substance could be used as a safe fertiliser in urban small-scale farming – thus protecting the groundwater. The final expert report containing findings and clear recommendations for the decision-makers was presented to the Cameroonian stakeholders in mid-2013.



▲ The distribution of nitrate in the groundwater varies significantly across Yaoundé. Green circles show permitted levels; red circles mark places where the concentration exceeds the maximum contaminant level for drinking water of 50 mg/litre. The circle sizes give an additional indication of the level of pollution. The white symbols indicate the type of water supply, such as "spring" or pumping well ("forage").



▲ Modern and unplanned housing in the Yaoundé urban area.



▲ African and German scientists analysing groundwater samples in the field.

The data from the survey and other data collected were linked with location data and then analysed using thematic maps. This allowed the scientists to identify hotspots in individual parts of town where

substance nitrate, as well as large amounts of sodium chloride can enter the groundwater.

Fertiliser from the latrine

According to BGR scientist Robert Kringel, "the salt and nitrogen loads in groundwater from human activities can in extreme cases amount to 95 percent of the total dissolved solids." Large amounts of nitrogen

www.bgr.bund.de/cameroon-epess

Contact: **Dr. Robert Kringel**

SQR map: yield potential of soils in Germany

Germany scores 62 points

German soils have a high yield potential

BGR scientists have created a new map of the soil quality of agricultural land in Germany. This shows the most fertile soils to be in the loess landscapes of the Magdeburg Börde, the Thuringian Basin and the Cologne Lowland. Overall, German soils have a high cereal yield potential.

Germany's granary is a sickle-shaped area between Hanover, Magdeburg, Leipzig and Erfurt. The farmland in this central German region was found to have a particularly high yield potential. The



▲ The new soil quality map was prepared based on the so-called Müncheberger Soil Quality Rating (SQR).

tural land in Germany is shown on a new map, which BGR scientists presented to the public in November 2013. "This is the first up-to-date map of the soil quality of agricultural land, covering the whole of Germany," according to project managers Klaus Kruse and Dr. Volker Hennings. The new BGR map, which is provided free of charge, is based on an international rating method, the Müncheberger Soil Quality Rating (SQR). Dr. Lothar Müller of the Leibniz Centre for Agricultural Landscape Research (ZALF) and Dr. Volker Hennings from BGR adapted the method originally developed by ZALF for work with the BGR soil maps.

Scores for fertile soils

The method rates the suitability of soils for agricultural use. It is an assessment of their fertility – which experts refer to as "yield potential". The soil scientists have defined eight basic indicators for rating a site. Points are awarded, for

The soil quality of agricul-



Source: fotolia - Olympus

▲ Thirty-two percent, or roughly 11.9 million hectares, of Germany's surface area are used as cropland.

instance, for the size range of the soil components (the so-called soil texture) or the "effective rooting depth", i.e. the depth at which plant roots can extract water from the soil. Sites with only a thin layer of topsoil above solid bedrock have a low rooting depth, which may hinder crop growth.

Following a complex procedure, the scientists award points for the various basic indicators, which are then added up to a total score. They then rate additional factors that hinder crop growth, the hazard indicators: a low rooting depth, drought, acidification and a high percentage of coarse soil texture fragments. At the end, every site is awarded a total score between 0 and 102. A higher score indicates better soil quality.

Impact of climate factors

"Unlike previous soil rating methods, SQR also takes into account climate data," stresses Hennings. "This gives us a practical method for rating the suitability of soils for agricultural use."

Almost half of Germany's surface area is used as agricultural land, about 70 percent of that for crop cultivation. The overall rating for German soils is good, say the BGR scientists. According to the new BGR map, roughly one quarter of the land has a "high" or "very high" yield potential. The national average score for cropland is 62 of a possible 102 points. The most fertile land is particularly suitable for cereal cultivation. According to the project managers, "just over half the rated

areas are wholly unaffected by any of the four hazard indicators".

In addition to the Magdeburg Börde, the Cologne Lowland and the Thuringian Basin, but also parts of the foothills of the Alps, the Elbe and Weser floodplains, and some marshes on the North Sea coast were given above average ratings. Soils in the Central Uplands are less fertile. They often have a low rooting depth and contain coarse soil texture fragments. Some sandy soils in eastern Germany also have lower yield potentials, particularly in areas where there is a risk of drought in the summer. Cropland in the moorlands of Lower Saxony has the lowest yield potential. With scores of less than 35 points, these sites ranked at the lower end of the scale.

Contact: **Klaus Kruse**

Clean groundwater in the Lake Chad region

BGR project studies groundwater recharge in west-central Africa

In the region around Lake Chad and its tributaries, large volumes of water percolate into the ground – recharging the groundwater BGR has studied the quality and flow behaviour of the groundwater in this region.

A peculiar body of water lies at the southern edge of the Sahara Desert. Lake Chad, once one of Earth's largest endhoreic lakes, is only about three times the size of Lake Constance today. With its depth of only a few metres, the lake's shorelines can move by several kilometres from one year to the next, depending on the amount of inflow from its southern tributaries.

“Even in its shrunken state, the lake is of major importance for the region,” says BGR water expert Dr. Sara Vassolo. Because, as BGR findings show, large volumes of groundwater are recharged both around the Lake Chad itself and along its



▲ Growing lettuce on the river banks.

tributaries. During the wet seasons in the catchment area of Lake Chad's tributaries, the rivers' banks break, forming vast temporary wetlands. “These wetlands are one source of groundwater recharge in the upper aquifer,” says Vassolo.

Together with her colleagues, the BGR scientist has analysed the groundwater quality based on samples from 420 water wells in Chad and Cameroon. The team has also measured the volume of water that the Logone River carries during the dry and wet seasons, and used stable isotopes to trace the groundwater flow movements.

“In almost all parts of the Chad Basin that belong to the Republic of Chad, the groundwater is of a very high quality,” reports Vassolo. Since groundwater is the main source of drinking water for the rural population of Chad, she adds, the wetlands



▲ Trading on the river banks.



▲ Cattle breeding is crucial for the regional economy.

and especially Lake Chad need to be preserved to ensure the water supply.

www.bgr.bund.de/lcbbc

Contact: **Dr.-Ing. Sara Ines Vassolo**

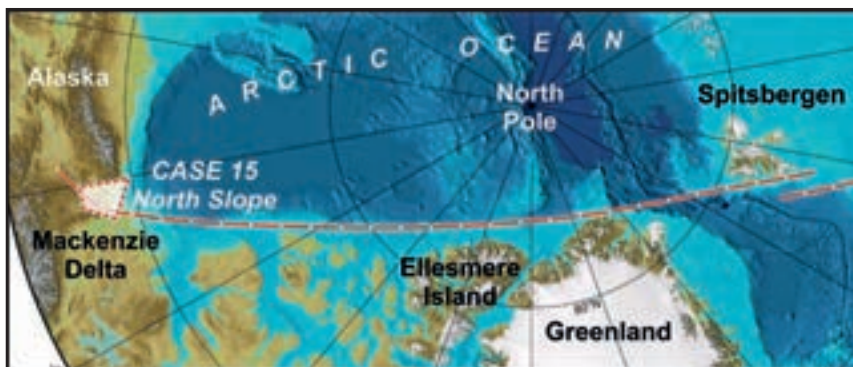
Exploration of Polar Regions

CASE: Circum-Arctic Structural Events

On the outer edges of Laurasia

Field work in the Arctic shows where the Earth's crust once moved

In northwest Canada, BGR geologists have found traces of an enormous fault zone – the edges of the ancient continental mass Laurasia. The zone may have played a part in the formation of the Arctic Ocean.



▲ The major fault system on the northern edge of the American continental plate extends over a distance of 2,500 kilometres from Spitsbergen (right) to the Mackenzie Delta and further towards Alaska.

Roaming herds of caribou, smouldering coal seams, and fossils of previously unknown tree species – the international team of scientists visiting the northern Yukon Territory in summer 2013 could

certainly not complain about a lack of variety. But the main aim of the CASE 15 expedition was to study a large fault system west of the Mackenzie Delta. These faults form the boundaries between the



▲ Tightly folded chalk sediments on the northern coast of North America, on the boundary between Alaska and the Mackenzie Delta

looking for evidence of the formation of the Arctic Ocean there.

For five weeks, they explored the geology of this vast, mosquito-infested tundra region by helicopter and aeroplane. They were able to show, for instance, that the history of the fault zones in the Mac-



▲ The Destor-Porcupine fault is several kilometres wide and probably forms the beginning of a fault zone across the entire Arctic, from North America to Spitsbergen.

remaining parts of the broken-up landmass of Laurasia and Eurasia. The scientists led by Dr. Karsten Piepjohn (BGR) and his Canadian colleague Dr. Maurice Colpron of the Yukon Geological Survey were

kenzie Delta is similar to that of faults on the Arctic islands Ellesmere Island and Spitsbergen. “They may well be part of a larger, 2,500 kilometres long fracture zone in the Earth’s crust that runs from Spitsbergen to the western coast of Alaska,” says Piepjohn. “That fault zone would be the largest geological structure found in the Arctic to date.”

Contact: **Dr. Karsten Piepjohn**

Geochemical north-south divide

Soil samples from across Europe show the distribution of trace elements in agricultural land

In the GEMAS project, 60 international organisations analysed the background levels of different metals in European soils. This was prompted by the EU Regulation REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals), which requires the metal industry to prevent contaminations. BGR participated in this huge project.

The last ice age divided Europe into two halves: while the north was buried by mighty glaciers, the south remained free of ice. As temperatures rose again, a completely reshaped, young landscape emerged from underneath the ice. Southern Europe, by contrast, was continually exposed to the forces of weathering.

To this day, the chemical composition of the soils reflects this division. The levels of many trace elements, such as arsenic, gold, manganese, lithium or nickel, are almost two to three times higher in the older and intensely weathered soils of Southern Europe than in Northern Europe. A large natural variation range is also found for other metals.

Harmonised information on a European scale

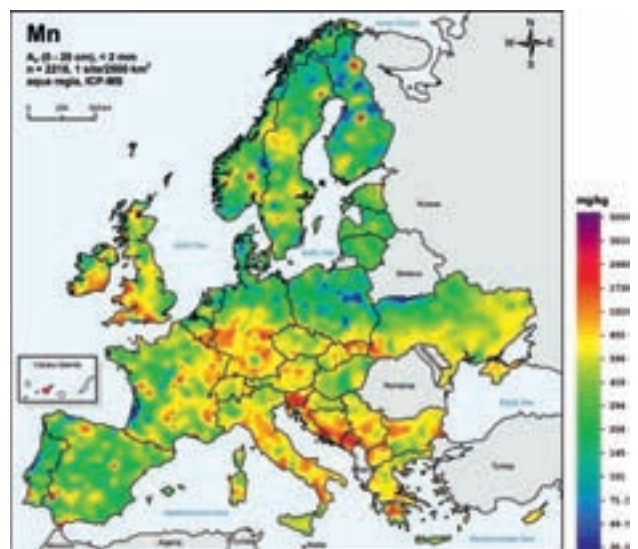
The GEMAS (Geochemical Mapping of Agricultural and Grazing Land Soil) project was a collaboration between the Geochemistry expert group of the European Geological Surveys (EuroGeoSurveys) and Eurometaux, the European Metal Industry Association. The purpose of GEMAS was to provide harmonised data for geochemical background levels at the continental (European) scale. The participating scientists also ana-

lysed soil properties, which determine the bioavailability and toxicity of the metals.

GEMAS was truly a huge project: a total of 60 international partners were involved, including a BGR team headed by Dr. Manfred Birke. In 2008 and 2009, geochemists took to the fields in 33 European countries, taking more than 4,000 samples from cropland and grazing land between Norway and Sicily. “Our aim was to compile harmonised data sets that would be directly comparable,” says Birke.

One atlas for more than 50 elements

In all samples from agricultural land and grazing land – each representing 2,500 square kilometres on average – the levels of more than 50 metals were



▲ Distribution of manganese concentrations (AR, ICP-MS) in European agricultural soil.

determined, in some cases using several analytical methods. The Slovak Geological Survey prepared all samples. The subsequent analyses were all carried out in a single laboratory.

The data formed the basis for dossiers that the European metal industry had to prepare for the EU Commission. At the end of 2013, the GEMAS Atlas was complete. "This is the first quality-assured set of geochemical data for European agricultural and grazing land," says the project manager. The atlas also shows the bioavailability of different metals across Europe. This allows a realistic risk assessment as required under REACH, according to Birke.

Wide natural variation

The element zirconium held a sur-

prise for the scientists, as it was found to be very common in parts of Central and Eastern Europe. This would indicate that loess soils there are spread over larger areas than previously thought.

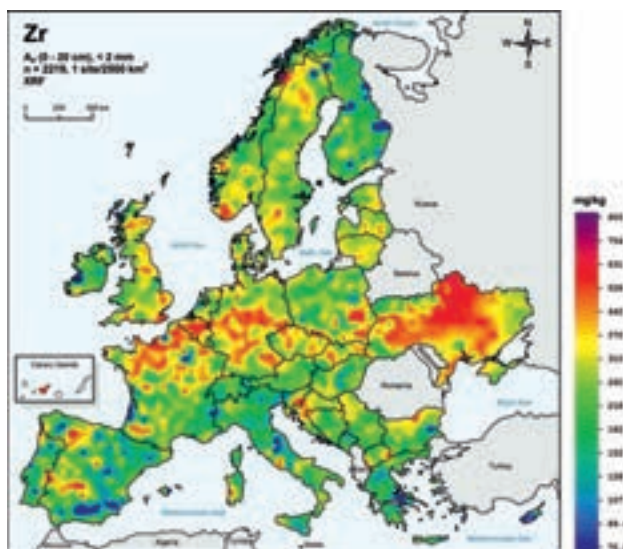
The spatial patterns of element distribution were largely identical in samples from both agricultural and grazing land. However, the median values within some countries differ by a factor of up to 100. "Given the geochemical difference between Northern and Southern Europe, it is impossible to define uniform soil background levels that would apply to the whole of Europe," stresses Birke.

The geochemical maps strongly reflect the impact of geology and climate. For instance, unusually

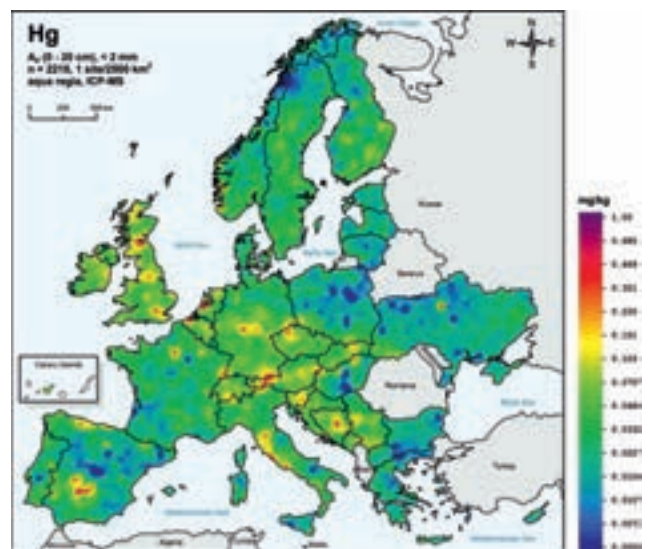
high levels of metals often occur in areas near known ore deposits and mining areas. And around the conurbations of London, Paris, Rotterdam and Kiev soils were found to have higher levels of heavy metals such as lead, mercury, gold and silver. Beyond that, the maps show little evidence of pollution from human activities. "We would need a far higher sampling density to reliably detect anthropogenic impacts," says Birke. Only in a small number of samples did the scientists discover critical metal concentrations.

www.bgr.bund.de/GEMAS-Projekt_en

Contact: **Dr. Manfred Birke**



▲ Distribution of zirconium concentrations (XRF) in European agricultural soil.



▲ Distribution of mercury concentrations (AR, ICP-MS) in European agricultural soil.

From Braunerde to Cambisol

BGR software converts German soil classification to international system

When soil scientists from different countries share information, they refer to soils as classified under the internationally used World Reference Base for Soil Resources. However, Germany also has its own soil classification system. BGR soil scientists have now developed a software application that automatically recategorises soil profiles from German databases according to the international classification system.

Soil science with its complex technical terminology is a complete mystery to the uninitiated. What could terms such as Chernozem, rendzina-like soil or Kolluvisol possibly mean? But even soil scientists from different countries sometimes find it hard to communicate. The German term “Tschernosem” – which refers to fertile, humus-rich black earth – is not necessarily equivalent to the international label “Chernozem”.

This is because every country uses a different soil classification system. In Germany, BGR in collaboration with the individual states’ geological surveys publishes instructions on the mapping and classification of soils, the “Bodenkundliche Kartieranleitung”. The fifth edition was pub-

lished in 2005. A different system is used internationally, the World Reference Base for Soil Resources (WRB) of the International Union of Soil Sciences (IUSS).

Internationally harmonised soil data

“With such an international classification system soil information from different countries can be shared, for instance, in a European context,” explains BGR soil expert Dr. Einar Eberhardt. In recent years, the international reference base has increasingly gained in importance, and has found practical application even outside academic circles.

But the WRB approach and structure differ considerably from the

German soil classification system. “You can’t simply assign German soil types to the international reference soils,” says Eberhardt. This is because, in some cases, the German system offers far more options for differentiation.

Initially, the soil formation processes and the source materials are recorded separately. “The WRB, by contrast, links soil genesis and material composition from the start,” says Eberhardt. This system features 32 reference soil groups, ranging from A for “Acrisol” (a red, acidic tropical soil) to V for “Vertisol” (dark



▲ According to the German classification system, this is a sulphur-rich Organomarsch soil. Within seconds, it is recategorised as a Haplic Gleysol in the international system.

soils with a very high clay content). At a second level, the soil types are differentiated based on additional properties, using so-called qualifiers.

Automatic categorisation

To permit better use of existing soil data from Germany in an international context, a team led by Einar Eberhardt has now developed what could be called a conversion wizard. This software automatically derives WRB labels based on data from soil databases. The team of scientists, including partners from several universities, tested their derivation key on a set of data from the Brandenburg State Authority for Mining, Energy and Geology comprising 263 soil profiles.

The test was a success: “More than 90 percent of the profiles were categorised in the correct reference soil



▲ From mapping instructions to international soil classification in the World Reference Base for Soil Resources.



▲ The database application provides menu navigation for the entire derivation process.

group,” says Eberhardt. The profiles that were incorrectly categorised had important information missing. During their work, Eberhardt and his colleagues also discovered some gaps, logical inadequacies and slight inaccuracies in the WRB system. Their

recommendations for improvement have been included in the new edition of the WRB, which has been published in 2014.

Another side effect of the work was this: the team discovered that some

soil profiles with very complex soil horizon boundary structures were described in a number of different ways. “Until now, there were no clear rules for the description of such boundaries,” says Eberhardt. The BGR scientists therefore proposed new rules for distinguishing horizons, to be included in the revised versions of the German and international mapping instructions. There are plans to apply the derivation key to data from other German regions in 2014. The software also needs updating, to be compliant with the new 2014 version of WRB.

Contact: **Dr. Einar Eberhardt**

New discoveries beneath the seabed

BGR coordinates German contribution to international ocean drilling programme

Since 2013, there has been a new scheme to explore the seabed, the International Ocean Discovery Program (IODP). Its focuses are different to those of its predecessor schemes. BGR has taken on the coordination of activities in Germany.

The abbreviation is still the same, and so, too, is the essential content: like its predecessor, the Integrated Ocean Drilling Program (IODP), the International Ocean Discovery Program (also IODP) is dedicated to exploring the seabed in drilling expeditions.



▲ Japanese IODP drilling vessel Chikyu.

Between 2013 and 2023, scientists from 26 nations will continue in their efforts to gain a better understanding of the interactions between the Earth's hard crust and its plastic interior, the sea, the polar caps, the atmosphere, the Earth's magnetic field and the living environment.

The deep biosphere and tsunamis

The new programme's research plan focuses are different to those of its predecessor scheme. Future drilling projects will investigate primarily climate change, extreme habitats, geochemical exchange processes and natural disasters such as earthquakes.

BGR is coordinating German interests on the programme's international panels and in the European Consortium for Ocean Research Drilling



▲ Sampling of a core during IODP expedition 347 – Baltic Sea. During sampling for geomicrobial tests at BGR, the scientists on board Greatship Manisha wear surgical masks and gloves to prevent contamination.

(ECORD), an association of 17 European countries, Canada and Israel. The coordinator, Dr. Jochen Erbacher, and his team have many important responsibilities: they notify the German programme participants of any news, such as calls for proposals, workshops or summer schools. In addition, they advise them on the planning of expeditions and together with co-coordinator Prof. Dr. Rüdiger Stein of Alfred Wegener Institute for Polar and Marine Research in Bremerhaven prepare decisions for the German Research Foundation (DFG).

Support for DFG

“As the spokesperson and coordinator, I am supporting the German Research Foundation, who provides priority programme funding for IODP,” says Erbacher. He also manages the coordination fund, which provides scientists with the financial means to participate in expeditions and attend conferences or workshops.

www.iodp.org/

Contact: **Dr. Jochen Erbacher**

An end to licensing confusion

New model regulates access to public geodata

The GeoLizenz.org web portal offers standard web-click licence agreements for businesses. This nationwide service by the Federal Ministry for Economic Affairs and Energy greatly simplifies the licensing of geodata.

Three words describe access to public geodata as businesses would like it to be: fast, simple and free. “Geodata are a major resource in our digital age,” says Dr. Jörg Reichling, head of the German GeoBusiness Commission (GGC) office at BGR.

Licences play an important role in data use, even though they are often available free of charge. “What businesses are mainly concerned with is certainty,” says BGR expert Lars Behrens. “Commercial use requires a reliable framework.”

A flexible tool for all sectors

But currently, there are thousands of licences for geodata, at the national, state and local levels. For businesses, it requires an enormous effort to find their way through this maze. Now this uncertainty has come to an end. On the German-language website www.GeoLizenz.org the GGC office has been providing a standard licensing model since autumn 2013. This comprises only eight licence types that cover all possible combinations of types of use and target groups. Any public authority in Germany



▲ The GeoLizenz.org web portal is a joint project by the Federal Ministry for Economic Affairs and Energy and the GeoBusiness Commission at BGR.

can quickly and easily assign a web-click licence to its geodata products. The licence agreement is sent to the commercial user via e-mail. “This makes licensing far less time-consuming for both providers and users,” says Reichling.

For the start of CeBIT 2014 in Hannover, an e-payment feature was added to the GeoLizenz.org site – so the licensing and billing of pay-for products will in future be equally fast and simple.



Source: fotolia

▲ For German businesses, getting a licence via GeoLizenz.org takes little more than a virtual handshake.

 www.geolizenz.org/modules/clip/?language=en_EN

Contact: **Dr. Jörg Reichling**

Completed after more than 50 years

International Hydrogeological Map of Europe is complete

The groundwater situation of an entire continent can now be viewed on the 25 sheets of the International Hydrogeological Map of Europe at a scale of 1 : 1.5 million. In 2013, the last two missing sheets "Budapest" and "Bucureşti" were published. BGR and UNESCO have joint responsibility for this project.

Europe is a continent of many colours. On the International Hydrogeological Map of Europe IHME 1500, three colours dominate the picture: blue, green and brown. Groundwater reservoirs in porous sediments such as sand and gravel are shown in blue, groundwater reservoirs in fissured hard rock such as limestone in

green, and areas with little groundwater in brown.

Where the water flows

This consistent hydrogeological map of the entire continent is the result of more than 50 years' work. Although most European countries already had hydrogeological maps in 1960,

each nation's experts used different colours, symbols and scales to represent the flow paths of groundwater. "With these differences international comparisons were very hard to make," says Klaus Duscher

of BGR. The International Association of Hydrogeologists (IAH) therefore decided in 1960 to develop a consistent map series.

In the first few years, the participating scientists had to agree on many details: What scale should be used? What should the legend look like? What method should be used to compile the data? They eventually agreed on a scale of 1 : 1.5 million. One centimetre on the map is thus equivalent to 15 kilometres in real life – enough to include details such as salt domes, large-scale groundwater drawdown or drainage channels, but too large to show the whole of Europe on a single map. A decision was therefore made to create 25 individual sheets, each measuring 92 by 69 centimetres.

From Lisboa to Kirov

Each sheet bears the name of a major city, for instance, London, Oslo or Moskva. While there was initially no suitable international model for the legend, the working group had developed a proposal by 1963. The project was conducted under the auspices of UNESCO, the United Nations Educational, Scientific and Cultural Organization. In the preparation of the first sheet "Bern" several different versions of the legend were tested. As the work progressed, these were fine-tuned into



▲ Simplified overview of the printed IHME map sheets.



▲ Detail from IHME sheet C4, Berlin.

the representation method used today. The sheet was finally completed in 1970.

Right from the start, BGR and UNESCO took on the funding and coordination of the scientific and editorial work. Both organisations are also responsible for the cartogra-

phy, printing and marketing of both the map sheets and the explanatory notes.

Over the following decades, more than 300 scientists from 40 nations collaborated to complete the map series. Explanatory notes as supplements to the maps were also published. They contain additional information, such as on the climate, the chemical composition of the groundwater, or on geology. With the publication of the last two sheets "Budapest" and "București", the printed map series was finally completed in 2013.

Next step: digital maps

"The IHME gives the first consistent overview of European groundwater resources," stresses BGR expert Klaus Duscher. The map provides information on the rock types that

form aquifers in a particular region and how productive these aquifers are. It also shows details such as geological faults, springs, boreholes or regions with groundwater affected by seawater intrusion. Groundwater experts can refer to the maps for research issues and international planning, or as a basis for detailed hydrogeological mapping.

But although the last sheets are now finished, the work is far from complete. In a next step, the existing data will be digitised and integrated in a geographic information system. Some digital maps are already available. They are a welcome tool for hydrogeologists, says Klaus Duscher: "With digitisation, there are new options for analysis at the continental level."



▲ Participants of the International Workshop on Groundwater Systems in Europe, held in Berlin to mark the completion of the printed IHME map sheets.

www.bgr.bund.de/IHME1500

Contact: **Klaus Duscher**

Under the sign of the giraffe

BGR coordinates African geoscience information network

Since 2009, African geoscientists have been meeting regularly to share their experience. The mission of the GIRAF network is to help improve living conditions in Africa – and to include the continent in international projects.



So far, the range of GIRAF activities is limited: a newsletter is published once or twice a year; the website provides up-to-date geoinformation for Africa; and every two years, GIRAF members meet at an international workshop. But the network is growing fast: “GIRAF currently has 337 members from 37 African



Source: M. Toloczki

▲ Gold panning in Ghana.



Source: M. Toloczki

▲ Digital mapping in the field.

countries and 15 non-African states,” reports BGR scientist and GIRAF network coordinator Dr. Kristine Asch. The network brings together geoscientists from geological surveys, universities, research institutes and private businesses, to share information. “Geoscience information can contribute significantly to improving the living conditions of people in Africa,” stresses Kristine Asch. The network is receiving international support from UNESCO, the Commission for the Management and Application of Geoscience Information in Africa, which have to date been rather fragmented. The network aims to forge closer links between geoscientists and geoscience initiatives in Africa, which have to date been rather fragmented. The network is receiving international support from UNESCO, the Commission for the Management and Application of Geoscience Information in Africa, which have to date been rather fragmented. The network aims to forge closer links between geoscientists and geoscience initiatives in Africa, which have to date been rather fragmented. The network aims to forge closer links between geoscientists and geoscience initiatives in Africa, which have to date been rather fragmented.



Source: J. Harbrecht

▲ Small-scale mining for gold in Africa.

mission for the Geological Map of the World. BGR considers major benefits of GIRAF to be, firstly, the linking of bilateral projects funded as part of the German federal government's development cooperation on the African continent and secondly, it will improve the chances to initiate new projects.

Recommendations for small-scale mining

The network's third workshop was co-organised by BGR and the Australian International Mining for Development Centre. It was held in September 2013 in Accra, the capital of Ghana, to mark the 100th anniversary of the foundation of the country's Geological Survey Department, who also hosted the event. In line with its theme "Geo-information, Sustainable Mining and



Source: K. Asch

▲ Participants of the 2013 GIRAF workshop in Dar es Salaam, Tanzania, pictured with the Deputy Head of the German embassy, Thomas Wimmer (centre).

Mapping", the workshop addressed in particular sustainable mining, small-scale mining, geological mapping techniques and regional development. Around 120 participants discussed different African geoscience projects, reported on progress made since the first two workshops, and engaged in information sharing across political borders.

At the end, a working group was formed who is aiming to develop rec-

ommendations on the social compliance and sustainability of small-scale mining in Africa. Another aim is for 14 GIRAF ambassadors to set up national groups – GIRAF Embassies – in their home countries and initiate activities to encourage further growth of the network. The next GIRAF workshop will be held in Mozambique in 2015.

www.giraf-network.org

Contact: **Dr. Kristine Asch**

D-AERO: Airborne mapping of clay deposits

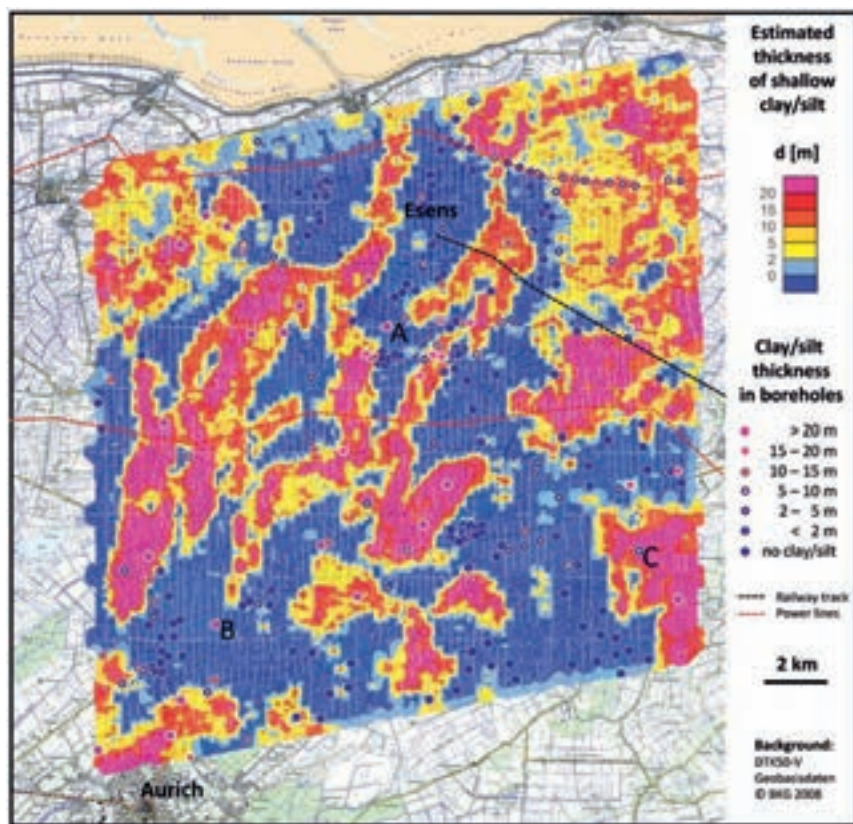
East Frisia under investigation from above

BGR scientists map clay deposits in Esens survey area

As part of the D-AERO project, BGR is relying on airborne geophysical methods to investigate groundwater salinisation and clay deposits on the North Sea coast. The analysis results are now available for a survey area in East Frisia. The results of the helicopter-borne electromagnetics survey largely correspond with the data from the boreholes.

During the ice ages of the past 400,000 years, East Frisia was covered by sediments with an average thickness of 30 to 60 metres and consisting mainly of clay and sand. The glaciers from an early glacial period

cut valleys into the ground, in which meltwater lakes formed later. On the bed of these lakes, fine-grained silt and clay was deposited. During the last ice age, the prevailing westerly winds blew large amounts of sand over and piled it up to form dunes. When temperatures rose, around 10,000 years ago, moorland and marshland formed in many places, covering the ice-age sediments with only a thin layer.



▲ Comparison of clay/silt thicknesses derived from airborne electromagnetic results and found in the boreholes.

Legacy of the ice age

A BGR team led by Dr. Bernhard Siemon has now revealed the distribution of the glacial clay deposits. “The findings relating to these clay deposits are important for groundwater protection,” explains the geophysicist. Salty groundwater from the North Sea is moving inland everywhere. Where and how far the salt water can spread depends also on where groundwater is extracted

and where wetlands are drained. “It is easier to assess the impact of such interventions on fresh water reservoirs when you know where sand aquifers and impermeable clays are located in the subsurface,” says Siemon. The construction industry is also interested in the location of fine-grained silts, because they are an ideal material for making bricks.

As part of the D-AERO project, BGR and the Leibniz Institute for Applied Geophysics (LIAG) together carried out an airborne survey of the Esens area in East Frisia between 2008 and 2009. This lozenge-shaped survey area whose sides are 19 kilometres long extends from about Aurich and Dornum in the West to Wittmund and Werdum in the East. The BGR helicopter completed a total of 23 survey flights, covering a distance of 1,950 kilometres along 75 north-south profiles and eight east-west tie lines.

The problem with groundwater salinisation

The BGR helicopter system simultaneously used three different geophysical methods to survey the subsurface: electromagnetics, magnetics and gamma-ray spectrometry. As a result, the scientists obtained the electrical resistivity at different depths. These values indicate whether salt water with a high con-



▲ BGR helicopter surveying East Frisia.

ductivity or fresh water with a lower conductivity can be at the individual depths. Clay and sand can also be distinguished based on their resistivities.

The scientists have now evaluated the data. They determined, for instance, the resistivities at a depth of 10 metres and compared these values with data from the boreholes. The borehole database of Lower Saxony lists the thickness of the clay at more than 100 sites in the survey area. “There is an obvious good correlation between low resistivities and boreholes where clay or silt was found,” says Bernhard Siemon. By contrast, boreholes with little clay or silt were normally located in areas with higher resistivities.

A glance beneath the top layer

Based on the resistivities, Siemon and his colleagues in collaboration with Lower Saxony’s State Authority for Mining, Energy and Geology (LBEG) created a map that shows the thickness of the clay layers in the survey area down to a depth of about 30 metres. “Correspondence with the boreholes in most cases is good,” says the geophysicist. “You could say that the airborne electromagnetic system allows us a glance beneath the thin top layer,” he adds. “The findings from this airborne geophysical survey of a large area are an ideal complement to data from sparsely distributed boreholes.” The BGR helicopter, which was unavailable for service between 2010 and 2012 as it was having additional equipment fitted, continued the survey in the neighbouring Jever region in May 2014.

http://www.bgr.bund.de/aerogeophysik_en

Contact: **Dr. Bernhard Siemon,**
Dr. Uwe Meyer

Use of geoinformation across borders

EU Directive INSPIRE now being implemented

The INSPIRE Directive specifies the aim of creating a European Union spatial data infrastructure by 2019. BGR scientists were involved in defining the standards right from the start. Now their expertise is needed for the implementation. In workshops, they provide information to other users about the requirements.

Both public and private organisations use geoinformation in their everyday work. A city council, for instance, has to designate areas for new business park developments. A geothermal energy company is looking for sites where they can drill wells. Or a state authority needs to manage flood control measures along a river.

“Eighty percent of decisions made in the public administrations and in industry are made based on spatial information,” says Tanja Wodtke, head of the Geodata Management unit at BGR. Where a project concerns several municipalities, German states or even EU member states, data retrieval soon becomes difficult. Users have to deal with different formats, definitions and ratings, and data are often not compatible. “That results in more work and thus higher costs,” says Wodtke.

Standard requirements

Adopted in 2007, the EU Directive INSPIRE aims to solve this problem at EU level.



The objective is to create a geoportal that will facilitate access to environmental geodata in the 27 EU member states by 2019. This infrastructure will enable joint use of geodata from different sources.

All bodies within Europe that keep geodata are required to prepare and share their data in the same way. There are rules on data storage and preparation, and rules on so-called metadata, which describe the data, making them available for further applications. Another major component of the future geoportal are applications such as search and display features. In December 2013, the last rules for implementation of the directive were adopted; the next step is implementation.

Involved right from the start

BGR experts were involved early on in the work of the EU bodies that defined the standards. They contributed, for instance, changes to drafts, were involved in the review process, and represented Germany in the working groups on soil and geology. “This has helped to integrate Ger-

man expert knowledge of geology and soils into the INSPIRE process," stresses geology representative Dr. Kristine Asch, head of the BGR Geological Information unit.

National and international bodies have already benefited from this expert knowledge. In February 2013, for instance, BGR organised a workshop for the state geological surveys of the German states. The event was attended by 70 participants, who were able to find out more about the tasks involved in the INSPIRE process.

Information about implementation

Another INSPIRE workshop was held in November 2013, hosted by the Federal and Regional-State Soil Conservation Board of the Envi-

ronmental Ministers' Conference (LABO) in Frankfurt am Main. The target group were the soil conservation authorities in the federal states. At this event, BGR presented information on two topics: firstly, on data specifications that are relevant to soil conservation; and secondly, on the availability of digital soil information throughout Europe.

Experiences with INSPIRE are also of interest to international partners. The 2013 annual meeting of BGR scientists with colleagues from the China Geological Survey focused on the topic of geoinformation. Two BGR experts introduced around 30 Chinese colleagues to the subject INSPIRE. They gave an overview of the political structures in Europe and Germany, outlined the development

of INSPIRE, and explained how INSPIRE requirements would be implemented in Germany, the German states, and at BGR.

BGR has been collecting data on different geoscientific topics for decades as well as analysing and presenting them, for instance, in the form of maps. BGR is on schedule in the INSPIRE process: it is already providing INSPIRE-compliant download services online. INSPIRE-compliant viewing and metadata services are at the final coordination stage.

Contact: **Tanja Wodtke,**
Dr. Kristine Asch

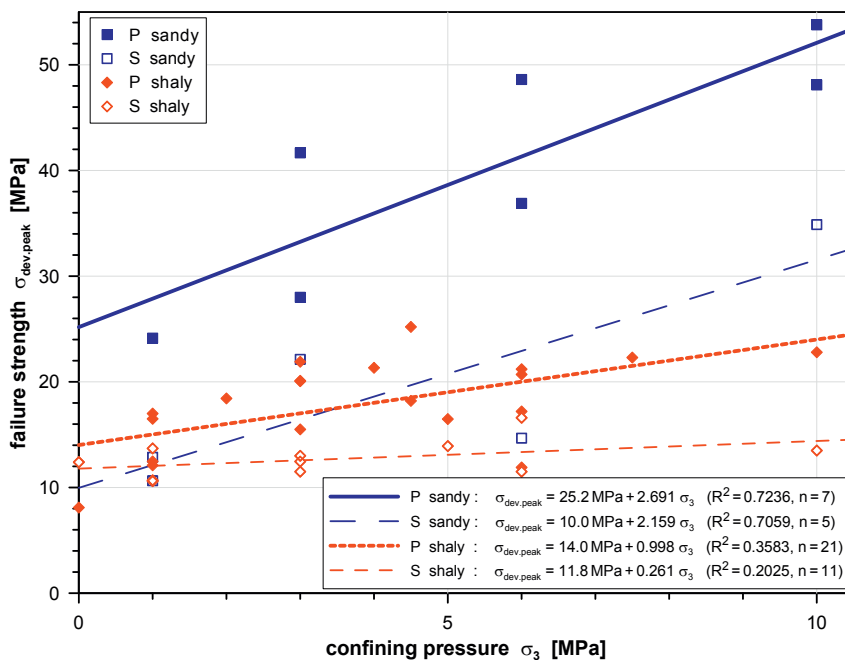


▲ BGR representatives Tanja Wodtke (front row, second from left) and Dr. Kristine Asch (front row, second from right) with colleagues from the China Geological Survey during the INSPIRE workshop in the Chinese city of Xi'an.

The impact of microstructure

BGR scientists analyse clay stone in the geomechanical laboratory

In Germany, salt was long regarded the best possible host rock for the final disposal of high-level radioactive waste. Now clay stone is being considered as an alternative. However, clay stones have a far more complex structure than salt and knowledge of their mechanical properties is still incomplete. That is why BGR scientists are currently studying the microstructure of clay stones in the laboratory.



▲ Opalinus Clay displays different levels of breaking strength depending on the facies (sandy or shaly) and the loading direction (P = parallel, S = normal to the bedding plane). These levels also rise with an increase in the supporting confining pressure ("triaxial strength").

In the eyes of repository research experts, salt as a host rock for the final disposal of radioactive waste has both advantages and disadvantages. Dr. Annette Kaufhold of BGR explains: "It is extremely water-impermeable and has outstanding thermal conduc-

tivity – but it is also water-soluble." Clay stone, on the other hand, does not dissolve when it comes into contact with water. It even expands when it becomes moist and existing fissures may close again as a result. A disadvantage of clay stone is that it dissi-

pates the heat which develops during the storage of high-level radioactive waste far less effectively than salt.

New questions

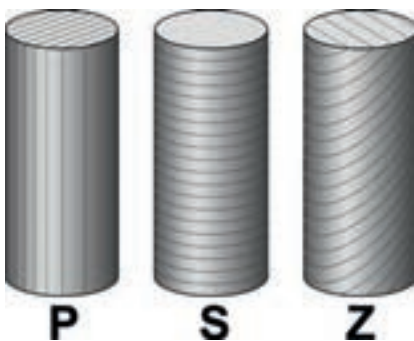
To date, BGR scientists engaged in repository research have mostly focused on salt in their laboratory tests to establish whether it would be a suitable host rock for radioactive waste. But in July 2013, the Repository Site Selection Act entered into force. In this law, the German federal government has embodied its decision to consider also clay stone and crystalline rock as possible host rocks. "But we know far less about the mechanical properties of clay stones than about the properties of salt," says Dr. Werner Gräsle.

He and his BGR colleagues are therefore now facing a number of new questions: What deformation of clay stone takes place when the stress state in the rock changes? How permeable are different clay stones and in what way do their elastic properties differ?

How does the pressure in the tiny pores rise when mechanical loads act on moist clay? “We need to find answers to these questions to assess the strength of a repository layout and judge long-term safety,” stresses Gräsle.

Focusing on clay

Currently, the BGR team are therefore focusing on clay material. BGR has been a partner in the international Mont Terri research project since 1997. At the Swiss underground



▲ Specimens with different orientations: P=parallel to the bedding plane; S=normal to the bedding plane and Z=45° to the bedding plane.

research lab of the same name, the properties of so-called Opalinus Clay are studied. This clay formation dates from the Jurassic period and can be found in the subsurface in parts of Southern Germany and Switzerland. Switzerland is considering it as a possible repository formation. At the French underground research lab in Bure, BGR scientists are also involved in research work on clay stones dating

from slightly younger strata of the Jurassic period.

With clay, unlike with salt, the so-called microstructure is important, i.e. the arrangement of the microscopic mineral particles. Clay stones consist of many different minerals, including grains of sand and limestone, but their most important constituents are platelet-shaped clay minerals. “Their mechanical properties depend both on the composition and on the arrangement of the mineral particles,” explains Annette Kaufhold.

The role of carbonates

In their experiments, BGR scientists compared the mechanical strength of different types of clay stones from Bure and Mont Terri. They discovered that carbonates are crucial for strength. “Minerals such as calcite can either strengthen a material or increase its tendency to fracture,” says Kaufhold. The scientists analysed the microstructure of the samples, using, among other methods, a scanning electron microscope and a CT scanner. They found that carbonates can have a stabilising effect when they are finely distributed in the matrix. Coarse-grained carbonates such as shell fragments, on the other hand, have a destabilising effect.

Challenges in the laboratory

Clay stones present a new challenge



▲ Storage of samples in so-called liners (pressure vessels) in a nitrogen atmosphere.

for BGR’s petrophysical laboratory, since they have a far more complex structure than salt rock. “Unlike with rock salt, it will probably not be possible to deduce the mechanical behaviour from few, well-understood physical mechanisms in the near future,” regrets Werner Gräsle.

Since clay stones are expansive, their mechanical and hydraulic properties cannot be studied separately. BGR scientists can therefore not simply carry out the same tests as on salt rock. They have to develop more refined testing methods and devices to understand this system of mineral matrix, pore water and pore air. In future, they are planning to investigate the complex issue of the mechanical and hydraulic behaviour of clay under different moisture conditions.

Contact: **Dr. Annette Kaufhold,**
Dr. Werner Gräsle

Sediment mobility caused by CO₂?

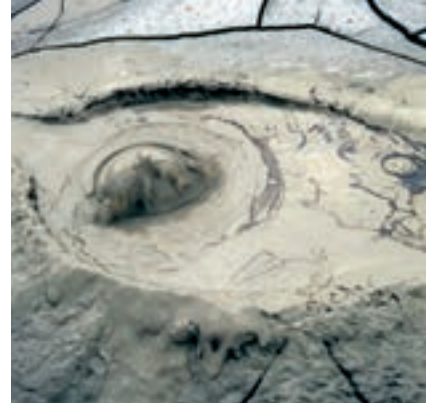
BGR scientists looking for potential leakage paths

Unconsolidated rocks in the subsurface could jeopardise the safety of CO₂ storage sites, when they are mobilised. A BGR project is investigating the processes of sediment mobilisation.

Mud volcanoes are fascinating natural phenomena. Normally, they form small craters that exude a dirty grey sludge. They bear no relation to real volcanoes. A mixture of gases, liquids and sediment bubbles in their craters. Mud volcanoes are formed in regions where young unconsolidated rocks saturated with water and gas, for instance, sand or clay, can be found in the subsurface.

the surface, a mud volcano is formed. On the seabed, funnel-shaped craters form where the mixture exudes, called pockmarks.

Sediment mobilisation is widespread, also in the North Sea. Subsurface features formed by sediment mobilisation processes could be a safety hazard for potential CO₂ storage below the seabed. That is why BGR scientists led by



▲ Formation water, clay and hydrocarbons exude from a mud volcano in the north of New Zealand.

Dr. Franz May are investigating in a new research project under what conditions sediments could be mobilised through the injection of CO₂ into the deep subsurface. In collaboration with Jena University, laboratory tests are carried out to understand and quantify critical conditions of sediment mobilisation.

Contact: **Dr. Franz May**

Because of the pressure from overlying rock strata, these sediments are sometimes forced upwards. When the mixture of water, gas and fine-grained sediments reaches



▲ Clastic dyke in shale on the east coast of New Zealand.



▲ Utsira Sand. The world's first CO₂ storage site is in the Norwegian sector of the North Sea, where CO₂ has been injected into unconsolidated sand since 1996.

Geology across borders

The GEOPOLD project studies geological formations in Germany and Poland

A vast sedimentary basin extends from the North Sea to Poland. Over more than 200 million years, from the Permian to the present, layers of sediment several thousand metres thick were deposited here; particularly clastic sediments such as sand, silt and clay stones, carbonates and salts.

Today, this basin, the Central European Basin, extends across the borders of several countries: the Netherlands, Denmark, Germany and Poland. The sedimentary rocks located in its subsurface are increasingly gaining in importance, for instance, as potential storage or repository sites for gases, liquids and solids.

German-Polish collaboration

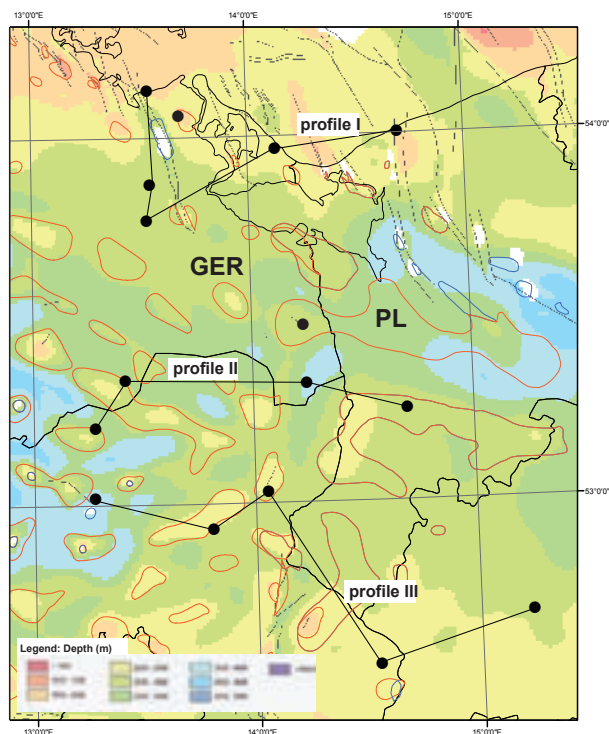
As part of the German-Polish GEOPOLD project, BGR scientists together with colleagues from the Polish Geological Institute and the state geological surveys of the states of Mecklenburg-Western Pomerania, Brandenburg and Saxony are developing a 3D geological model that will capture potential storage and barrier rock formations across national borders.

Porous sandstones and porous or fractured carbonate rock in particular could be potentially used for storage,

provided it is overlain by dense salt rock or clay stone. Experts use the

correlating the individual strata on both sides of the national borders, i.e.

determining which rock formations have the same age and under what conditions they were deposited. Because major properties of the storage rock – such as porosity or permeability – depend on the regional geological setting and the development over time, such as the conditions prevalent when the sediments were deposited or the burial depth of the rock.



▲ The working area with today's depth of the base Triassic, showing the boreholes used in the GEOPOLD project on the German and Polish sides. The three correlation profiles analysed in the project describe, for instance, where rock formations of the same age are located.

term “sequestration system” to refer to the storage rock and the associated barrier rock.

Correlation of sequestration systems

The scientists have defined seven sequestration systems from different geological time intervals. They are now

Germany and Poland regarding deposits from the Jurassic period,” reports Dr. Gesa Kuhlmann of BGR. The 3D model the scientists are working on is a prerequisite for further dynamic reservoir modelling.

Contact: **Dr. Gesa Kuhlmann**

The chemistry of associated incidental substances

How pure does a carbon dioxide stream have to be for geological storage?

CO₂ that is removed from the flue gases of power stations or industrial plants still contains other substances. In the COORAL collaborative research project, BGR is studying the impact of these associated incidental substances on geochemical reactions in the deep subsurface.

When carbon dioxide (CO₂) captured from power stations or industrial plants is stored in deep rock strata, it may react with the formation water and the surrounding rock. Storage of the greenhouse gas CO₂ in deep rock formations is part of so-called CCS (carbon capture and storage) technology. This involves separating CO₂ from flue gases and permanently storing it in porous rock strata at depths of more than 800 metres to prevent it being re-

leased into the atmosphere. “The separated carbon dioxide streams have different compositions, depending on where they originate from and what capture technology was used,” says Dr. Heike Rütters of BGR. “But we don’t know enough yet about how rock in the deep subsurface changes under the impact of incidental associated substances, so we can’t yet make reliable forecasts about long-term geochemical processes,” she adds.

The impact of associated incidental substances

When CO₂ dissolves in formation water, it may react with the surrounding rock: carbonates may dissolve and feldspars may be converted into quartz, clay minerals or carbonates. Quartz, by contrast, hardly reacts with the aqueous solution containing CO₂. It is unclear if the associated incidental substances in the separated carbon dioxide stream – such as oxygen, nitrogen oxides, hydrogen



▲ Siderite and ankerite grains (size: 100 – 200 µm) change under the impact of CO₂ and oxygen (left: source material, right: reaction product).

sulfide or carbon monoxide – affect the geochemical reactions significantly. “CO₂ streams separated by oxy-fuel combustion contain oxidising and acidifying substances, for instance, sulphur oxides, nitrogen oxides or oxygen,” explains Rütters. By contrast, CO₂ streams produced by the so-called pre-combustion technology contain reducing compounds such as hydrogen sulphide, ammonia, carbon monoxide or hydrogen.

A BGR team has now studied the possible impacts of such incidental associated substances on the behaviour of carbon dioxide in the subsurface as part of the collaborative research project COORAL (CO₂ Purity for Capture and Storage), which ended in autumn 2013. The investigations were motivated by the question of how high the levels of different associated incidental substances in the carbon dioxide stream can be without jeopardising geological storage safety.

Experiments in gold-titanium reactors

The scientists based their investigations on different generic scenarios: The carbon dioxide stream is separated from a coal-fired power station and transported via a pipeline either to a saline aquifer in Rotliegend sandstone at a depth of 3,000 metres,

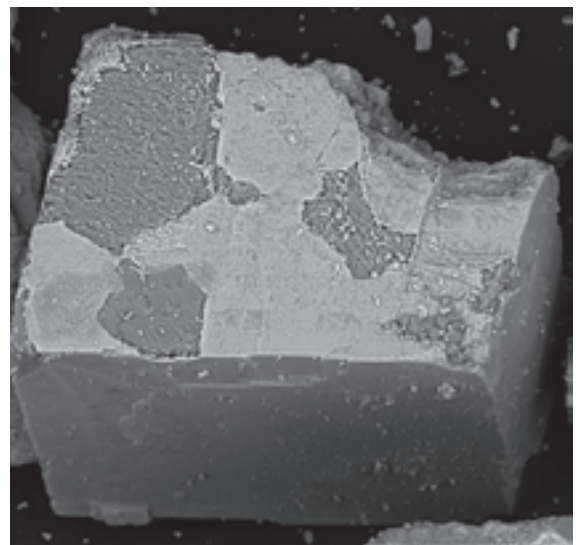
or to an aquifer in Buntsandstein sandstone at a depth of 1,500 metres. In laboratory tests, the BGR team studied the interactions between carbon dioxide, formation water and different minerals. “We used special gold-titanium pressure vessels for geochemical experiments with selected minerals that occur frequently alongside quartz in sandstones,” says Rütters. In these reactors, the team exposed minerals such as siderite (iron carbonate) in artificial formation water to a mixture of CO₂ and one of the possible associated incidental substances. In some cases, the impact of the mixture was visible to the naked eye: for instance, a dark oxidation crust formed on the light-coloured siderite grains in the reaction chamber.

Modelling support

In order to gain a better understanding of the processes observed in the experiments, the scientists carried out geochemical modelling. Which geochemical reactions occur in CO₂ storage reservoirs depends not only on the composition of the carbon dioxide stream, but also on the composition of the reservoir rocks and the formation water,

and on the pressure and the temperature in the storage reservoir. “The reaction paths differ, depending on whether the carbon dioxide stream contains oxidising or reducing substances,” stresses Rütters. “From a geochemical perspective, any recommendations regarding the level of purity of the carbon dioxide stream are necessarily specific to a certain plant and storage site.”

Contact: **Dr. Heike Rütters**



▲ Scanning electron microscope image of the oxidation crust formed on a siderite crystal during the experiment.

Storage sites for the energy reforms

BGR scientists develop methods for predicting subsidence above cavern fields

Salt caverns are versatile storage facilities: in these artificial cavities, oil and natural gas can be stored. There are plans to store also compressed air and hydrogen underground, for the energy reforms. But above the caverns, at the surface, the ground could subside. BGR has now developed methods to predict the extent of such subsidence.

There are about 250 salt caverns in Germany. These cigar-shaped cavities are located deep below the surface in salt rock. Some are 600 metres high, with diameters of up to 80 metres. Most of these caverns are used for the seasonal storage of natural gas, to ensure that the increased demand for gas in winter can be met. Others serve as oil storage sites, for times of crisis.

Cigar-shaped underground storage sites

In the course of the energy reforms, many more caverns could be leached out of the salt, for the intermediate storage of compressed air or hydrogen, for instance. But before a new storage cavern can be created, the operator must provide evidence that it is safe. “Investigations are carried out, for instance, to ensure that the load on the salt rock caused by the caverns is not too high,” reports Pro-

fessor Stefan Heusermann of BGR. The impact on the surface is also analysed using modelling. “Over time, salt rock displays a behaviour that is called creep deformation,” explains Heusermann. As a result of creep deformation, the cavities in the salt converge, i.e. their volume is reduced.

Subsidence at the surface

This often has an impact on the surface too. The deformation of the caverns also affects the surface, where a subsidence trough will form. “Its shape depends on a number of factors, for instance, the ability of the salt rock to creep, the depth and number of the caverns, and the operating conditions,” explains BGR expert Ralf Eickemeier.

Subsidence of the ground can cause leaning of buildings or water saturation of the land. “Predictions

are important to permit an assessment of possible impacts,” stresses Eickemeier.

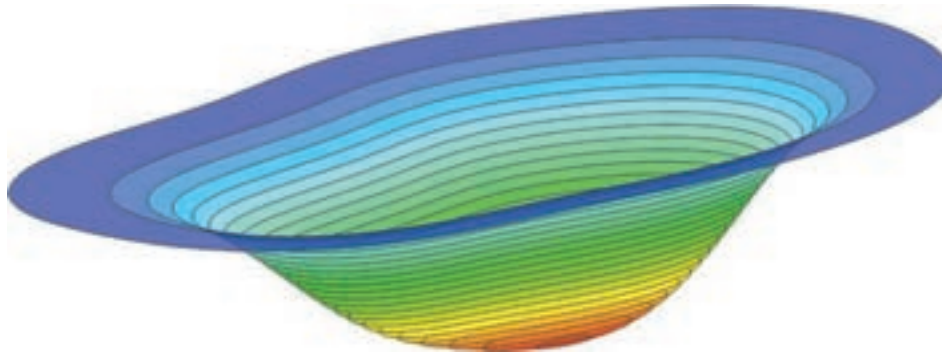
Software for subsidence predictions

Over the past years, BGR has developed a method that permits reliable predictions of subsidence above cavern fields in salt rock. This requires

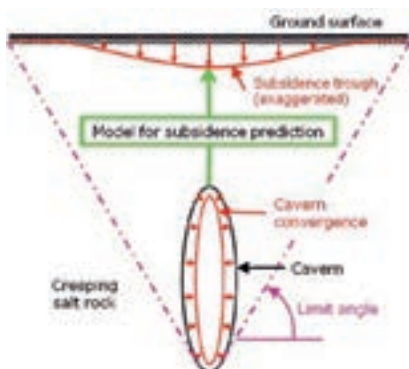


▲ Caverns in salt rock.

Source: IVG Caverns



▲ Calculated subsidence trough (vertically exaggerated by a factor of 1,000) above a cavern field (red: maximum subsidence at the centre, blue: slight subsidence at the edges).



▲ Schematic diagram of ground subsidence caused by cavern convergence.

regular surveying of the caverns, to determine the rate at which the cavity volume decreases. These data together with geodetic levelling at the surface serve to define model parameters. A software tool developed by Ralf Eickemeier can then make subsidence predictions.

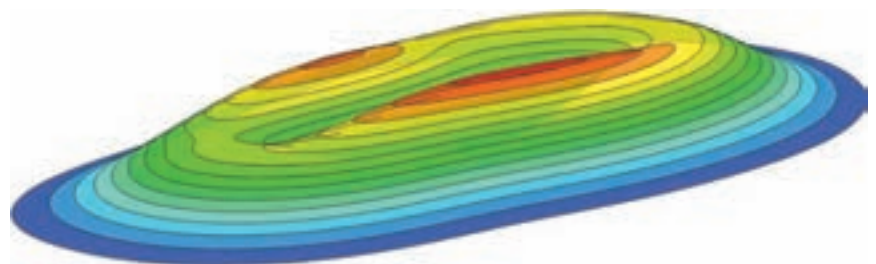
In addition to subsidence, the program can also predict tilting, horizontal displacements, and distortions of the Earth's surface. Based on these results, predictions can be made of potential damage to build-

ings, roads or bridges in and around the subsidence trough.

Application for cavern building

In recent years, the BGR prediction method has been widely used. "We have made subsidence predictions for cavern fields in Northern Germany and in the Netherlands," reports Ralf Eickemeier. In a blind study, the BGR scientists were able to show the reliability of their method. Their prediction of the subsidence above an actual cavern field was later compared with existing survey data – and shown to be correct. "Our method is generally suit-

able for other types of cavern use, too," says Stefan Heusermann. Examples include compressed air and hydrogen as sources of energy. They are far more often pumped into and out of caverns than oil or natural gas. In these cases, too, the BGR software tool can provide reliable subsidence predictions.



▲ Calculated tilting of the ground surface (red: maximum tilting on the sides of the subsidence trough; blue: slight tilting at the centre and the edges of the subsidence trough).

Contact: **Prof. Dr.-Ing. Stefan Heusermann, Ralf Eickemeier**

Fascinating structural diversity

In the German sector of the North Sea, the subsurface is characterised by salt structures

BGR scientists are exploring the structure and the development of different salt structures, to be able to assess their potentials for use. Salt dome overhangs, for instance, can trap hydrocarbons. Salt structures themselves serve as storage sites for energy sources and could also be used as disposal sites.

In the current climate conditions of Northern Germany it is hard to imagine large salt lakes here, such as those in the Australian desert. But the landscape looked quite different just over 250 million years ago. At that time, a body of extremely salty water, probably largely devoid of any living organisms, covered the northern part of Germany as well as Poland, Denmark, the Netherlands, and large sections of what is today the North Sea, up to Britain. This Zechstein Sea left an enormous legacy: deposits that are in places more than 1,500 metres thick, consisting mostly of rock salt, potassium salts, carbonates and anhydrite.

Today, thick salt rock formations can still be found almost everywhere below the North Sea and the North German Plain. Originally, the sediments were deposited horizontally, but their position has changed over millions of years, in



▲ Map of a selection of different salt structures in the so-called “Duck’s Bill” (“Entenschnabel”) area in the northwest of the German sector of the North Sea. Some salt structures are taller than the highest peaks of the Alps.

some cases significantly so. Under pressure from thick sedimentary layers from later geological periods and the impact of fault zones, and because of changes in the stress states of the subsurface, the rock salt began to flow, but at a very slow speed. Over the years, the salt rock rose in many places to form mushroom-shaped or pointed structures (diapirs), breaking through younger layers of rock. Some of the salt

diapirs thus formed and salt walls stretching across many miles are taller than the highest peaks of the Alps.

Current BGR work on salt structures of the German North Sea

In recent years, BGR scientists have gained new insights into the diversity of salt structures in the German sector of the North Sea, during the project Geoscientific Potentials of

the German North Sea (GPDN). In collaboration with the Lower Saxony State Authority for Mining, Energy and Geology and the German Federal Maritime and Hydrographic Agency, BGR has analysed seismic and borehole data and created 3D models of the geological subsurface of the North Sea.

This work forms an important basis for future investigations and for an assessment of the potential uses of these salt structures. Salt domes, for instance, are of interest to the oil industry, because oil and natural gas are frequently trapped in their vicinity. Moreover, salt caverns are used for the storage of energy resources. The use of salt structures for disposal or as final repositories

for toxic chemical or radioactive waste is also conceivable.

Versatile structures within the "Duck's Bill"

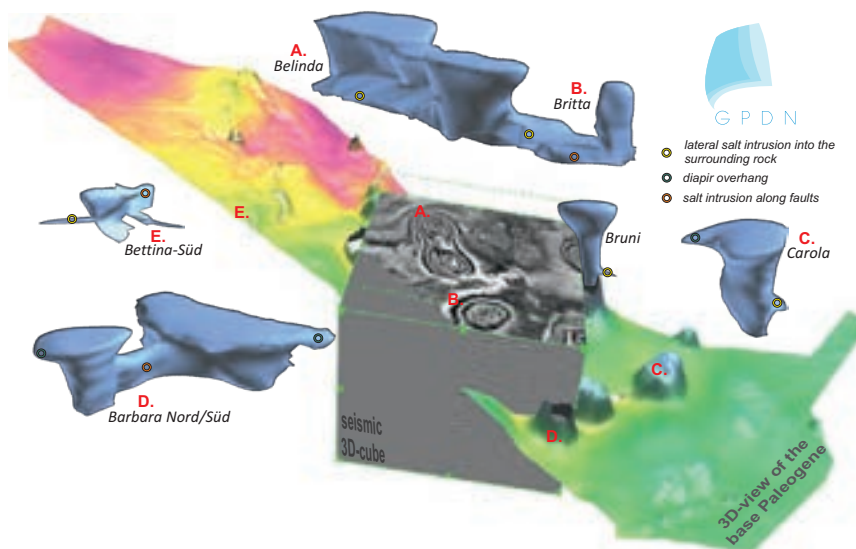
Before the project, the northwest of the German sector of the North Sea, known as "Duck's Bill" ("Entenschnabel") because of its shape, was one of the few nearly blank spaces left on German territory. An analysis of high-resolution 3D seismic data has now shown that the salt domes and salt walls in that area have very complex geometries. They are, for instance, often associated with fault systems. The data also show that rock salt from some diapirs has intruded laterally into the surrounding sedimentary rock, forming wedge-shaped branches of

these diapirs. With their data on the subsurface, the BGR experts are hoping to contribute to a better understanding of the development of salt structures.

New findings

The new 3D models show that the salt structures in the northwest of the German sector of the North Sea differ significantly from those in the adjacent North Sea area to the east. BGR scientists were surprised at the diversity of salt structure geometries.

Further, even more comprehensive 3D structural models of the deeper subsurface of the German North Sea sector and Northern Germany are expected to provide fascinating insights into the diversity of salt structures in the next few years.



▲ Results of seismic mapping in the northwest of the German sector of the North Sea. This area differs both in structure and development from the adjacent North German Basin, immediately to the east, which is also partly reflected in the different salt structures.

www.gpdn.de (Language: German)

Contact: **Fabian Jähne-Klingberg**

Earthquakes in primeval times

Palaeoseismic database to determine seismic hazard

Central Europe is a region with relatively low seismicity, although strong earthquakes cannot be excluded altogether. To determine the level of hazard in Germany, scientists from RWTH Aachen and BGR have compiled all findings in one database.

The worst earthquake in recorded history hit Central Europe on 18 October 1356. This seismic event that is today thought to have been of a magnitude between 6 and 7 reduced

a large part of the city of Basel to rubble.

It is in many respects uncertain how often and where exactly in Ger-

paleoseismic investigations like excavations and sediment analysis to estimate how often earthquakes will recur in a particular fault zone. In Basel, for instance, experts expect a recurrence interval of 2,500 years.



▲ Sites of palaeo-earthquakes that occurred in Germany and the adjacent areas between 400,000 and 10,000 years ago.

many and its neighbouring countries earthquakes of a similar strength could occur. Geoscientists do know which geological fault zones could generate earthquakes – faults in the Upper Rhine Graben or the Lower Rhine Basin, for instance. But since reports of historical earthquakes only go back about 1,200 years, earthquake geologists have to rely on

This is why scientists from RWTH Aachen and BGR are now developing a palaeoseismic database for Germany and its neighbouring countries. This will for the first time systematically combine and graphically display all information about primeval earthquakes and the associated geological faults.

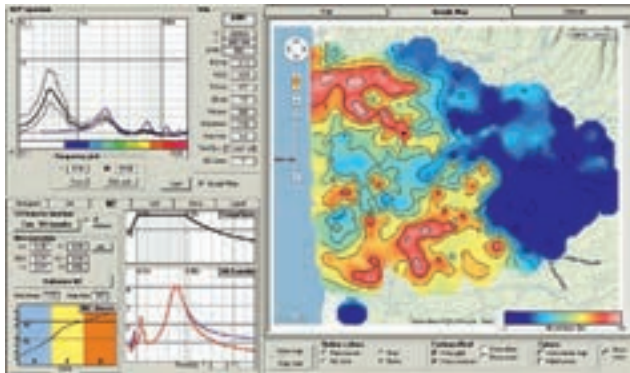
The PalSeisDB project was set up in response to the revision of regulations on the safety of nuclear power plants, introduced in 2011. This states that palaeoseismic findings must be taken into account in the design of nuclear power plants in Germany. At the same time, the study is a pilot project for the Vienna-based International Atomic Energy Agency (IAEA).

Contact: **Dr. Thomas Spies**

On solid ground

BGR experts support Geological Agency of Indonesia

The amount of damage to a building that an earthquake causes depends to a large extent on the properties of the ground on which it is built. In the Georisk Indonesia project, BGR experts are introducing their Indonesian colleagues to new methods for assessing ground properties.



▲ Software for processing seismic data for microzonation studies.

For the 400,000 inhabitants of the city of Mataram on the island of Lombok, as for almost the entire population of Indonesia, earthquakes are a permanent threat. The islands of this southeast Asian state are located directly on the seismically active Sunda Arc, which is frequently shaken by severe tremors.

But the damage caused by an earthquake can vary widely within a city. Where the ground is formed by solid rock, the earthquake waves do not normally gain in amplitude and duration as much as they do in areas of a city that is built on soft sediments like sandy or swampy ground. Thanks to the German-Indonesian Georisk project (Mitigation of

(Badan Geologi) carried out seismic surveys in Mataram to determine the distribution of areas with soft sediments. The result of these tests was a so-called microzonation map with areas of seismic hazard marked in the city. “Maps like these can help the authorities in



▲ Employees of the Geological Agency of Indonesia during seismic surveys for the microzonation map.

Georisks), the authorities of Mataram now know where the hazard from earthquakes is highest.

In 2013, experts from BGR and the Geological Agency of Indonesia

earthquake-prone regions with tasks such as spatial planning or emergency management,” stresses Dr. Malte Ibs-von Seht, a BGR expert on the Georisk team. The aim of this BGR project in In-



▲ The microzonation map of the city of Mataram shows areas with different levels of seismic hazard (blue=lowest, orange=highest), relative to the city's average level of hazard. The map is based on seismic surveys at about 500 points in the city area.

onesia is to strengthen the skills of the Geological Agency of Indonesia, particularly in advising the local authorities on georisk issues.

Contact: **Dr. Thomas Spies,**
Dr. Malte Ibs-von Seht

On stable ground

PanGeo project provides information on ground movements in 52 European cities

Radar satellites can detect sites where the ground rises and falls. In the PanGeo EU project, these data are linked with geological information to identify potential geohazards. BGR has evaluated these data for Berlin and Hanover.

How stable is the ground on which we live? The PanGeo project can answer this question for 52 large European cities. “Previously, information about ground instabilities or ground movements was hard to get,” reports BGR expert Corinna Wolf. Now, local authorities, insurance companies, emergency management agencies or the general public can access information on potential geohazards via a free online portal.

Based on satellite radar data, scientists from the 27 participating na-

tional geological surveys of the EU identified ground movements in a number of European cities from A for Aalborg to Z for Zaragoza. They were able to detect uplifts and subsidences of just a few millimetres per year. In order to investigate the affected areas in greater detail, the scientists also evaluated existing geological information and carried out site inspections.

The final geological report is intended to help public authorities or private businesses in their decision-making processes and reduce risks. The sci-

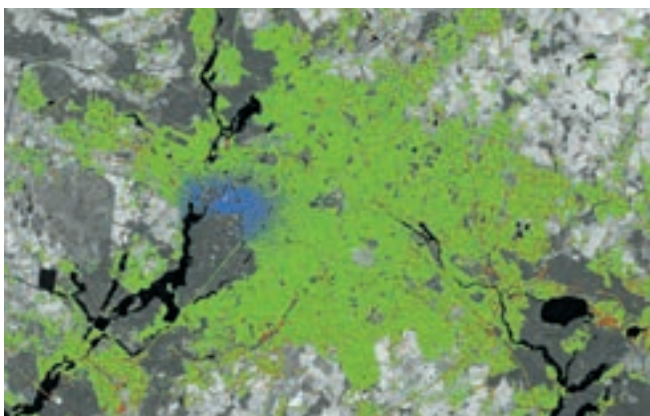


▲ Official project logo.

entists identified only few ground movements in the Hanover and Berlin urban areas. “In Hanover, there are a few incidences of subsidence, mainly caused by consolidation movements,” reports Corinna Wolf. The Charlottenburg-Wilmersdorf area of Berlin moved upwards by up to six centimetres between 1992 and 2001 after an underground gas storage site was set up there. Since then, the ground in this area has remained stable.

www.pangeoproject.eu/

Contact: **Corinna Wolf**



▲ Ground movement data for Berlin from satellite data (green: stable ground, red: subsidence, blue: uplift).



▲ Areas of uplift and subsidence (orange) derived from the ground movement data for Berlin.

Reverberant infrasound of a fireball

Infrasound stations around the globe registered explosion of Chelyabinsk meteorite

BGR infrasound arrays are part of a global network that monitors compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The Chelyabinsk meteorite provided the BGR team with an opportunity to test the detection performance of the stations around the globe.

The infrasound stations of the CTBT network had never observed such an intense signal before: on 15 February 2013, a meteorite measuring about 20 metres in diameter entered the Earth's atmosphere at high supersonic speed above the Russian town of Chelyabinsk. It exploded at an altitude of around 30 kilometres with an explosive energy equivalent to 500 kilotons TNT. The explosion generated low-frequency waves that are not perceived by the human ear – infrasound.

These waves travelled in the atmosphere around the entire globe. They were detected by 21 of the 45 stations of the international infrasound monitoring network. "Some stations registered the blast waves after they had already travelled around the Earth twice," reports BGR geophysicist Dr. Lars Ceranna. These waves reverberated for three days after the event.

For the infrasound scientists at BGR and their international colleagues, the Chelyabinsk meteorite marked a milestone: "It was a global reference event that permitted us to test the performance of the entire infrasound network," says BGR scientist Dr. Christoph Pilger.

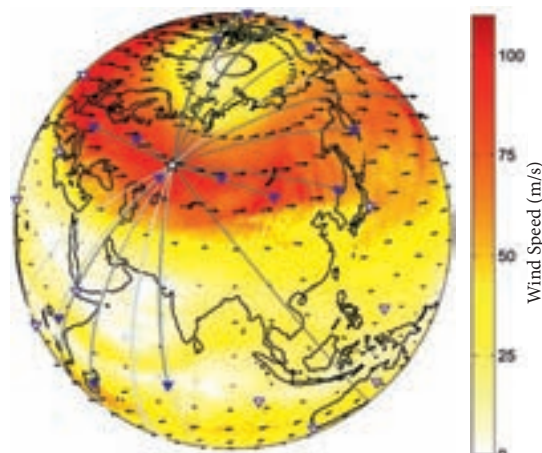
Using meteorological data such as temperature and wind conditions, Pilger and his colleagues developed a model to show how the blast waves propagated around the globe. This allowed them to determine the signal paths and compare them to the recordings. They found out

why the blast was not registered by all network stations.

The infrasound recordings thus also supplied important information about the dynamics of the atmosphere. BGR is therefore involved in the European ARISE (Atmospheric dynamics Research InfraStructure in Europe) research project, which compiles information of this kind.

<http://arise-project.eu/>

Contact: **Dr. Christoph Pilger,**
Dr. Lars Ceranna



Global view of the infrasound waves propagating from the Chelyabinsk meteorite event (white star) to the CTBT infrasound stations (blue triangles). The direction of the wind is marked with black arrows. Additional stations that recorded no readings are marked as white triangles.

When the ground trembles

BGR scientists develop method for determining seismic hazard near geothermal power plants

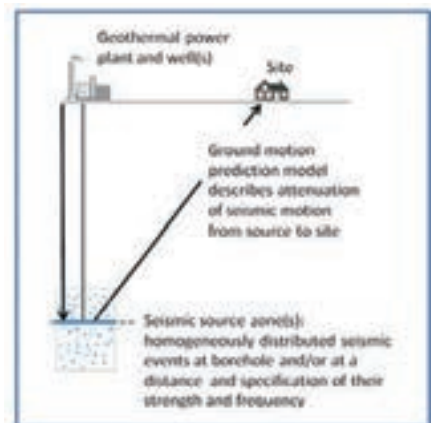
Seismologists rely on probabilistic seismic hazard assessment to calculate the probability that a site will be subject to ground motion of a certain magnitude caused by natural earthquakes. BGR scientists have now applied this method to industrially induced earthquakes.

Although geothermal energy is considered environmentally friendly, power plant operators have come under fire for some time: residents worry about damage to their houses as there have in recent years been several noticeable earthquakes in the vicinity of geothermal power plants, which were related to their operation.

“Anyone designing or operating a geothermal power plant has to be able to specify the possible size of ground motion from this so-called induced seismicity,” say BGR geo-

physicists Dr. Thomas Spies and Dr. Jörg Schlittenhardt. Today, seismologists can calculate quite well the probability of ground motion of a specific magnitude at a specific site. As part of the MAGS project, the engineering seismology team at BGR has now modified the PSHA method in such a way that it can also be applied to industrially induced earthquakes.

“We had to develop special ground motion models for weak seismic events,” report Schlittenhardt and Spies. Another special feature of in-



▲ Design sketch showing a geothermal power plant and the site for which the seismic hazard is calculated.

duced earthquakes that the scientists took into account, were the short distances between the seismic events and the surface of the Earth. The BGR team was able to transfer methods from construction standards, which apply to natural earthquakes and oscillation phenomena, to induced seismicity.



Source: Sankt Galler Stadtwerke, Geothermie-Projekt

▲ Geothermal project at St. Gallen, Switzerland.

Contact: **Dr. Thomas Spies,**
Dr. Jörg Schlittenhardt

Stress during the earthquake

BGR scientists develop new method for monitoring changes in Earth's crust

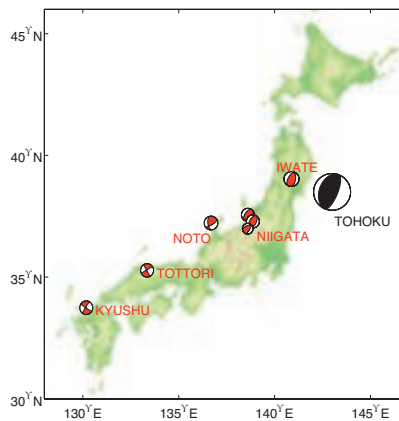
To date, it has been difficult to measure stress in the Earth's crust. BGR is now testing a new method for measuring seismic wave speeds, which relies on so-called seismic noise. The aim is to study the changes that are caused by large-scale earthquakes.

A seismometer's needle is never still. Even when there is no earthquake it moves constantly, because the Earth's crust is always in motion. One reason for this is, for instance, the impact of surf hitting the seashore. But even strong winds, a goods train or an electricity pylon shaken by the wind can cause weak oscillations in the Earth's crust.

This seismic noise can now be used to determine the speed of seismic waves in the Earth's crust between two seismographs. That in turn makes it possible to monitor the state of the Earth's crust, because the speed of the waves depends on a range of factors among them stress.

A German-Japanese team led by Dr. Ulrich Wegler of BGR has now

made use of this correlation to study the impact of earthquakes on stress in the Earth's crust. For

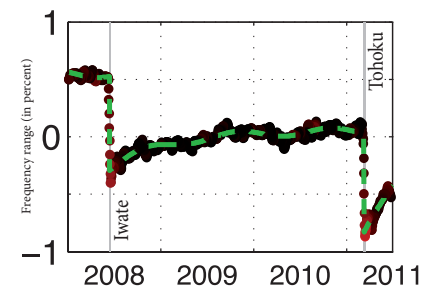


▲ Map of Japan marking the sites of the seven analysed earthquakes on land (red) and the 2011 Tohoku earthquake (black).

this purpose, the scientists evaluated data from Japan, where several large earthquakes have occurred since 2000. They found that seismic speed dropped by about one per-

cent during an earthquake. Afterwards, it increased again without, however, reaching its prior level.

In the long term, the scientists are planning to use this method for monitoring the Earth's crust, for instance, in highly earthquake-prone regions. It may also be suitable for



▲ Drop by about one percent in the relative elastic wave propagation speed in the Earth's crust in northern Japan at the times of the Iwate (2008) and Tohoku (2011) earthquakes..

monitoring the condition of CO₂ storage sites or repositories for radioactive waste.

Contact: **Dr. Ulrich Wegler**

Inventory in the Middle East

First catalogue of cross-border water resources

Many rivers and groundwater reservoirs in the Middle East are used by several nations – between whom there is, however, little collaboration to date. A joint study by the United Nations Economic and Social Commission for Western Asia (UN-ESCWA) and BGR provides a first cross-border overview of the region's water resources.

In antiquity, the marshland located between the Syrian Desert, the Zagros and Taurus mountain ranges, and the Persian Gulf was known as Mesopotamia, “land between rivers”. Today, four countries share the waters of the Euphrates and Tigris rivers and their tributaries: Iran, Iraq, Turkey and Syria. The uncoordinated use of water re-



▲ UN-ESCWA and BGR present the basic document on water resources in the Middle East and on the Arabian Peninsula at the press conference for World Water Week in Stockholm, Sweden.



▲ Presenting the new basic document on water resources in the Arab world: (left to right) Roula Majdalani (ESCWA), Franca Schwarz (BGR) and Ali Subah (Ministry of Water and Irrigation, Jordan).

sources in this crisis-ridden region has a high potential for conflict. “Because of water scarcity in the Middle East, the water management in each country strives first and foremost to use all available

water resources,” reports Vanessa Vaessen, project manager of the Policy Advice Groundwater project at BGR. “Neighbouring nations are hardly interested at all in jointly managing these water resources.”

Although 70 percent of all rivers and groundwater reservoirs on the Arabian Peninsula and its neighbouring states provide water to several countries, cooperation is rare. That is the result of a study presented by BGR together with UN-ESCWA in September 2013.

The scientists involved recorded more than 30 cross-border surface and groundwater resources in the Middle East. “This inventory provides the first ever overview of the state of these water resources,” says BGR expert Andreas Renck, formerly the project manager for this project by BGR and UN-ESCWA.

With their study, BGR and UN-ESCWA are encouraging dialogue on the management of jointly used water resources. The aim is to support the development of a legal framework for cross-border water management.

Contact: **Dr. Arne Hoffmann-Rothe**

Water knows no borders

Groundwater management training manual for technical experts in Africa

Water management in Africa usually neglects groundwater. BGR aims to enhance the technical knowledge in regional basin organisations by means of training courses.

“Kôom yaa vim” – water is life – is what they say in Burkina Faso. But in many African countries, this essential

resource is in a poor state. Groundwater in particular is polluted, and in many places the water table is falling. stop at national borders, it needs to be managed across borders,” says water expert Vanessa Vaessen of BGR.



▲ Because of population growth and climate change, the water table is falling in many locations.

resource is in a poor state. Groundwater in particular is polluted, and in many places the water table is falling.

BGR has been commissioned by the German Federal Ministry for Economic Cooperation and Development to help regional basin organisations in Africa address the issue of groundwater. “Since groundwater does not

has so far been focused on lake and

river management. To help them to include groundwater in their scope of responsibilities, BGR in collaboration with the Africa Ground-

water Network (AGW-Net) ran a workshop for representatives from different African basin organisations. This was held in Ouagadougou, the capital of Burkina Faso, in February 2013. During the event, the BGR experts aimed to find out to what extent groundwater is addressed in the organisations’ everyday work. In a next step, they developed a training manual. A first training event was held in September 2013, others are to follow in 2014.

Regional basin organisations do exist in Africa, such as the Niger Basin Authority (ABN), which unites the nine West African states through which the Niger flows. But most basin organisations’ work

Contact: **Vanessa Vaessen,**
Ramon Brentführer



For Africa’s rural population, groundwater is often the only source of drinking water. ►

Night flights in the Rift Valley

BGR and African Union cooperate on geothermal development projects

The Geothermal Risk Mitigation Facility supports geothermal exploration in East Africa. The programme aims to reduce the financial risk for investors. Moreover, BGR scientists are training their African colleagues in the latest exploration methods.

Almost no other region in the world is as suitable for the use of geothermal energy as East Africa. In the area around the active volcanoes of the Great African Rift Valley geothermal power plants could generate 15 Gigawatts, according to experts.

But so far, investors in geothermal energy projects in Africa have been facing a high financial risk. Because, despite the high underground temperatures, only a borehole will reveal whether a reservoir is actually suitable. Borehole exploration can account for up to two thirds of investment costs.

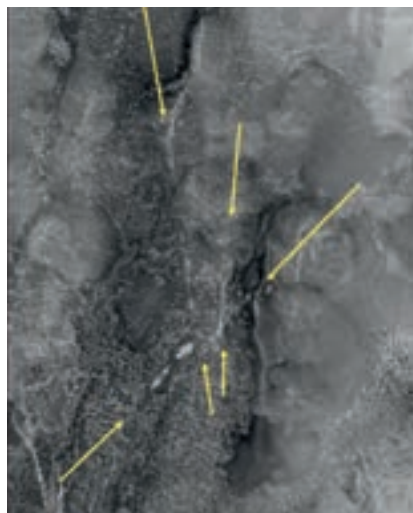
Via the GEOTHERM programme BGR is involved in the Geothermal Risk Mitigation Facility (GRMF) set up by the KfW Development Bank and the African Union (AU). GRMF provides funding for surface exploration and drilling; the necessary administrative support is offered by the AU's Geothermal Energy team. GRMF thus helps to reduce the financial risk for investors, with the

aim of promoting geothermal energy use in East Africa. Since July 2013, a BGR employee has been permanently assigned to the African Union's Geothermal Energy team based in the Ethiopian capital Addis Ababa.

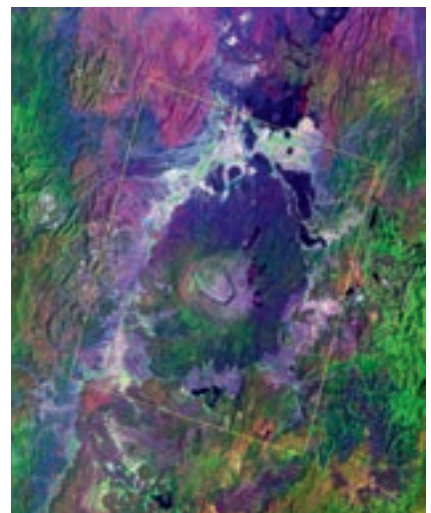
One project within the GEOTHERM programme was an airborne survey of the remote Silali volcano in Kenya. The thermal images show that the fumaroles form part of a system of faults where volcanic heat escapes

from the ground. One project goal was to train employees of the Kenyan Geothermal Development Company in the use of the latest exploration methods.

Contact: **Andrea Friese,**
Max Winchenbach



▲ Detail from a thermal mosaic at the eastern side of the Silali volcano in Kenya. The yellow arrows indicate areas of thermal interest.



▲ Satellite image of the Silali volcano in Kenya. The yellow rectangle indicates the geothermal working area.

Nuclear Test Ban Monitoring

Comprehensive Nuclear-Test-Ban Treaty: North Korea's third nuclear test

Nuclear test in North Korea

Evidence from seismological signals and radioactive traces

BGR operates the National Data Centre for monitoring compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Relying on its expertise, evidence of a nuclear test in North Korea in February 2013 was quickly provided.

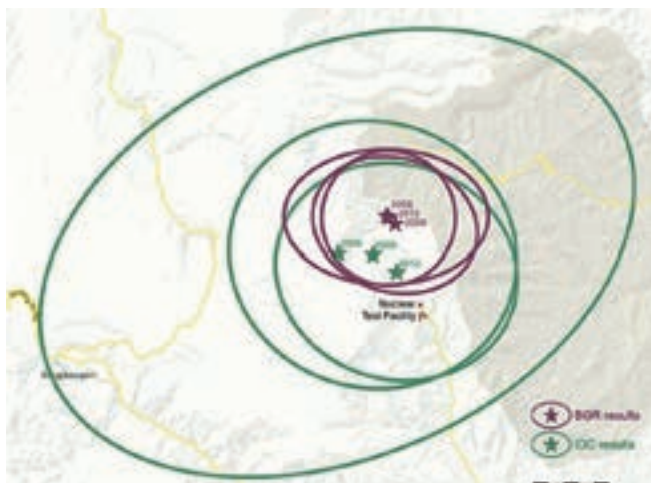
When BGR's seismological station in the Bavarian Forest registered suspicious signals on 12 February 2013 at 03:09 UTC, everything indicated an explosion in North Korea, possibly a nuclear test. The International Monitoring System, a network comprising 321 stations distributed across the globe, four of them operated by BGR, is in place to detect all nuclear explosions, using seismology, infrasound, hydroacoustics and radionuclide technologies. When

a suspicious explosion occurs, the participating scientists investigate immediately whether it was in fact a nuclear blast.

This is precisely what happened on 12 February 2013 and it soon became clear that North Korea had conducted a third nuclear test. At seven o'clock in the morning, BGR submitted a first expert report to Germany's permanent mission to the United Nations in Vienna. Be-

fore midday, a preliminary report including first seismological findings had been published. This also contained a forecast on the meteorological conditions affecting the dispersion of radioactive fission products that might have been released. The BGR scientists included data from other stations of global seismological networks near North Korea in their evaluation. This made it possible to locate the test site with greater precision and compare the test to the earlier 2006 and 2009 tests, which had been of a lower magnitude.

Fifty-four days after the test, radionuclide stations in Japan and Russia recorded unusual levels of certain xenon isotopes. Decay calculations showed that they could be explained by a nuclear explosion in mid-February. A simulation of the dispersion of the isotopes in the atmosphere showed also that they could have been released on the test site in early April 2013, possibly through a partial opening of the tunnel system.



▲ Sites of proven nuclear explosions in North Korea in 2006, 2009 and 2013. The sites determined by BGR are marked in red, those by the CTBT Organisation international data centre in Vienna in green. The coloured ellipses indicate the uncertainty range of the localisation.

fore midday, a preliminary report including first seismological findings had been published. This also contained a forecast on the meteorological conditions affecting the dispersion of radioactive fission products that might have been released.

www.bgr.bund.de/kernwaffenteststoppabkommen_en

Contact: **Dr. Jens Ole Roß**

■ Sustainable Livelihoods

When rock turns into soil

Sample testing of landscape evolution model

The permanent cycle of weathering slowly transforms solid rock into a crumbly, usually brown mass: soil. The soil properties depend largely on the source rock – but not completely. The climate, particularly precipitation, and the land relief also determine the thickness of a weathering layer and its chemical and physical properties.

Soil scientists have long wanted to determine soil properties directly from geological maps. In collaboration with Universität Hamburg, BGR is therefore developing a landscape evolution model, which

currently permits, for instance, forecasts of how thick the layer of loose, already partly weathered rock above the solid rock is.

To refine the model further, BGR together with clay mineralogy consultants Butz-Braun and experts from the German states have taken and analysed numerous samples from the German Central Uplands. First forecasts made with the landscape evolution model are currently being verified by means of boreholes.

Contact: **Dr. Rainer Baritz**



Source: Butz-Braun

▲ Profile for sampling the weathering properties of the Buntsandstein.

■ Securing the Supply of Raw Materials

Raw materials overview

DERA sets up interactive information system

Complete information about energy resources, metals and industrial minerals – that is what businesses and interested users will in future find in the new raw materials information system developed by DERA, the German Mineral Resources Agency. “Our interactive website caters for a wide range of users,” says BGR expert Dr. Torsten Brandenburg. “It will provide businesses and interested individuals with a quick overview of a particular natural resource.”

Users will be able to access, for instance, information about global production, reserves, and the price trends of individual raw materials.

The data will be presented in interactive maps, illustrations and charts to facilitate understanding. “That will increase market transparency,” says Brandenburg.

The information system is based on the extensive databases of BGR’s department Energy Resources, Min-



▲ The web-based information system will provide data on mineral resources and energy resources. ▼



eral Resources. A web application for visualisation of the data is due to be developed in 2014.

Contact: **Dr. Torsten Brandenburg**

■ Development and Linking of Geoscientific Knowledge

Looking deep inside the Ore Mountains

BGR tests electromagnetic survey methods

The Greifensteine rock formation near the German town of Geyer in the Ore Mountains is a popular destination for day trippers. The strangely shaped granite rock forms the tip of a huge underground rock body, which may hide deposits of metals of economic importance, such as tin, tungsten, zinc and indium, underneath.

In collaboration with Helmholtz Institute Freiberg for Resource Technology and TU Bergakademie Freiberg, BGR is planning to carry out airborne surveys in a



▲ Exploring the northern edge of the Ore Mountains from the BGR helicopter.

pilot area around the Greifensteine on the northern edge of the Ore Mountains up until spring 2016. BGR's electromagnetic (EM) sensor system can explore roughly the top 150 metres of the Earth's subsurface.

The project team will later use other methods providing exploration depths of up to 500 metres. "We would like to explore ore deposits that are located even lower down using electromagnetic methods," says geophysicist Dr. Bernhard Siemon of BGR. "If a new airborne EM system becomes early enough available, we will also test another method."

BGR and its partners will together evaluate and interpret the data.

Contact: **Dr. Bernhard Siemon**

■ Development and Linking of Geoscientific Knowledge

World map of karst aquifers

BGR scientists collaborate on international project

Carbonate rock such as limestone or dolomite play an important role for drinking water supply worldwide. Experts estimate that for about a quarter of the world's population, at least part



▲ Karst spring in Greece.

of their drinking water originates from karst areas, i.e. areas with carbonate rock with caves and fractures running through it. However, karst aquifers are very easily polluted and also difficult to manage. Since rain-water quickly drains through the fractures, the flow rates of karst springs can vary considerably.

In order to gain a better overview of karst aquifers around the globe, the International Association of Hydrogeologists launched the World Karst Aquifer Mapping Project (WOKAM)

in 2012. The project aims to create a world map of karst aquifers. Earlier maps will be revised and refined. The new map will show both near-surface and deep karst aquifers, but also major karst springs and caves.

The map will be compatible with the existing global map of groundwater resources, WHYMAP. The WOKAM and WHYMAP teams are therefore collaborating closely.

Contact: **Andrea Richts**

■ Exploration of Polar Regions

The lost plate boundary

CASE 16 expedition takes scientists to east coast of Ellesmere Island

Although only 30 to 50 kilometres of water separate Ellesmere Island off Canada from the northwest coast of Greenland, the two arctic land masses are located on different continental



▲ View of the Victoria and Albert Mountains on the east coast of Ellesmere Island.

plates. Whereas Ellesmere Island belongs to North America, Greenland for some time formed its own micro-continent. But the exact location of the plate boundary is a disputed issue among experts. In summer 2014, a German-American team of scientists led by Dr. Karsten Piepjohn will be exploring the southern part of the sea passage between Greenland and Ellesmere Island, the so-called Smith Sound, as part of the CASE 16 expedition to find the continuation of the fault zone that is located further to the north.

“There is no clear geophysical evidence of a large fault in the Smith Sound, but there is in the northern section of the sea passage,” reports Piepjohn. “We are hoping to resolve this contradiction during CASE 16.” Piepjohn and his colleagues suspect that the fault zone does not run through the sea passage, but instead appears on the surface on the east coast of Ellesmere Island.

Contact: **Dr. Karsten Piepjohn**

■ Securing the Supply of Raw Materials

Licence to explore

BGR submits application to International Seabed Authority

The meeting of the Legal and Technical Commission of the International Seabed Authority in July 2014 is of great interest to Germany. The commission will decide whether to grant BGR an exploration licence for an area of 10,000 square kilometres on the sea floor of the Indian Ocean southeast of Madagascar. To prepare their application, BGR scientists carried out several expeditions in the area since 2011, discovering interesting deposits of so-called polymetallic sulphide ores. These ores contain metals that are needed in many high-tech applications.



▲ Presentation of Germany's licence application to the Legal and Technical Commission of the International Seabed Authority: (left to right) Head of the delegation Josef Beck, ambassador to Jamaica and to the International Seabed Authority; Dr. Ulrich Schwarz-Schampera, BGR project manager; Dr. Michael Wiedicke-Hombach, head of the BGR Marine Geology unit.

Experts also expect a licence for exploration to boost German industry. Mechanical and plant

engineering firms could start to develop environmentally friendly, low-maintenance machinery for deep sea mining.

If the licence is granted, Germany will be one of the few states that are exploring a number of mineral resource deposits on the deep seabed. Since 2006, Germany has held a licence for exploration of so-called manganese nodules in the Pacific Ocean.

Contact: **Dr. Ulrich Schwarz-Schampera**

■ Subsurface Use

Rock lab research

BGR continues work in Mont Terri underground rock laboratory

How can underground cavities and boreholes in clay stone be sealed well enough to permit the safe storage of high-level radioactive waste? This is one of the issues that BGR scientists are investigating with their work at the Mont Terri underground rock laboratory (URL) in Switzerland.

BGR has been a consortium partner of the Mont Terri project since 1997. Currently, the team led by Dr. Kristof Schuster is carrying out two of its own experiments as well as collaborating on twelve other tests. The focus of the planned work is on describing in detail the properties of Opalinus Clay, the

potential host rock for final disposal in Switzerland. The scientists are carrying out geophysical and geotechnical tests



▲ Geophysical and geotechnical measurements at the Mont Terri underground rock laboratory (2013).

on site. These include, for instance, determining the permeability of the clay or its response to mechanical loads. In addition, the scientists are planning to study microstructural and thermal processes in Opalinus Clay.

Clay stone has for some years been considered as a potential host rock for the final disposal of high-level radioactive waste in Germany. The experiences gained in the Mont Terri project are helping to answer a number of major questions.

www.mont-terri.ch

Contact: **Dr. Kristof Schuster**

■ Subsurface Use

Erosion below the glacier

Tunnel valleys below glaciers to be taken into account in choice of repository sites

When a thawing period occurs during a glacial period, large volumes of meltwater collect at the base of a glacier. As this glacial meltwater cascades down, it can cut tunnel valleys into the rock below the ice sheets, several hundred metres deep.

This phenomenon must be taken into account in the search for a repository site for radioactive waste. Because this form of subglacial erosion could result in linear erosion of the overburden above a repository, or even the

host rock itself, during a new glacial period.

In Southern Germany, clay stone formations have been considered as potential host rock for the final disposal of radioactive waste since 2007. BGR scientists are planning to investigate there to what extent the phenomenon of tunnel valley formation could affect the safety of a potential repository. For that purpose, they are studying what happened below the glaciers during earlier thawing periods.

For their study, the scientists will initially engage in literature research, review the findings from field work and boreholes and compile the spatial data in a geoinformation system. To analyse the long-term safety of possible repository sites in clay stone as a host rock, they will develop different scenarios. These will take into account information about tunnel valleys.

Contact: **Anke Christina Bebiolka**

■ Securing the Supply of Raw Materials

A strategy for Europe

What developments are there in the supply of and demand for mineral resources?

Commodity markets are subject to rapid change. Price fluctuations, increased demand and the fear of sudden shortages are part of everyday life.

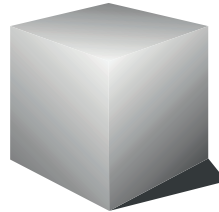
To prepare politics and businesses in Europe better for these changing markets, the geological surveys of 28 European countries have now formed a network as part of the Minerals4EU project. They are planning to set up an online knowledge data platform, providing data, information and intelligence about mineral resources.

As part of the Foresight study work package headed by BGR scientist Dr.

Henrike Siev-

ers, studies on

the future supply of raw materials and on specific raw materials will be prepared. Scientists from twelve organisations are together defining and exploring crucial factors affecting supply and demand, especially of critical raw materials. They include, for instance, political and economic developments or technology trends.



MINERALS 4EU

▲ Official logo of the Minerals4EU project.

The studies will be updated on a regular basis.

www.minerals4eu.eu/

Contact: **Dr. Henrike Sievers,**
Dr. Dominic Wittmer



Advertisement

Higher-quality basalts

A method for improving road surface quality? That is what BGR scientist Dr. Stephan Kaufhold has developed, together with his colleagues Prof. Dr. Harald G. Dill and Dr. Reiner Dohrmann – and recently had patented.

What exactly is the patent for?

It is for a method of interpretation that permits a better quality rating of crushed basalt. These crushed stones are a constituent of asphalt and other materials. They are used in road construction to improve road surface grip. As rail track ballast, they enhance the stability of the trackbed. These basalts contain expansive clay minerals. The higher the content of these minerals, the lower the grip and the quality of the material may be.

What does the method entail?

It relies on near-infrared devices such as are used in the chemical industry. The infrared beam of such a device registers the content of the individual components. Ideally, each component has its own signal. This is sent to the device, which determines the exact content of the mineral concerned in the basalt. It took one year of intensive research to analyse in detail basalt rock from different sources. We worked out which signals belong to which basalt components, and how to convert the signals into the content.

What gave you the idea?

It was an enquiry from the basalt industry. The infrared radiation

measurement technique, so-called near-infrared spectroscopy, has been in use for some time. By adapting this method, we have made it possible to measure the clay mineral content of basalt directly in the field with an accuracy range of roughly two percent. That was not possible before.

Why did BGR carry out research in this area?

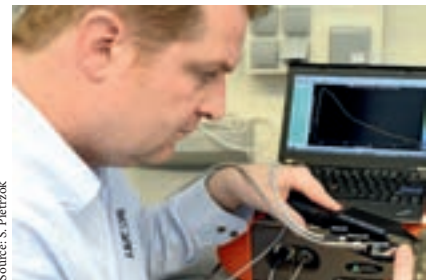
Because of BGR's special experience in the analysis of expansive clay minerals, we were explicitly asked to include this issue in our preliminary research work. Industry would, of course, prefer to obtain basalt of the highest possible quality before processing it further.

Are you planning any follow-up projects on this method?

Over the past ten years, the use of near-infrared spectroscopy has gained in importance in the geosciences. We are currently working on refining the method even further in several projects.

Is there a specific project that you personally would like to implement?

Not a specific project, but it would



Source: S. Pietrak

▲ Dr. Stephan Kaufhold using the new method to measure the clay mineral content of a piece of basalt rock.

be something to develop a reliable quantitative measurement method for minerals that non-mineralogists could use as well. Businesses would then be able to advance process optimisation and quality control of their products on their own, without having to rely on expert knowledge. In other words, it would then be possible to interpret the measurements without any expert knowledge. Such a development would help advance mineralogy.

Interview: **Janine Seibel**

From the Barents Sea to Greenland

As part of BGR's PANORAMA project, Dr. Kai Berglar and his team are exploring the oil and natural gas resource potentials of marine areas in the European Arctic. Their expeditions take them to some previously unexplored regions.



▲ Dr. Kai Berglar analysing data.

What is PANORAMA short for?

PANORAMA is the abbreviation of Petroleum Assessment of the Arctic North Atlantic and Adjacent Marine Areas. Specifically, it is an assessment of the oil and natural gas deposits in the European sector of the Arctic. This includes assessing the risks of a potential use of these energy resources. To date, large parts of the Arctic such as the northern sectors of the North Atlantic and the Barents Sea have not been sufficiently explored geologically.

What is BGR's approach in such exploration?

Since the 1970s, BGR has been involved in a range of – often international – research programmes in the Arctic. The destination area of this project comprises the European sector of the Arctic Ocean, ranging from the Barents Sea in the east to the east coast of Greenland, and including Baffin Bay west of Greenland. Over the next few years, we are planning to collect more facts about the region with sep-

arate individual projects, focusing on the areas with the largest data gaps.

What makes the Arctic regions particularly attractive for exploration activities?

Germany imports most of its oil and gas from the Arctic states Norway and Russia. In recent years, these countries have focused increasingly on the northern regions. In view of the foreseeable rising global demand for energy resources, BGR needs to explore the future availability of oil and natural gas in the Arctic as elsewhere, and to make the information gained available to policy makers, industry and the public as a basis for discussion, as set out in the guidelines of German Arctic policy.

What partners is BGR working with and what happens to the collected data?

BGR is collaborating closely with the geological surveys of the Northern European countries Denmark, Norway

and Iceland, and with Canada, Russia and some universities. The data will initially be available for evaluation to the participating scientific working groups and will then be published in international journals. Central findings from our research will be disseminated in separate studies.

In your opinion, what are the greatest challenges in this project?

The Arctic is a region with many blank spaces on the map that makes it particularly exciting. Many areas are covered with ice almost all year round, which can make research work there very difficult.

What is currently happening with PANORAMA?

We are busy analysing the data collected during our last expedition, and in the middle of planning our field work for 2015 and 2016.

Interview: **Janine Seibel**

Sharing experiences with China



▲ Safety measures in China for protection against mudslides after the 2008 Wenchuan earthquake.

In November 2013, a BGR delegation visited Shanghai in order to plan new projects with colleagues from the Chinese Geological Survey (CGS). The two organisations have been collaborating since 1979. In 2014 and 2015, BGR and CGS are planning

joint work on issues such as CO₂ storage, geothermal energy and hot dry rock technology. Two projects on the monitoring of landslides and on karst aquifer systems are in preparation, both scheduled to run over several years.

Resources Conference attracts strong interest



▲ 2013 BGR Resources Conference.

In November 2013, around 180 experts from politics, science and industry met at GEOZENTRUM Hannover for the 2013 BGR Resources Conference. On the first day of the conference, the main topics were global market analyses and current procure-

ment risks; the second day focused on alternative procurement strategies and options available to companies to secure their supply chains. The next BGR Resources Conference is scheduled for 2015.

DERA Information for industry



▲ DERA industry workshop on antimony at Berlin-Spandau.

Two industry workshops, hosted in June and October 2013 by DERA, the German Mineral Resources Agency, in Berlin-Spandau, focused on price and supply risks for antimony and tungsten. DERA presented the latest studies on the supply

situation for the two metals. The workshops were attended by businesses using these mineral resources in their products.

Conservation in military training areas



▲ Mortar target area at Baumholder training area.

BGR is currently investigating the military training areas near Baumholder in Rhineland-Palatinate and Upper Lusatia in Saxony, particularly exercise facilities such as explosion test grounds and firing areas. The project aims to assess the

hazard potential of these exercise facilities for groundwater and surface water bodies. The scientists are planning to establish to what extent soil and rock protect the water from contaminants.

BGR at the Agritechnica trade fair

From 10 to 16 November 2013, BGR participated in Agritechnica in Hannover, the world's largest trade fair for agricultural machinery and equipment. At the German Agricultural Society's "Smart Farming" special exhibition, the BGR soil scientists presented a new map on the soil quality of agricultural land in Ger-



▲ BGR stand at the German Agricultural Society's "Smart Farming" exhibition.

many. The map was shown both in digital format and as a walk-on

map. Using maps, posters and a web portal, BGR experts provided information on yield potentials, possible uses, and on the impact of climate change to farmers and agricultural scientists.

Single database for earthquake catalogues

Two earthquake catalogues maintained by BGR are being merged. There is currently one historical catalogue listing all earthquakes between the years 800 and 2008, and another of all earthquakes since 1975 that have been evaluated using seismological instruments. To avoid a duplication of work, there will in future be a single earthquake database.

Currently, new data processing software is being developed. BGR scientists are reviewing the seismological data to ensure each earthquake is clearly matched. They are also re-evaluating historical sources and estimating the magnitudes of historical earthquakes. The database has to be extended to permit integration of the historical sources.

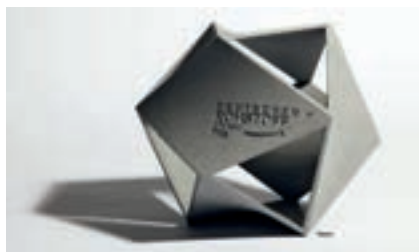


▲ Epicentres of around 12,000 earthquakes in Germany and geographical distribution of earthquakes as part of the new data processing software.

Success in the marketplace

In November 2013, the German Federal Ministry for Economic Affairs and Energy rewarded several tech-

nologies with the German Material Efficiency Prize: two innovative recycling methods, one resource-friendly galvanisation process, a new method for the manufacture of drywall structural profiles, and a material-efficient electrical conduit.



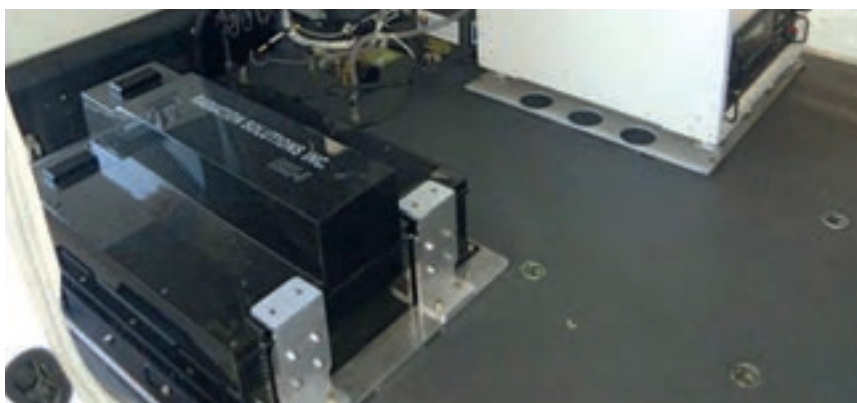
◀ The German Federal Ministry for Economic Affairs and Energy has been awarding the Material Efficiency Prize to companies and research institutes since 2011.

Under the expert guidance of DERA, this was the third year the prize, worth 10,000 euros, was awarded. It rewards outstanding solutions for resource-efficient and material-efficient products, processes or services, and application-oriented research results.

Gamma-ray spectrometer on board

In May 2013, the BGR helicopter was fitted with a new on-board measuring instrument: a high-resolution gamma-ray spectrometer. It measures natural gamma radiation, i.e. high-energy electromagnetic radiation resulting from the radioactive

decay of potassium-40, uranium or thorium. These elements occur in many types of crystalline rock. With the readings, it is possible to determine the type of rock and its natural radionuclide content.



▲ Gamma-ray spectrometer on board the BGR helicopter.

Let's talk about soil

In 2013, BGR's basic soil maps were in demand at several national and international events, such as at the first meeting of the Global Soil Partnership in Rome. During Global Soil Week, which took place in Berlin in October, BGR hosted a panel discussion on global soil information with UN representatives

and other partners. BGR scientist Dr. Manfred Birke was on that occasion honoured for his work in the analysis and quality assurance of the European geochemical soil inventory GEMAS. Moreover, BGR presented a walk-on soil map of Central Europe in Berlin.



▲ Plenary session at the celebration event by FAO, the United Nations Food and Agriculture Organization.

Groundwater workshop in Berlin

There was reason for celebration, and for a look ahead to the future: in 2013, after more than 50 years' work the International Hydrogeological Map of Europe (IHME) was completed. To mark the occasion, BGR hosted the International Workshop on Groundwater Systems in Europe. Experts from 19 European states met in Berlin in August to find out about possible future applications of the map series.

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

International Workshop on Groundwater Systems in Europe

On the occasion of the completion of the International Hydrogeological Map of Europe (IHME)

22 – 23 August, 2013
BGR Branch Office Berlin

ITRN
European Topic Centre
igrae
Announcement

▲ Flyer for the 2013 International Workshop on Groundwater Systems.

Long-term experiment completed after ten years

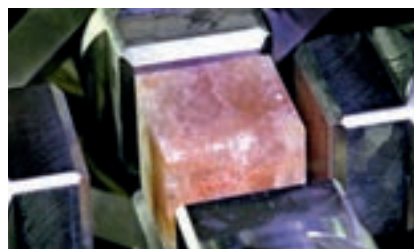
How does a salt pillar in a mine respond to carrying the weight of the overlying rock layers? That is the question BGR scientists in the Rock Physics unit aimed to answer in an experiment that lasted exactly ten years.

The laboratory test started on 1 April 2003. The scientists led by Dr. Otto Schulze exposed a rock salt specimen from the Morsleben repository mine to permanent stress of 12 MPa, which is 120 times the level of atmospheric pressure. The specimen served as

the model of a slim rock salt pillar supporting a cavern in a salt mine. The scientists were interested in reproducing the long-term processes in a repository mine in a condensed period. They were hoping to find out whether brittle cracks would form in such slim pillars – which would make them lose their load-bearing strength – or whether they would deform plastically and remain stable.

On 1 April 2013, the scientists removed the salt specimen from the

press. The result: “Even after a long time, there is no progressive damage,” says Schulze. The deformation of the test piece was mostly creep deformation.



▲ Rock salt specimen before the creep deformation test in a true-triaxial test apparatus.

Training in El Salvador

In August 2013, BGR experts ran a ten-day training course in San Salvador, focusing on risk management for natural disasters. It was attended by 14 course participants, including spatial planners, geoscientists, civil engineers and GIS experts from several ministries and other organisations of this Central American state. In 30 units, they were given extensive and in-depth information on how adequate planning can help minimise the risk from natural disasters in the medium and long term.

In addition to theoretical background information, the agenda also included hands-on exercises. These taught the participants to carry out

so-called risk exposure analyses. For instance: how can clever risk management prevent severe damage from earthquakes, flooding or landslides.

The course participants were delighted with the training course and

stressed its great practical use. With it, BGR is continuing its efforts to support spatial and development planning in El Salvador. BGR's georisk experts are planning to run more courses in Latin America in summer 2014.



▲ Course participants at the August 2013 georisk training course in El Salvador.

New computer system at BGR

Over the past few months, BGR staff in the Geodata Management unit have completed a huge task. They have migrated the BGR intranet software from Microsoft SharePoint Server 2003 to SharePoint Server 2010. This involved moving more than 30,000 documents, almost 900 web pages, 1,200 document libraries and just under 2,000 user accounts.

Migration to the new system GINO2013 was necessary since Microsoft no longer supports the previous software version. The new intranet provides a range of new functions, such as for social media or document management. Documents can now be edited simultane-

ously by several people, for instance. In the new system, all content can be accessed via a powerful search function. With the new page layout and the new structure of web pages and content, navigation and the search for information have become much easier.

BGR staff had planned and prepared the migration together with an external consultant.



▲ The new GINO2013 intranet portal also offers social networking functions.

Fracking – opportunity or risk?

The extraction of shale gas can help stabilise the decreasing domestic production of natural gas. That is the conclusion reached at the conference on environmentally compatible fracking, held at GEOZENTRUM Hannover in June 2013. More than

200 experts from politics, science and industry met at the event to share information on the topics shale gas and hydraulic fracturing (fracking). International experts from the United States, United Kingdom, Poland and other European countries also reported their experiences.

This states, among other things, that fracking in Germany must use environmentally compatible methods. Protecting the drinking water has the highest priority. The experts recommended establishing in each case whether fracking activities could be environmentally compatible. This should be done in stages and transparently.



▲ A video of the discussion at the June 2013 fracking conference can be viewed on the BGR website.

After the conference, BGR, the Helmholtz Centre Potsdam – German Research Centre for Geosciences (GFZ) and the Helmholtz Centre for Environmental Research (UFZ) together published a joint statement, the so-called Hanover Declaration.

www.bgr.bund.de/frackingkongress (Language: German)

Selection of BGR publications

BGR publishes a wide variety of map materials and books about their work. All titles can be purchased from Schweizerbart'sche Verlagsbuchhandlung (www.schweizerbart.de) or as digital documents (www.bgr.bund.de).



A. Schreiber

*Die Kalksteine des Wildenfels-Zwischengebirges
– Petrographie, Stratigraphie und Chemismus*

[Geologisches Jahrbuch A 159]

199 pages, German

ISBN 978-3-510-95970-9 € 49,80

The limestones of the Wildenfels-Zwischengebirge

Geologisches Jahrbuch (Geological Yearbook) A 159 for the first time reports in greater depth on the findings from extensive stratigraphic, palaeontological, petrographic and chemical research carried out on the numerous and varied limestones of the Wildenfels-Zwischengebirge. The Wildenfels-Zwischengebirge is located in Saxony, about ten kilometres south of Zwickau between the towns of Wildenfels, Hartenstein and Langenweißbach.

Most of the limestones occurring there are the easternmost deposits of their kind in Germany. The Tentakulitenknollenkalk Formation of the Lower Devonian, for instance, is found in two varieties. The Tentakulitenschiefer above it bears numerous radiolarite bands of lesser thickness; this is unique to Wildenfels.

Several geological-tectonic overview maps of the surroundings of Wildenfels (scale of 1 : 15,000) and the Wildenfels limestone deposit (scale of 1 : 4,000) are included in the publication. Previously unpublished abridged borehole logs from selected major boreholes (for instance, by the SDAG Wismut mining company) complete the publication.



Report on resources situation in Germany2012
(PDF, 14 MB , German):
www.bgr.bund.de/rohstoffsituationsbericht-2012

Report on resources situation in Germany

BGR has published its latest report on the resources situation in Germany. Since 1980, this annual publication has provided information to policy makers and industry about current developments in raw materials production, foreign trade, price developments, and the consumption of mineral and energy resources. In addition, it looks at developments on international commodity markets. The report is available as a free download.



H. G. Hilpert, St.-A. Mildner (ed.):*Fragmentation or Cooperation in Global Resource Governance? A Comparative Analysis of the Raw Materials Strategies of the G20* (PDF, 1 MB)
www.bgr.bund.de/raw-materials-strategies-G20

Raw material strategies of the G-20 countries

“Fragmentation or cooperation?” is the title of a study published by BGR jointly with the German Institute for International and Security Affairs. In it, the scientists analyse the G-20 countries’ resources strategies. The study focuses on exploring the opportunities and challenges of greater international cooperation concerning mineral resources. It is available for download from the BGR website, both in German and in English.



Languages (DVD):
German, English, French,
Spanish

Contents:
Water Cycle, film (mp4: all languages),
Water Cycle, poster (PDF: all languages),
Description of the water cycle (PDF: German,
Spanish, French),
The Long Trip, story (PDF: all languages)
www.bgr.bund.de/Watercomic

Water Cycle DVD reloaded

This five-minute film is the animated version of the first story – The Long Trip – in The Worldwide Adventures of Droppy comic. During their exciting journey, Droppy and his water droplet friends experience the Earth’s water cycle. The German version has been translated into English, French and Spanish.

All four films can be found on the free DVD, which also includes additional material. To obtain the DVD, please send an e-mail to Vertrieb@bgr.de or download the film and accompanying material for free from the BGR website.

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About BGR

The Federal Institute for Geosciences and Natural Resources (BGR) is a higher-level technical and scientific federal agency that reports to the German Federal Ministry for Economic Affairs and Energy (BMWi). In its role as Germany’s centre for geoscientific expertise, BGR advises and informs the federal government and German industry on all questions relating to geosciences and natural resources. BGR’s work facilitates the security, and economically and ecologically compatible utilisation of natural resources, and thus the provision of basic needs. In its role as Germany’s national geological service, BGR participates in numerous international duties. At home, it assumes predominantly coordinating functions. Together with the State Authority of Mining, Energy and Geology (LBEG) and the Leibniz Institute for Applied Geophysics (LIAG), BGR forms the GEOZENTRUM Hannover.

BGR Report

The PDF-version can be downloaded from:



www.bgr.bund.de/Report2013_en

www.bgr.bund.de

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