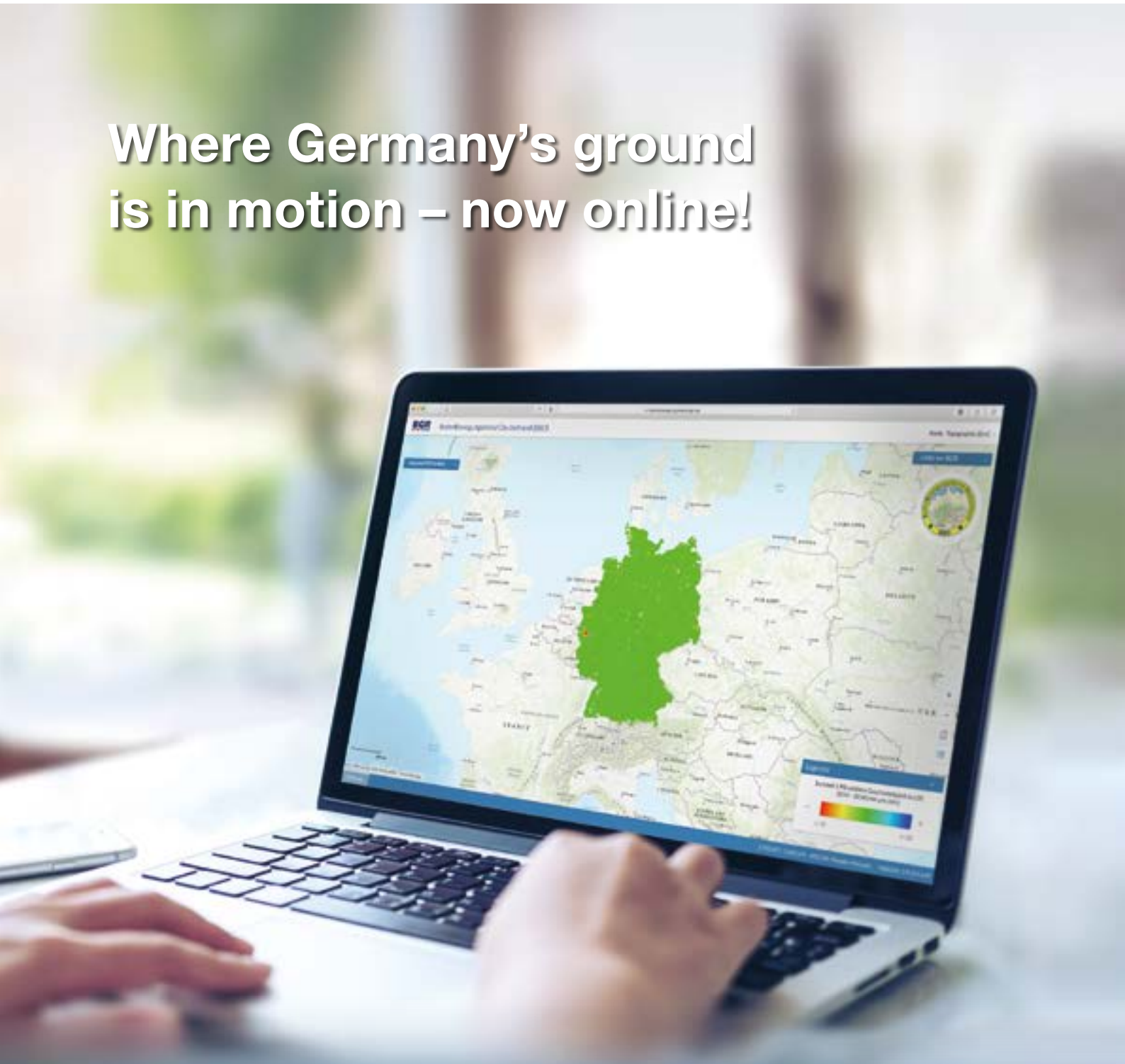
# BGR Report

FEDERAL INSTITUTE FOR GEOSCIENCES AND NATURAL RESOURCES **APRIL 2021**

## Where Germany's ground is in motion – now online!



**STRATEGY BGR 2025+**
A new strategy for urgent challenges, page 6

**FINAL DISPOSAL**
Quality assurance in final disposal research, page 32

**INTERNATIONAL COOPERATION**
60 years of technical cooperation with Jordan, page 34

# Imprint



**Contact**
Federal Institute for Geosciences and Natural Resources
Stilleweg 2
30655 Hannover
Telephone: +49 (0)511 643 0
Telefax: +49 (2304)511 643 0
Email: info@bgr.de
www.bgr.bund.de

**Editors**
Sina Vollbrecht (responsible for content)
Andreas Beuge
Claudia Blume

**Assistant editors**
Sonja Göcke
Dr. Ralf Klingbeil†
Bettina Landsmann
Dr. Rüdiger Lutz
Dr. Marc Filip Wiechmann

**Texts**
Dr. rer. nat. Tamara Worzewski

**Layout**
René Winkler Grafik Design

**Print**
Linden-Druck Verlagsgesellschaft mbH
Printed on 100% recycled paper, FSC certified. It was produced using electricity from renewable energy sources, with inks from renewable resources and odourless print coatings.

**Image sources**
Figures and photographs with no named source were produced or taken by BGR staff.

Author photos: BGR/BILDKRAFTWERK/Weiler, exceptions: Ms Rebscher, Mr Günther, Mr May (private);
p. 1: Farknot_Architect iStock; p. 3: Stocktrek Images/Getty Images; p. 8, 2. Images from top: Zukunft ERDGAS iStock;
pp. 20/21: LBEG, Dr. Stefan Frank; p. 23: Norsk Elektro Optikk (Norway); pp. 24/25: ESA 2014;
p. 36 bottom: Jozef August „Seppe“ Deckers; p. 42: Hoffotographen; p. 44, left: Heinke Träger; p. 45, right: IODP

This brochure is provided free of charge and may be requested from: info@bgr.de

**Month of publication**
April 2021

**This BGR report presents BGR projects and work from the years 2018 to 2020.**

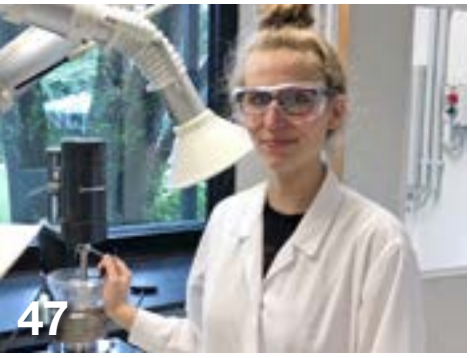
ISSN 2364-7736

# Planet Earth represents the basis for all our lives, its resources are limited.

This is why BGR is committed to protecting the human habitat and promoting the sustainable use of natural resources.

# Contents



# Editorial

**Prof. Dr. Ralph Watzel,**
President of the Federal Institute for Geosciences and Natural Resources

## *Dear Readers,*

*with the addition of the Ground Motion Service Germany (BodenBewegungsdienst Deutschland BBD) to its digital information offer, BGR delivers an important service to the general public: after complex validation procedures, extensive satellite surveys are made publicly accessible via a user friendly web application. This makes quantifiable geogenic and anthropogenic motion of the earth s surface visible throughout Germany. A useful and helpful service in view of the motion processes that are transmitted from the underlying geology to the surface of the earth – with various consequences such as uplift and subsidence, or landslides. BBD supplements conventional, terrestrial based monitoring techniques with observations from space. The cover story of the BGR Report,* ***Where Germany's ground is in motion – now online!*** *describes the complex technology behind the BBD (pages 24 27).*

*BGR's* ***Deutsche Rohstoffagentur*** *(DERA – German Mineral Resources Agency) has been advising companies on issues relating to the availability and sustainable use of mineral raw materials, as well as on current market developments, for 10 years. In a recent study, DERA delivered a comprehensive insight into China s raw materials industry, the most important actor on the international commodities markets. Read how it was possible to take a look behind the scenes of the world s largest producer and consumer of raw materials beginning on page 10.*

*BGR conducts important research in the quest for a safe final disposal of high radioactive waste. The issue of a final disposal, which is an extremely sensitive topic in our society, places special demands on this research and requires a high level of transparency and quality assurance. Read how BGR ensures the highest quality standards in research and the long-term verifiability of its results, among other things, beginning on page 32.*

*For 60 years – longer than any other German institution – BGR has been involved in technical cooperation with Jordan. Priorities have shifted considerably during this period. Today, BGR supports Jordan, which is one of the most arid countries in the world, on issues such as groundwater management and protection. The challenges facing Jordan here are discussed in the article beginning on page 34.*

*We have described how BGR is preparing for pressing future responsibilities in the geosector in the coming years in the new* ***BGR 2025+*** *action strategy, which we would also like to present to you in this report (pages 6 9).*

*I hope you have an enjoyable read!*

Strategy process kick-off event on 19 February 2018.

# BGR 2025+

## A NEW STRATEGY FOR URGENT CHALLENGES

Politics, business and society expect from BGR as the central geoscientific authority providing advice to the Federal Government in all geo-relevant questions, not only scientific insights, but also specific contributions – for example regarding the long-term security of the natural resource and energy supply or in sustainable georesource management. In order to better fulfill its mandate in the light of both national and international challenges, BGR has adjusted its spheres of action under the headline *BGR 2025+ – Strategy for the sustainable use of the earth's resources*. The primary objective of the thematic focus is to continue to identify the correct responses to urgent issues in the future.

The developments that influence our lives even in Germany and Europe include a steadily growing global population and increasing urbanisation, as well as globalised economic cycles, combined with partly very dynamic economic developments, especially in emerging economy countries. Added to this are the effects of climate change, the increased use of renewable energy sources and the issue of migration. All of these factors together increase the competition for, and pressure to exploit, the earth's natural resources.

It is against this backdrop that BGR has intensively discussed the strategic orientation of its objectives and responsibilities over the past two years, including incorporating the recommendations emerging from BGR's evaluation by the Science Council in 2017.

The *BGR 2025+* strategy is the result of a broad discourse within BGR. In 2018, BGR's President presented the initial strategic deliberations to the employees and then continued to develop them with the participation of the employees and the BGR Board of Trustees. At the end of 2019, the time had arrived: the new BGR strategy came into force once the Federal Ministry for Economic Affairs and Energy (*BMWi*) had given its approval and now forms the basis for further content-related orientation and task planning. It is regarded as a living document – that is, something to be continuously developed – and forms the thematic framework for our scientific work. This move was supported by *BMWi* in the shape of a new adaptation of the BGR's founding decree.

One of the primary objectives of BGR's work is to sustainably secure the natural basis for life and prosperity. Here, the focus is on the topics of water, food, energy and raw materials. In these subject areas, it is important to develop suitable forecasting and monitoring technologies and thus to identify reliable options for action which support decision-making processes in politics, business and society. This is underpinned by targeted networking with other institutions. For example, BGR collaborates with the state geological surveys of the German federal states and the EU member states, as well as numerous universities and research institutions, at national and international levels.

BGR President Ralph Watzel at the presentation of the interim results on 5 June 2018.

Colleagues discussing the topics at the kick-off event on 19 February 2018.

Colleagues discussing the topics at the kick-off event on 19 February 2018.

Copies of the BGR 2025+ strategy at the final presentation on 7 October 2019.

Discussion results on 19 February 2018.

The most important element of the work carried out by BGR scientists is data collection and analysis. To a large extent, self-developed analysis or survey methods are employed. Thus, BGR makes the physical and chemical properties of the geological subsurface accessible – including beneath the oceans – as well as the processes taking place there. BGR then utilises this knowledgeto classify different usage options and to identify methods to either reduce or prevent geohazards respectively. The need to develop adequate technologies to deliver the most reliable forecasts and impact assessments possible with regard to human interventions in the subsurface is highly visible. Special monitoring technologies also allow forecasts to be reviewed and – wherever necessary – new courses of action to be developed.

As a result of the global developments of recent decades, questions regarding the consequences of the human influence on georesources and the need for sustainable resource management have assumed a position of central importance. On one hand, growing global prosperity leads to expanding demands for *traditional* and new resources – particularly for energy supplies, including the necessary storage media, and for digital technology. In addition, in Germany and numerous other parts of the world, aftercare in mining regions is a focal issue. The objective of future BGR work is to focus scientific performance and consulting expertise on the decisive elements of the sustainable use of georesources and to produce added value through professional networking with regard to these topics.

The guiding principles of BGR's work are thus sustainability, responsibility and security. As far as possible, BGR adopts a holistic perspective in its projects. In addition to domestic legislation and the strategies of the Federal Government, the relevant programmes led by international organisations, such as the UN and the World Economic Forum, draw attention to the importance of sustainable resource use. They represent a mandate and an obligation to BGR, one of the key players in the field of georesources. ■

# THEMATIC EMPHASES OF THE *BGR 2025+* STRATEGY

**Mineral resources:**

- Expanding the global monitoring system, ore deposits research and cooperation
- Improving information on domestic mineral resources and mineral production
- Supporting good mining practice and efficient resource extraction as well as responsible mineral supply chains
- Exploration of marine mineral resources, including scientific research on the potential environmental impacts of commercial deep-sea mining

**Energy resources:**

- Securing supply – global and regional assessments of fossil fuel energy resources
- Environment impact studies of fossil fuel production

**Groundwater:**

- Providing spatial information for groundwater management and planning
- Evaluating groundwater potentials worldwide
- Further development of instruments for predicting the evolution of groundwater flows
- Strategies for groundwater use in arid regions and coastal zones
- Sustainable development of post-mining landscapes

**Soils:**

- Providing basic spatial information on soil for land-use planning and management
- Investigating properties of soil substances and processes in soils
- Assessing of soil functions for food security and resource protection
- Sustainable development of post-mining landscapes

**Final disposal of radioactive waste:**

- Characterising host rocks and geotechnical barriers
- Advising the project proponent BGE on implementing the site selection process for a future final disposal
- Developing a *safety case* for long-term safety
- Supporting exploration for the current sites at *Morsleben*, *Konrad* and the *Asse II* mine repositories

**Utilisation of the deeper subsurface:**

- Identifying potentials for storing energy from renewable sources
- Evaluating carbon dioxide storage potentials
- Developing methods for increased utilisation of geothermal energy

**Nuclear-test ban and geohazards:**

- Creating synergies in the function of a national data centre for verifying the nuclear-test ban and as the Federal Seismological Survey
- Developing strategies to increase the resilience of urban areas and other environments against natural hazards
- Operating Ground Motion Service Germany (BodenBewegungsdienst Deutschland BBD) and advising Copernicus based European Ground Motion Service

**International geoscientific cooperation:**

- Stronger participation in international collaborations and programmes
- Developing consulting expertise in development cooperation
- Continuing geoscientific research in the Antarctic (within the framework of the Antarctic Treaty System) and the Arctic (including its resource potentials and associated environmental research)

**Technical cross-sectional tasks:**

- Further development of existing scientific infrastructure
- Deploying and developing cross-scale and cross-topic methodologies
- Increasing the use and development of machine learning and artificial intelligence potentials
- Expanding geodata infrastructure

**The complete strategy:**
www.bgr.bund.de/bgr2025

# NEW INSIGHTS INTO CHINA'S RAW MATERIALS INDUSTRY

Interview with Dr. Yun Schüler-Zhou from the German Mineral Resources Agency, who conducted in-depth research into the world's largest consumer and producer of raw materials.

China is increasingly aligning its economic model in favour of sustainable growth, and is thus changing the conditions for the development of its raw materials sector. It was previously almost impossible to estimate what consequences these natural-resource policy measures would have for the global raw materials markets. The German Mineral Resources Agency (DERA) at BGR, which acts as the raw materials industry competence centre, and is the key information and consultancy platform for German industry, therefore decided to tackle the complex analysis of the overall situation. Its study was published in September, and contains a unique and comprehensive insights into the structure of China's raw materials industry.

**Dr. Schüler-Zhou, how did this study come about in the first place, and what does it look at?**

There was a great deal of interest from several directions because China is very difficult for many to comprehend: the market mechanism functions in a different way to Germany's, and its industry is still undergoing a transformation process. As a result, the political, economic and environmental conditions are changing continuously. The aim of this general study is therefore to provide insight into the economic system, and the interrelations with the raw materials industry in China. It sheds light on how the paradigm shift in China's economic and industrial policies affect raw materials consumption, and the production of the non-ferrous metals in the country. These consequences have a direct impact on the global raw materials markets because China has been the largest consumer of raw materials since 2002, and is by far the largest producer of refined goods: being responsible for half of global refinery production.

**Your DERA study, which is over 100 pages long, and which was conducted in co-operation with the German Chamber of Commerce in Beijing, contains numerous diagrams, tables and detailed explanations of the overall raw materials industry structures in China. What was the main challenge in compiling this comprehensive overview?**

The main challenge is that there are only a few scientific studies focused specifically on China's raw materials sector – it is a sensitive industry, which has so far hardly been analysed in detail. This means that one needs to look personally at a huge number of original documents written in Chinese, and talk to a lot of people within the country, to gain any insight at all into the overall raw materials industry structure in China.

**China has been increasingly focusing its economy on sustainability since at least the change in leadership in**

The Lala copper mine operated by the mining company Chinalco in the Chinese province Sichuan.

**2013. Have you seen any specific effects on the supply of raw materials since then?**

The strong focus on sustainability in the Chinese metals industry frequently led to short-term shortages in mine and refinery production in the past, which in turn led to price volatility on the raw materials markets. In addition, it also alters the structure of the sector in the long term, and the more stringent environmental regulations give rise to higher production costs. We also observe that the refinery production of non-ferrous metals (excluding some high-tech metals) has been growing much more slowly overall since 2013: from 2006 to 2010, the average annual growth rate was almost 14%, but this dropped to below 5% from 2016 onwards. Investment in the exploration and extraction of raw materials has also declined overall since 2013.

**So how has this affected demand?**

The economic re-alignment led to a differentiation in the development of demand for raw materials. The strength of China's economic growth has been declining for several years. This means that the growth in demand for base metals is much slower than it was in the past, whilst there has been an increasing demand for high-tech metals, such as lithium, cobalt and magnesium. The refinery consumption of non-ferrous metals overall (excluding high-tech metals) is also growing much more slowly: from 15.5% between 2006 and 2010, to probably only 4.1% between 2016 and 2020. On the global market, China is increasingly competing with the EU and the USA for access to raw materials for future technologies.

**What strategy is China pursuing to meet its growing demand for these sought-after metals, and how is it reforming its raw materials industry?**

To safeguard the supplies of raw materials for the downstream manufacturing industries, China is pursuing a two-pillar raw materials policy. On the one hand, Chinese companies are increasing the amount they invest abroad, and on the other hand, domestic raw materials production is also maintained. This puts the country in the position to dominate entire value-added chains. In addition, the whole domestic raw materials sector is being modernised and consolidated. We also observe reform measures such as the scaling back of over-capacities, increased investment in R&D, and a rise in environmental and social standards.

**What does the re-aligned Chinese economic policy mean for German industry?**

Opportunities as well as risks: on the one hand, the technical modernisation of the mining and raw materials processing industries, as well as the improvement in environmental standards, open up new sales opportunities for German mechanical engineering companies and suppliers of environmental technologies. On the other hand, China increasingly intends to use strategically important raw materials for its own industrial production, and to fabricate higher quality products. This can affect the supply of raw materials to German industry, and lead to more intense competition. Closer co-operation between Germany and China is essential – especially when it comes to sustainability issues. ■

**Dr. Yun Schüler-Zhou**
B1.1 German Mineral Resources Agency, DERA

✉ Yun.Schueler-Zhou@bgr.de

# OUR SOILS: THE CHANGING FOUNDATION OF LIFE

How much impact can Germany‘s soils withstand? BGR analyses soil humus storage and the future effects of climate change on the long-term usability of soils.

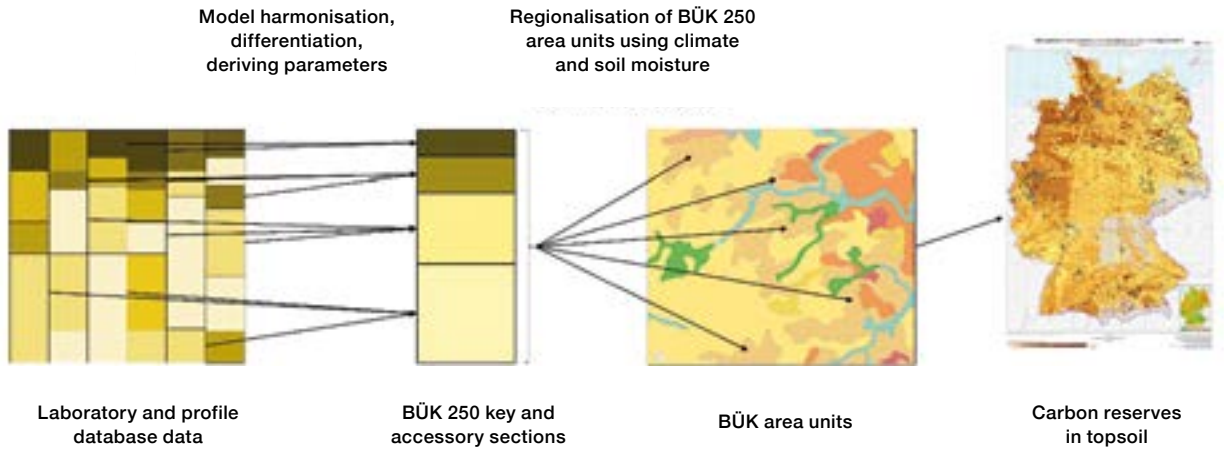
Soils are true marvels: they form the basis for our food production and serve as habitats for flora and fauna. Soils store water, filter pollutants and even store more carbon in their organic matter than all of the aboveground vegetation together. Soils are thus carbon sinks, but they can also release carbon when they dry out and become a carbon source – and this makes them climate-relevant.

How exactly soils function, for example how they store and filter nutrients or water, is a complex matter. Key parameters for understanding these processes are soil moisture and carbon content, which in turn depend on other parameters such as precipitation, the soil water balance or the soil type. These key parameters are, among other things, essential for agricultural planning; however, they are not only altered in the long term by humans in their use of the land, but also by climate change.

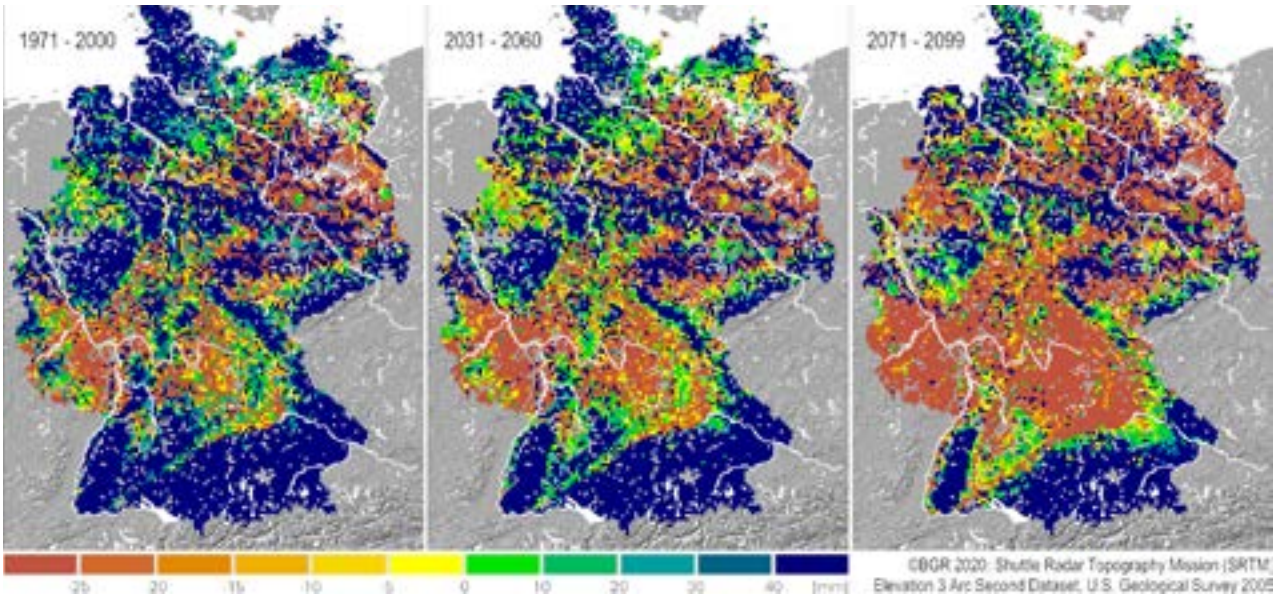
“Climate change rises additional challenges, for which adaptation strategies must be developed”, says Dr. Andreas Möller, whose research focus is on soil organic matter as a key factor for soil functions such as soil fertility, carbon storage and habitat. “To achieve this, the complex relationships within the soil must be elucidated and utilised as baseline data for advising politics and society.” The soil expert has been investigating the relationships between environmental influences and soil organic matter – in other words: humus – for many years. Humus is a guarantee for healthy soil. It is a nutrient storage, water reservoir, food for microorganisms and it loosens the soil, allowing it to absorb rain and breathe better. In close cooperation with the state geological surveys (*Staatliche Geologische Dienste* – SGD) of the federal states, Möller is now developing a detailed soil carbon model for the whole of Germany based on 106,000 soil samples from laboratory and profile data.

The complex data is prepared in several steps: first, the localised point data from all SGD’s must be harmonised and and quality controlled. Möller then assigns the harmonised point data to the profiles representative of the area units according to strict criteria and thus to the areas on a *generalised soil map* (BÜK 250) – an expert based soil map, mapped by the individual SDG’s (see figure below). The resulting generalised map shows the distribution of organic carbon stocks (a measure of humus) throughout Germany, as a mean over the last few decades.

Sina Schulz, in contrast, looks to the future. The geologist and pedologist develops methods to measure the vulnerability of soil functions to climate change impacts. “The anticipated climatic changes also influence the long-term usability of soils”, explains the scientist from BGR’s Berlin branch. “This applies to both cultivation options, and agricultural and forestry yields.”




Schematic of the method of deriving organic carbon stocks, a measure of humus content.




Water balance of soils in summer calculated using climate scenario data. Soils that are already dry (red areas) are likely to be even more extensive and drier in the future.

*"It is important to conserve soils as the basis of our lives, so that future generations can also benefit from this precious resource."*

Dr. Andreas Möller

Schulz creates maps of the distribution of soils and their properties for the whole of Germany and combines them with selected climate scenario data from Germany's National Meteorological Service. Using the forecast temperature, precipitation, wind speed and evaporation data, she models the soil's reaction to altered environmental conditions. Her evaluation show important parameters for soil productivity and soil hazards: the effective water balance in summer (see figure above), the potential soil erosion risk by water on arable soils and the annual percolation rate.

These and similar key data are used in policy making, agriculture and industry as a basis for decision-making in numerous problems, including soil conservation. For example, the percolation rate describes how much water seeps into the soil and exits the root zone, and represents a quantitative measure of groundwater recharge. In addition, qualitative statements about the contaminant load can be derived because soil characteristics and the length of time water remains within the soil define how well a soil fulfils its filter function.

So soil conservation is an investment in the future, as Möller summarises: "It is important to protect soils as the basis of our lives, so that future generations can also benefit from this precious resource." ■

**Sina Schulz**
B2.2 Basic Information Groundwater and Soil

✉ Sina.Schulz@bgr.de

**Dr. Andreas Möller**
B2.4 Soil as a Resource – Properties and Dynamics

✉ Andreas.Moeller@bgr.de

# PRODUCING USEFUL INFORMATION FOR EUROPE

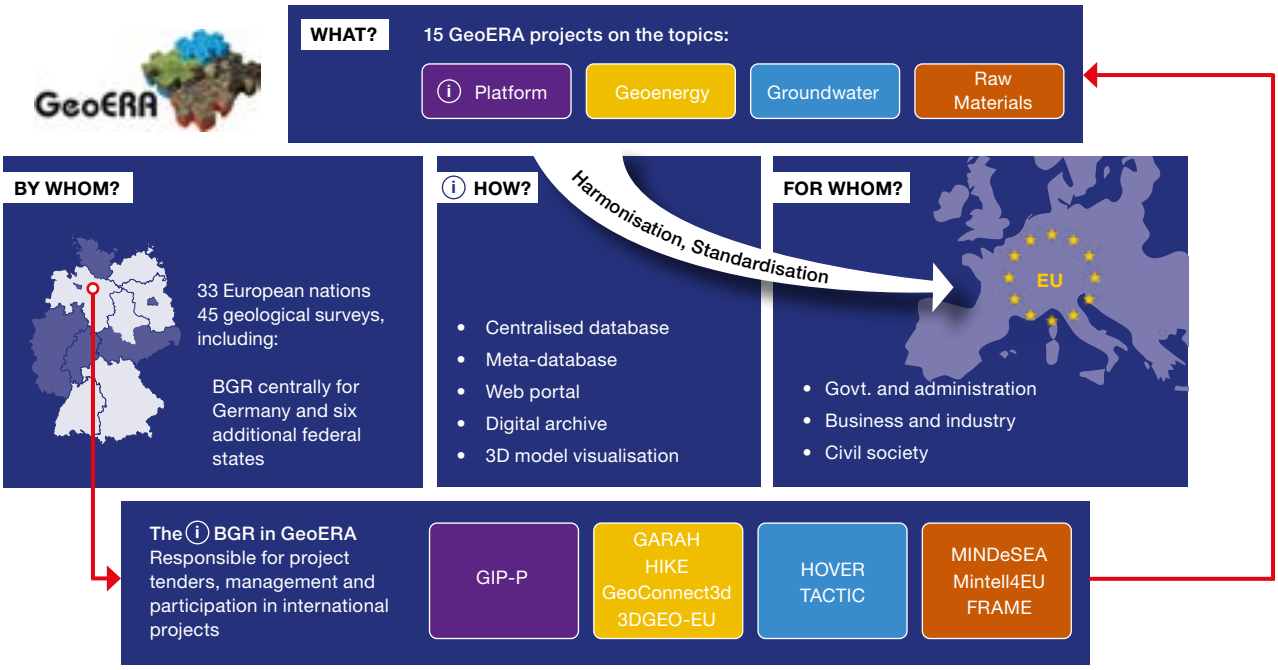
What resources can Europe and the EU actually call their own? The EU Commission funds the *GeoERA* collaborative project and explores Europe's geopotentials in order to identify potential resources. BGR is involved in this project, the largest collaboration of European geological surveys so far. Jörg-Uwe Damm explains the background in this interview. He has been coordinating BGR's participation in the collaborative project since 2015.

**Mr. Damm, there is a well-known saying that Geology does not stop at political borders, but it doesn't often appear that way when you look at different maps, right?**
If the geological information for two neighbouring countries is compared, one in fact often stumbles across major inconsistencies along the borders which, among other things, make it difficult to consistently evaluate geopotentials across those borders. In Germany, this is generally the result of data incompatibility between the federal states or, in Europe, between the different states: the geodata are not *harmonised*.

**Why have no *harmonised* data been available to date and why should this change now?**
The data structures are heterogeneous and have evolved historically. Data harmonisation and standardisation are the challenges of the day. However, EU nations are now united by a common, significant interest: in order to guarantee supply security, the aim is to identify Europe's own resources. This also includes transnational environmental protection and guaranteeing the supply of clean drinking water.

**In the context of a five-year EU funding programme, a total of 45 geological surveys from 33 nations came together in 2017 to form the *GeoERA* network. What are you doing?**
The geological surveys are currently jointly running 15 projects on the four topics of geoenergy, groundwater, natural resources and information platforms in order to provide new and harmonised information offers across national borders. The geological surveys have never

BGR's role in GeoERA




GeoERA is an EU project in the *Horizon2020* research and innovation programme. www.geoera.eu

In search of natural resources: mining spoil tips can contain valuable resources.

before come together in such large numbers to address joint actions.

**You coordinate BGR's part in the GeoERA project. What role does BGR play in this?**

BGR is currently working on various levels with its national and international GeoERA partners. For example, it leads the *3DGEO-EU* project which, among other things, serves to establish a uniform and standardised information platform. Here, BGR tests and improves 3D geospatial subsurface model harmonisation methods, together with both the state geological surveys of the German federal states and with those of its neighbouring European countries. The objective is to be able to correctly visualise and interpret transnational geology.

**What exactly is BGR doing in terms of the information platform?**

Among other things, it participates in what is known as the GIP-P project. Technical infrastructure for storing project data is being developed here, meaning the data can also be subsequently utilised by a broader group of users: for business, research, administration or interested citizens (also see *The nerve fibre of BGR's research and consulting services*).

**And what is BGR doing in the other subject areas of groundwater and natural resources?**

Here, too, BGR is actively involved and helps coordinate various international research projects. Geospatial data is collected, existing data processed, digitised, harmonised and transferred to the European platform, or new standardised databases established. This means that new maps, a web portal with thesauruses and uniformly interpretable data are also created.

**OVERVIEW OF BGR'S EU PROJECT PARTICIPATION**

- ANCORELOG – Analytical Core Logging System
- ENOS – Enabling Onshore $CO_2$ Storage in Europe
- EURAD – European Joint Programme on Radioactive Waste Management
- BEACON – Bentonite Mechanical Evolution
- KARMA – Karst Aquifer Resources Availability and Quality in the Mediterranean Area
- MiningImpact – Environmental Impacts and Risks of Deep-Sea Mining
- TOPSOIL – The climate challenge in the near subsurface

**Will this information be used by the EU as a basis for decision-making?**

Yes, precisely, but not only that: the EU possesses an extensive administrative apparatus and naturally also wishes to disseminate geological information at the EU level. However, because the EU does not possess its own geospatial data, it is dependent on the individual nations making theirs available. Thanks to the standardised data deliveries, GeoERA, in the 8th European research funding programme (*Horizon2020*), makes comprehensive access to joint geo-platforms possible. ■

**Jörg-Uwe Damm**
B4 Geoscientific Information, International Cooperation

Joerg-Uwe.Damm@bgr.de
www.geoera.eu

# THE NERVE FIBRE OF BGR'S RESEARCH AND CONSULTING SERVICES

BGR data management develops innovative geoinformation infrastructures and accelerates knowledge transfer: cross-linked, standardised data are accessible at any time.

If you need geoscientific data from BGR, there is no way around Tanja Wodtke. She is well-known in the Federal Institute, or at least what the data manager stands for is: innovation, standardisation and a weakness for technical progress. The data from various research groups and disciplines converge in BGR's geo-data infrastructure (*GDI-BGR*), which she controls – "like individual nerve fibres", explains the data manager. "Here, the data is harmonised and bundled into a nerve cord for research and consulting services." If specialist information systems are established or further developed at BGR – Tanja Wodtke and her team are on hand to advise.

The department has been managing internal and external data provision at BGR for a decade. Together with the specialist colleagues, the team creates internal requirement profiles, advises on the structure of the desired system and supports its technological design. The geodata management department recently designed the technological infrastructure for the new ground motion service (see cover feature: *Where Germany's ground is in motion – now online!*) – based on what is referred to as the Geoviewer. "This Geoviewer is the visualisation component of BGR's digital products and, together with the central product catalogue, forms the heart of the *GDI-BGR*", explains Tanja Wodtke. "Thanks to these digital tools, the federal government, the scientific community, businesses and the general public have easy access to geodata, raw data and research results", she says and also points out the intensive networking with national and international infrastructures thanks to a modern service architecture (see figure). To make the data available, Wodtke's team designed an open, reliable and trustworthy knowledge resource based on the *FAIR* principle. This ensures that data is made available in a Findable, Accessible, Interoperable and Reusable manner.

Comprehensive consultation, such as that offered by geodata management, would have been unthinkable before digitisation. "It wasn't too long ago that geodata were recorded by hand and on paper, or that research results were only published in expensive books", recalls Tanja Wodtke. At the same time, BGR's knowledge is now bundled through many new channels, directly and free of charge to the partners and users of the sophisticated geodata infrastructure. The benefit is accelerated knowledge transfer, and automatic database and map updating for everyone at any time. ■

**Tanja Wodtke**
B4.2 Geoinformation, Stratigraphy

Tanja.Wodtke@bgr.de


The GDI-BGR in a national and international context.

One of the high pressure reactors used.

Research on the H2_ReacT project in the high-pressure laboratory.

# HYDROGEN REACTIONS IN HIGH-PRESSURE REACTORS

Can large volumes of hydrogen be stored in the subsurface? The energy transition demands storage options for renewable energy. BGR is investigating geological storage options.

Ten special tanks are located in a BGR high-pressure laboratory: in these extremely thick-walled pressure vessels, the potential reactivity of hydrogen ($H_2$) when stored in underground rocks is investigated.

Safety precautions must be taken in the laboratory due to the presence of atmospheric oxygen: gas warning systems report any possible $H_2$ leakage and automated safety shutdowns can close down the system if conspicuous changes in temperature and pressure occur. Only specialist staff have access here, as Dr. Christian Ostertag-Henning, the laboratory manager wearing safety glasses and a white coat, explains. “Pressures hundreds of times greater than atmospheric pressure and hydrogen are two things that must be meticulously managed”, explains the geologist. His rock samples remain in the specially developed high-pressure vessels for days or months together with hydrogen gas, under conditions that also prevail at depths of one to three kilometres. This is because large volumes of hydrogen from renewable energy sources could be temporarily stored in sandstone pores or salt caverns at these depths – as an energy carrier for converted excess wind or solar energy.

“Our team is really excited about carrying out research for such an enormously relevant project”, says the team leader. The need for research is urgent, because it is assumed that the reactive $H_2$ in the surrounding sandstone may cause some minerals to dissolve and others to form. Other experts also fear hydrogen biodegradation: “Microorganisms living underground can also consume $H_2$”, adds Dr. Martin Krüger, head of the neighbouring laboratory. In his tanks, the microbiologist experiments with bacteria: “It would be disadvantageous to operations if underground microorganisms were to consume the stored $H_2$ and then reduce permeability in the storage system due to growing biofilms.”

In countless experiments, the teams investigate microbiological and geochemical $H_2$ reactions. Their results are central to future evaluations of storage structures with regard to their suitability as underground hydrogen storage facilities, because they define criteria to be avoided: $H_2$ is only converted microbially under specific conditions and only reacts with a few minerals, in particular those containing iron. Ostertag-Henning and Krüger summarise: “In general, the possibility of storing hydrogen underground in Germany looks very promising!” ■

**Dr. Christian Ostertag-Henning**
B1.5 Resource Geochemistry

✉ Christian.Ostertag-Henning@bgr.de

**Dr. Martin Krüger**
B1.5 Resource Geochemistry

✉ Martin.Krueger@bgr.de

# TRACKING DOWN NORTH SEA METHANE

Does the greenhouse gas methane leak from abandoned wells? In an interdisciplinary pilot project, BGR is investigating the German sector of the central North Sea and is finding methane leaks, at least outside the wells.

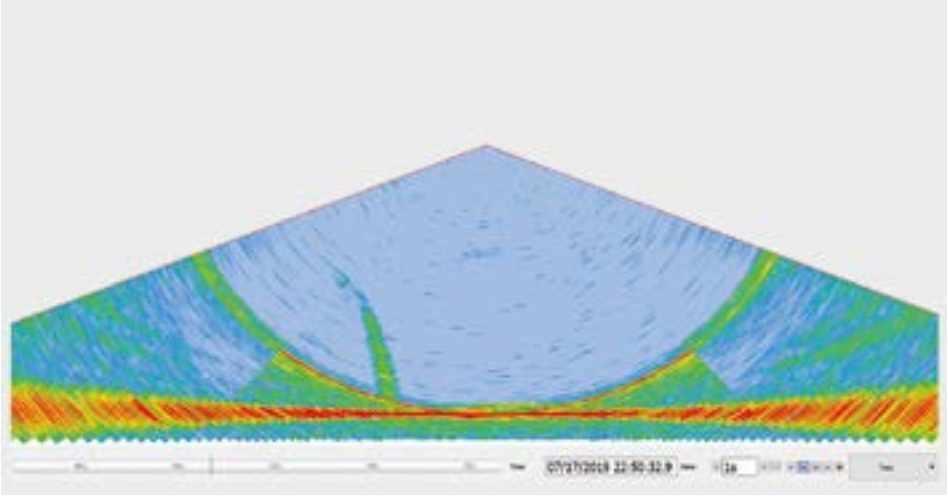
The wind lashes in the face, the waves washing on board soak the safety shoes. In these conditions, you can easily feel dizzy when working on deck and in the laboratory. Wind force 8 may not be unusual in the North Sea nor problematic for the German research vessel RV Heincke. However, some of the heavy and bulky instruments must wait for better weather conditions before it is safe enough to redeploy them to the seafloor. Only the hydroacoustics are currently operating: Like bats using sound waves for orientation, the multibeam echosounder installed beneath the ship's hull emits a swath of acoustic waves at selected frequencies, which are sensitive to detect gas bubbles leaking from the seafloor.

Methane is the second most important greenhouse gas after $CO_2$ and has its origins in both anthropogenic and natural processes. Small portions of methane are known to escape during oil and gas production and possibly from abandoned wells, which are recently increasing public interest. Methane can also be released during drilling processes, for example when penetrating gas-bearing layers. "However, it remains unclear how common these gas releases are, and how much gas is escaping along which pathways – also in comparison to natural seepage from the seafloor", explains Dr. Martin Blumenberg, head of the current BGR pilot project on North Sea methane sources. The geochemist wants to closely examine methane leaks in the duck's bill (german Entenschnabel), an area of the German North Sea sector where little is known about methane seeps.

With this in mind, Blumenberg sets sail on RV Heincke in summer 2019 with a team of 24 including the ship's crew and colleagues from BGR, MARUM Bremen, GEOMAR Kiel and GFZ Potsdam.

As the storm is ongoingly raging, BGR's chief scientist of the cruise Dr. Katrin Schwalenberg finally cancels also the hydroacoustic survey given that the data are too noisy to be useful. "All you can do is lie in your bunk", says the geophysicist, who is otherwise constantly coordinating, surveying or mediating between the deck crew, officers on the bridge and the scientific staff. It is a short break on RV Heincke as the scientific program usually

GOLDEN EYE in action in the North Sea on the research vessel RV Heincke. BGR's own deep-sea platform is equipped with cameras, various electromagnetic sensor systems and navigation instruments.



Section through a multibeam snapshot. Clearly discernible: a flare (gas leak) consisting of ascending methane gas bubbles.

runs 24/7 for the various disciplines and experiments. "The aim of our interdisciplinary approach is to use a variety of oceanographic, geophysical and geochemical methods to investigate the water column, the sea floor and the upper sediment layers", explains Katrin Schwalenberg and specifies: "We are searching for indicators of methane leaks and gas accumulations in the sediment around abandoned wells."

During the day, water and sediment samples are collected using a *rosette water sampler* and a *mini-multicorer*, and are analysed for methane and other hydrocarbons in the ship's geochemical laboratory.

Geophysical measurements are taken with the BGR-owned GOLDEN EYE electromagnetic surveying system, which reminds of a giant, bright yellow-colored film reel and MARUM's NERIDIS electromagnetic surveying sled. Both operate similar to metal detectors, imaging changes in the electrical conductivity, in this case of the seafloor. "Gas is electrically resistive and can be detected in our data where it accumulates in sufficient volumes", explains BGR scientist Dr. Hendrik Müller, who analyses the electromagnetic data sets.

Nighttimes are reserved to run the hydroacoustic systems in order to identify the highly reflective gas bubbles in the water column and the sediment. It gets tedious starring at the monitor hours for hours ready to capture the next gas flare which will appear only for a second on the screen. However, MARUM researcher Dr. Miriam Römer reports almost daily new, previously unknown gas flares in the target area. The new discoveries also guide the planning for the following geochemical sampling sites and geophysical surveys.

Every morning BGR's dual leadership of chief scientist and project manager head for the hydroacoustic watchkeepers on the bridge reporting on the latest discoveries of the past night. Together with the geophysical and geochemical investigations a pleasant overall picture gradually forms.

"We couldn't see any methane leaking around the investigated wells – that is good news!", Katrin Schwalenberg summarizes the preliminary outcome. Minor gas escapes cannot be completely ruled out. However, at least for the visited nine out of about 200 abandoned wells in the German North Sea she states: "We haven't observed elevated methane concentrations or accumulations of gas flares close to the wells."

Instead, the scientists recorded increased methane concentrations in individual clusters at distance from the abandoned wells. Even though Blumenberg has seen natural methane leaks in a number of other ocean areas, this findings are remarkable. "The large number of gas leaks in a relatively limited area is surprising", says the project manager and relates: „Compared to other sectors, e.g. the livestock industry, these methane leaks seem to play a minor role."

New questions arise from the outcomes of the expedition, for example what is the origin and spatial extent of these methane sources and do they depend on the tidal cycle? Blumenberg is hoping for a larger-scale follow-up expedition in the central North Sea as there is controversial demand for further research of methane leaks: "Understanding possible methane leaking from wells remains extremely important in a world that increasingly relies on natural gas as a bridge technology." ■

**Dr. Martin Blumenberg**
B1.5 Resource Geochemistry

✉ Martin.Blumenberg@bgr.de

**Dr. Katrin Schwalenberg**
B1.4 Marine Resource Exploration

✉ Katrin.Schwalenberg@bgr.de

# THE SHAPE OF THE BOGS: REVEALED ON THE FLY!

Because they store carbon, bogs are climate-relevant. The stored peat volume depends on the extent and depth of the bog. A new combination of existing BGR helicopter survey techniques now demonstrates how comprehensive airborne geophysical bog depth mapping will be possible in the future.

During fieldwork, Dr. Bernhard Siemon always has three personal highlights: first, when the BGR helicopter takes off with its specialised surveying instruments. What is known as a gamma spectrometer, which measures natural radioactivity in a similar way to a high-tech Geiger counter, is on board. Far below the helicopter hangs a 300 kilogram, cigar-shaped airborne probe about 10 metres long, which sends out and receives electromagnetic signals similar to a metal detector.

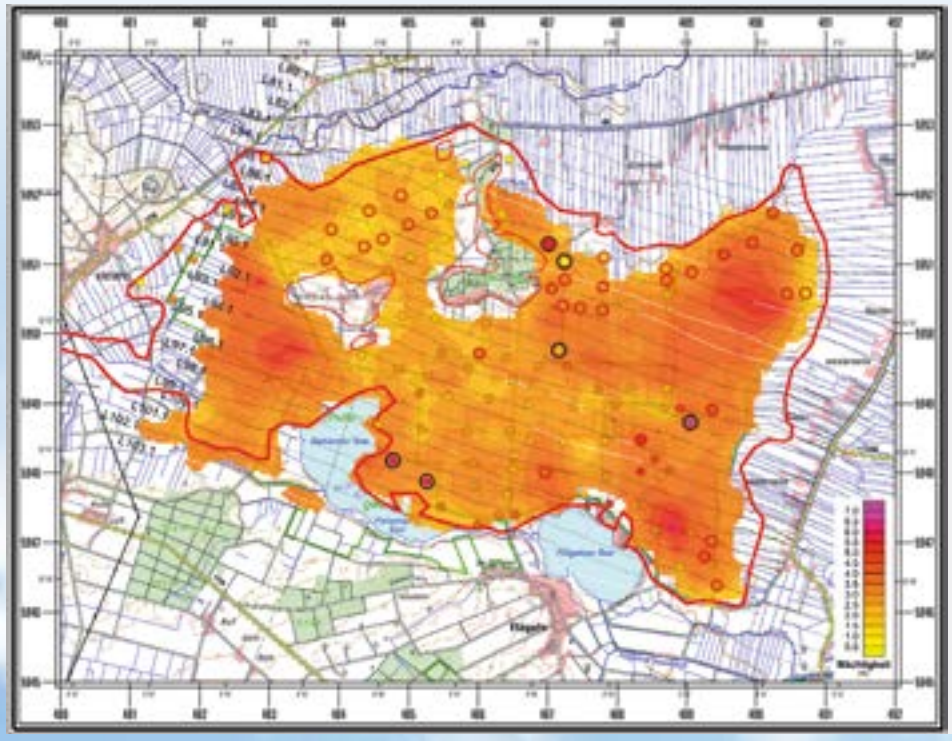
The second highlight for the head of unit is the landing after the systematic flight over the survey area. Flying itself is less exciting, it even makes some people feel ill, because the ascent and descent necessary for this survey method can affect the stomach in a similar way to being in an elevator. However, Siemon's third highlight stands out from the others: that is, when the geophysicist can view the initial survey data while still in the field. "The survey data, which look like brain waves, can be converted into preliminary maps in the field", explains the geophysicist and enthuses: "The first rough image of the subsurface – that gets an 'Ahh!' every time".

Following the fieldwork, the most complex part of the job begins: thorough data analysis. Siemon's working group looked for old electromagnetic survey data from 2004, which had originally been acquired in northern Germany to investigate groundwater salinisation. Almost 15 years later, the working group is now using this *Hadelner Marsch* data to delve into the boggy region – or more precisely: to get to the bottom of the bog.

Bogs have an important role to play in climate protection. Intact bogs are active carbon stores and when they dry out, greenhouse gases are released (also see *Our soils: the changing foundation of life*). Good knowledge of the lateral extent and depth of bogs is therefore essential. However, because progress would be slow using only scattered boreholes drilled down to the bottom of the bogs, considering the large number involved, the question arose: can the more efficient airborne geophysical methods also determine the lateral extent and the subsurface beneath large bog areas?

In order to investigate this, Siemon's team combined, for the first time, the survey data acquired using two different methods: airborne radiometry and airborne electromagnetics. Airborne radiometry utilises a 100 kg gamma spectrometer of the size of a washing basket to measure natural gamma rays originating in the subsurface, among other places (also see *Difficult drone deployment*). Because water absorbs gamma rays, this high-tech Geiger counter detects comparatively lower radiation values over wetlands, while they are substantially higher

BGR helicopter with airborne probe over the *Ahlen-Falkenberger Moor*.



Map of the bog thickness derived from airborne geophysics at the *Ahlen-Falkenberger Moor* compared at boreholes (dots).

in the surrounding dry areas. Following the complex correction of numerous interfering signals, such as cosmic background radiation or the natural radiation of the helicopter, airborne radiometry enables large-scale mapping of boggy regions – at least as far as the lateral extent is concerned. Siemon's team uses electromagnetic (EM) data to estimate the depths of the bog. In airborne electromagnetics, several coils emit low-frequency EM signals that penetrate the ground. Similar to a metal detector, EM response signals are generated that contain information about the electrical conductivity structure of the subsurface (also see *Tracking down North Sea methane*). In this way, the bog depths can finally be modelled by means of complex data analysis, because saturated peat is often more conductive than the predominantly sandy or partly clayey underlying sediment.

The methods complement each other perfectly: "The EM data provide the depth of the bog floor, but do not provide any clear information on the lateral extent in these survey areas", summarises Siemon. "The bogs here are surrounded by similarly conductive marshland – the electromagnetics cannot differentiate this. We therefore need the radiometric data to allow lateral delineation."

The new combination of methods is successful, as a comparison using 2007 data from around 100 boreholes of Lower Saxony's *Landesamt für Bergbau, Energie und Geologie* (LBEG) reveals: "On average, the airborne geo-physically acquired bog depths match the drilling results very well", says Siemon with satisfaction and summarises: "Information about the subsurface beneath the bogs can also be derived from the results of the electromagnetic surveys – whether it is composed of sand or clay, for example. The airborne geophysical results thus provide promising initial insights for non-contact mapping of large bog areas." ■

**Dr. Bernhard Siemon**
B2.1 Geophysical Exploration – Technical Mineralogy

✉ Bernhard.Siemon@bgr.de

# DIFFICULT DRONE DEPLOYMENT

Drones collect information efficiently and across the board and are indispensable for field operations in difficult-to-access or dangerous regions. However, this is not without its challenges. BGR develops innovative methods and new instruments for unmanned geoscientific exploration.

In Arctic temperatures, the photogrammetry drone slowly screws its way upwards. The monotonous whirring of the quadrocopter mingles with the gentle background noise of Spitzbergen's treeless tundra at 78° northern latitude. During its flight over the fjorded coast, the photogrammetry drone delivers important data for a high-resolution terrain model thanks to its special camera. Here, the landscape is rapidly changing as a result of intensified global warming in the Arctic. The thawing permafrost leads to the mobilisation of rock masses. If large masses of rock fall into the fjord, they can generate tsunamis, presenting a hazard to populated coastal areas. For the geologist Dr. Jewgenij Torizin, who is conducting the investigations with his colleagues, Svalbard is the ideal laboratory for studying how climate change can trigger mass movements.

But the scientist now worriedly studies the sky: "Oh no – not again", groans Torizin when he sees the Arctic Skua heading for the drone. One of these gulls previously misled the drone's obstruction sensors. Only through manual intervention in the otherwise automatic surveying routine was Torizin and his colleague Dr. Michael Fuchs able to safely retrieve the drone. "That cost us a lot of time and nerves", the researcher recalls. "The battery charge is limited when working in the field, so every minute of the flight counts", says Torizin. In addition, the researchers only have this one special drone, the position of which can be determined to within a few centimetres thanks to a ground-based mobile station and what is known as Real Time Kinematics (RTK), with them on this field campaign.

RTK drone model of the Forkastningsfjellet investigation area in Svalbard.

The precision technical performance in no way impresses the Arctic skuas in their attempted attacks on the drone. "Typical behaviour for this species of bird that hunts other sea birds to steal their fish", the accompanying guide narrates the scene for the concerned BGR researchers and explains: "When pressed, the hunted birds drop their prey or regurgitate it."

This time, the drone remains firmly on course and the Arctic Skua moves away. Such unpredictable challenges can occasionally present themselves during field operations – the subsequent photogrammetric data analysis of the drone images is, however, largely automated: after only a few days, Torizin receives a high-resolution 3D terrain model.

The methods and surveying instruments are as complex as the BGR's fields of deployment. This also applies to the drones used by BGR for scientific studies. The equipment includes a thermal drone which, with the help of a thermal imaging camera, enables soil moisture to be determined over a wide area or can identify potential areas for geothermal energy use. With the new hyperspectral drone, in contrast, organic carbon and clay minerals in the ground can be explored, as well as potential mineral resource deposits. In the hyperspectral analysis employed here, sensors record the sunlight reflected from surfaces, allowing geoscientific information to be collected. A team led by geologist Dr. Martin Schodlok is currently developing application-oriented analysis methods also aimed at handling satellite data from future missions. This includes, in particular, the hyperspectral data from the EnMAP earth observation satellite funded by the Federal Ministry for Economic Affairs and Energy (*BMWi*).

The BGR drone expert Dr. Malte Ibs-von Seht describes the scientific approach: "The methodological developments cover all scales from the earth's surface to the satellite. Using the drones, we can survey faster and with less interference than on the ground, but at the same time more precisely than from a helicopter at greater elevation, for example. We use the drones for geoscientific exploration at home and abroad, and increasingly also in technical cooperation."


A hyperspectral drone in action.

**DRONE-BASED SURVEYING SYSTEMS AT BGR**

**Photogrammetry drone**
A 20 megapixel camera enables a basic resolution of 2.74 cm per pixel when recording from a height of 100 m. An integrated real-time kinematics module enables positioning down to the centimetre, allowing the drone to be used for precise surveying tasks, mapping work and modelling 3D surfaces.

**Thermal drohne**
The drone is equipped with a thermal imaging camera that records thermal radiation from the surface. This allows temperature differences to be measured over a large area. This in turn enables conclusions to be drawn about the surface moisture of soils or regions for the potential use of geothermal energy.

**Hyperspectral drone**
Hyperspectral analysis is used to explore mineral resources and for soil exploration, among other things. While traversing an area, a sensor in the drone records the sunlight reflected from a surface. Mineralogical, geochemical and physical information can be derived based on the different reflections.

**Radiometry drone**
The drone carries a gamma spectrometer to measure natural and artificial radioactivity. This method is employed to map historical contamination from uranium mining and to characterise soil properties, among other things for agriculture. Here, the levels of the natural radionuclides potassium, uranium and thorium in the soil are measured.

Ibs-von Seht and another BGR team are developing a new radiometric drone for mapping abandoned uranium mining sites as part of the *DUB-GEM* project. These areas can be hazardous to humans because of the increased exposure to natural radioactivity and are therefore particularly suitable for unmanned surveys. A radiometry drone carries a gamma spectrometer on board. At its heart is a detector crystal that measures the incident radiation. "The measurement resolution depends primarily on the size and the material of the crystal", explains geologist Ibs-von Seht, whose group aims for the best possible resolution. "We rely on a particularly efficient, substantially dimensioned, 700 millilitre cerium bromide crystal."

To date, no drone in the world has carried such a large cerium bromide detector, because this crystal is extremely fragile and also particularly expensive. "The technical challenge is to lift our crystal detector safely into the air and be able to hold it there reliably", explains the scientist. Together with a company in Bielefeld, Germany, his team is developing a particularly crash-proof drone that remains below the allowable gross weight of 25 kilograms despite the heavy load of the gamma spectrometer.

So far, the scientist has only been able to model the anticipated resolutions and external influences, but real survey data often pose unforeseen challenges that he is actually looking forward to. Ibs-von Seht: "Uranium prospection by means of gamma spectroscopy has been carried out for decades from the ground, and from aeroplanes or helicopters, but there are still no well-tested analysis methods for the intermediate region using drones – so this will still be really exciting!" In 2021 the aim is to fly the prototype over the uranium-rich terrain of the Central Asian BGR partner countries. There won't be any Arctic Skuas there, but any other spontaneous challenges this field operation brings are anticipated with excitement. ■

**Dr. Malte Ibs-von Seht**
B2.1 Geophysical Exploration – Technical Mineralogy

✉ Malte.Ibs-vonSeht@bgr.de

**Dr. Jewgenij Torizin**
B4.4 Geo-Hazard Assessment, Remote Sensing

✉ Jewgenij.Torizin@bgr.de

# WHERE GERMANY'S GROUND IS IN MOTION – NOW ONLINE!

With the Ground Motion Service Germany (*BodenBewegungsdienst Deutschland,* BBD), BGR has developed a new type of web-based information service. Motion of the earth's surface in Germany can be seen on an online map. The web visualisation is created using radar images taken from orbit. With the help of satellites, referenced points on earth are surveyed, processed and visualised using computation-intensive big data applications. The technology supports identification of possible hazards originating underground – a useful service for authorities and the population.

Even though we don't notice it: the ground beneath our feet is in motion in numerous places. The causes of such dynamic processes are manifold. They are often the result of natural subsurface processes, for example rock dissolution by groundwater in subsurface gypsum and limestone, or uplift processes in swellable rock. However, humans can also trigger ground motion of the earth's surface, for example through mining or groundwater exploitation. Interventions in the subsurface often have long-term consequences.

Take the example of Hambach opencast mine in the Rhenish lignite district: in order to extract lignite, large volumes of groundwater must be pumped. This water removal leads to aquifer compaction – the consequence is extensive subsidence of several centimetres per year at the surface in the affected region. If the groundwater level rises again once mining activities have ceased, the ground will rise at that location. Over the course of several decades, the ground may move several decimetres in this way. We also recognise ground

motion at natural gas production areas. The subsidence there, are a few millimetres per year, and much slower than in open-cast lignite mining.

This long-term ground motion is almost always caused by the geological properties of the subsurface or its use and modification (see info box *What causes ground motion?*). Undetected ground motion poses a potential threat to buildings, infrastructure, businesses and the population.

This makes monitoring measures for the early detection of all these hazards the more important. One of the principal methods used is remote sensing. A few years ago, the European Earth observation programme "Copernicus" opened up completely new remote sensing opportunities. "With the help of the satellite data, large areas and even small-scale events can now be recorded and monitored", explains Dr. Michaela Frei. The geologist is a proven expert in the field of satellite remote sensing and the scientific part in the BBD team at BGR. "With its Sentinel-1 radar satellites, Copernicus collects important data for environmental, climate change, transport, economical and, of course, security purposes from orbit at an altitude of 700 kilometres", she explains. The satellite operates with different acquisition modes and the range of possible applications is enormous – from mass balancing continental ice shields to detecting oil pollution and on to individual ground motion, which is mapped by BBD. Michaela Frei: "Copernicus made high-quality satellite data suddenly widely available, in the long-term and free of charge – that was the basis for our Ground Motion Service."

Until then, monitoring techniques always had the disadvantage that they were only used in a concentrated manner where motion anticipated. "These data were then either only available selectively or for small areas with a few repeat measurements", explains Dr. Thomas Lege, head of the *Geo-Hazard Assessment, Remote Sensing* department and, with his team, BBD initiator.

**WHAT CAUSES GROUND MOTION?**

Long-term ground motion such as uplift, subsidence, settlement or compaction can influence the stability of slopes and building foundations, among other things. Possible causes lie in the geology and anthropogenic use, such as:

- oil/gas production
- soil compaction in coastal areas
- (salt) tectonics
- (abandoned) mines (e.g. rising mine water)
- operation of cavern storage facilities
- landslides
- subrosion (underground leaching and transport of easily soluble rocks such as gypsum, limestone or salt)
- shrinkage of clay when dry
- swelling of clay, anhydrite or gypsum on contact with water
- peat loss, renaturation
- geothermal energy (poorly executed boreholes)
- groundwater management
- structural and civil engineering

Radar pulses from the Copernicus satellite Sentinel-1 scan the earth's surface with a swath width of 250 km.

The technology on which BBD is based, on the other hand, can determine ground motion in Germany simultaneously and over a large area with a repetition rate of six days. The two Sentinel-1 satellites of the European Copernicus programme orbit the earth in this rhythm. The BBD is based on their data. A radar system on board the two satellites uses radar pulses to measure the distance to millions of objects on the earth's surface at this temporal frequency – including in Germany. Façade components, rail tracks, masts, structures, but also rock formations, all representing what are known as *persistent scatterers*, form the basis for reference-based monitoring.

The flight trajectory of the satellite is so ingenious that synchronised emission of radar pulses computationally simulates a radar antenna with a large emission area: it is referred to as synthetic aperture radar (SAR). The SAR sensor on the Sentinel-1 satellites scans the earth's surface in this way every six days. The radar pulses reflected or scattered by objects on the surface are recorded, individually and distinguishable from each other. This produces an enormous volume of complex data, which is meticulously organised and transmitted back to earth. In the radar images of the earth's surface calculated from this data, the persistent scatterers (PS) can be recognised as bright spots at the same positions in a large number of flyovers – comparable to the façades that flash for the passenger of an aircraft when they fly over.

Andre Kalia from the BBD team explains the survey method: "Very simply, if you superimpose all the radar waves reflected by a single one of these bright PS points on each satellite flyover, you see a single sinusoidal wave. That only happens if this PS point has not moved. But, if the point has moved a few millimetres, the reflected waves are displaced against each other. From the size of the displacement, referred to as interference, the motion of the individual PS reference point can be very precisely determined."

In the scientific jargon, this procedure is known as persistent scatterer interferometry (PSI) – one of several procedures belonging to the interferometric SAR methods (InSAR). A combination of numerous specialist disciplines is necessary to facilitate such procedures. Among others, they include statistics, atmospheric physics and satellite orbit corrections, as well as IT technology, artificial intelligence (AI) and BGR's geo-expertise. This allows ground motion, which also model changes over time in an annual cycle, to be recorded and analysed with millimetre precision.

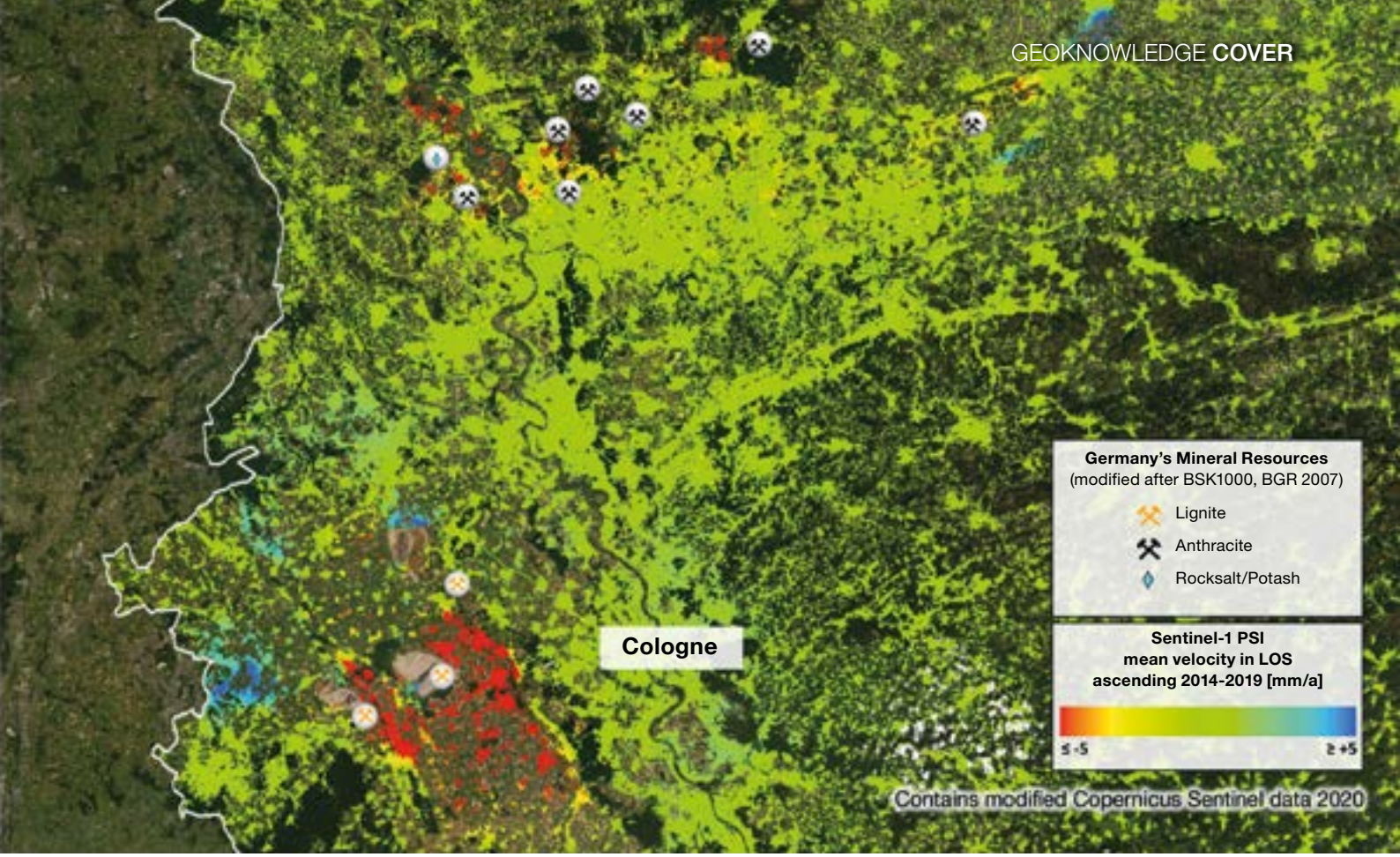
**WHAT DOES THE GERMAN GROUND MOTION SERVICE DO?**

- The BBD computes and prepares extensive SAR data from the Copernicus Sentinel-1 mission for all of Germany, thus enabling monitoring and detection of numerous processes.
- It is precise to within a few millimetres per year (mm/a) at more than 30 million consistently measured locations in Germany.
- The BBD data are online, downloadable free of charge and transparently processed. The online community is provided with user-friendly instructions and can integrate and process data in its own geographic information systems (GIS).

Although the surveying principle appears simple – the analysis is complex. In radar remote sensing, a satellite sensor scans the earth's surface with microwave radiation. A radar antenna sends out microwave pulses and receives the echo scattered back from the earth's surface. This response can be processed into image data and data products using special analysis methods. The motion of the earth's surface can be monitored on every flyover, regardless of cloud cover and time of day. The Sentinel-1 satellites can thus continuously collect processable data. "In order to process the resulting huge volumes of data, new algorithms needed to be developed to allow large areas to be consistently visualised", notes Kalia, who is responsible for developing algorithms in the BBD team.

Visualisation of the scientific Big Data in the BBD web application is user-friendly. The upward and downward motion of the earth's surface observed from space appear as coloured marker points in the web view. Subsidence is shown in red and yellow, uplift in blue and purple. Where it appears green – and that is the majority of the area – no significant motion has been detected so far. BBD co-initiator Lege: "The Ground motion Service thus enables continuous observation of possible hazards and with this, appropriate preventive measures."

BGR was supported in implementing BBD by research institutions, universities, government agencies and




BBD product with over 30 million data points nationally.

industry. BGR commissioned the German Aerospace Center's (DLR) Remote Sensing Technology Institute (IMF) in Oberpfaffenhofen to develop and process the BBD's first InSAR products. Methodological development took three years before BBD could go online in 2019. In the BBD's web view, ground motion is consistently provided at more than 30 million data points throughout Germany (see figure above). The temporal development of the motion is visible online for each data point with one click (see info box *What does the Ground Motion Service Germany do?*).

BBD monitoring activities help to identify hazards at an early stage and thus implement safety measures in good time – for example, if buildings are located on obviously unstable ground. The end users are provided with data and instructions for use, on the BBD web service's user-friendly interface as part of the BGR *geoviewer concept* (also see *The nerve fibre of BGR's research and consulting services*). Here, the monitoring data can be visualised and the relevant information obtained.

The respective geological surveys of the federal states are responsible for evaluating ground motion, such as in the Hambach opencast mine. In its function as the Federal Geological Survey for Germany, BGR has, with the Ground Motion Service Germany, created the necessary framework to allow geogenic processes to be observed and analysed even more accurately in the future. ■

**Andre Kalia**
B4.4 Geo-Hazard Assessment, Remote Sensing

✉ Andre.Kalia@bgr.de

**Dr. Michaela Frei**
B4.4 Geo-Hazard Assessment, Remote Sensing

✉ Michaela.Frei@bgr.de

**Dr.-Ing. Thomas Lege**
B4.4 Geo-Hazard Assessment, Remote Sensing

✉ Thomas.Lege@bgr.de

# THE SEARCH FOR A FINAL DISPOSAL – CAN VOLCANIC ACTIVITY FORECASTS BE IMPROVED?

It sounds logical: volcanoes and a safe final disposal for radioactive waste are mutually exclusive. This makes volcanic activity an exclusion criterion when searching for a site. BGR helps to improve the implementation of this criterion.

The Site Selection Act for high Radioactive Waste (*StandAG*) stipulates that all regions of Germany in which there have been volcanic eruptions in the past 2.6 million years (during the Quaternary) are excluded as final disposal sites. This was the case in the Eifel and Upper Palatinate regions. However, nor may any disposal be built anywhere where future volcanism is anticipated. *Federal Company for Radioactive Waste Disposal (Bundesgesellschaft für Endlagerung mbH)* commissioned BGR to assess the options available for predicting futurevolcanic eruptions in Germany. As the developer, BGE has been searching for a site for a final disposal for high-level radioactive waste in Germany since 2017. On the basis of a cooperation agreement, BGR addresses both geoscientific and geotechnical questions surrounding the procedure for selecting sites on behalf of BGE, for example on geoscientific exclusion criteria, prioritisation criteria or stability investigations. The aim of the process is to identify, by 2031, the best possible location in deep geological formations that will safely protect people and the environment from the ionising radiation emitted by the waste – and what's more: for a million years.

This period is also that specified for predicting *volcanic activity*. However, eruption predictions can currently only be made for a few large active volcanoes such as Vesuvius in Italy. Here, decades of scientific monitoring enable forecasts covering a period of a few weeks or years. It is more difficult to predict the eruptions of small volcanoes that occur in clusters in *volcanic fields*.

"Volcanoes are merely the 'tip of the iceberg', as it were, because eruptions on the earth's surface are ultimately only the result of extensive subsurface magmatic processes extending to several hundred kilometres deep that last for several millions of years", as BGR geologist Dr. Franz May explains the problem. The scientist comes from the Eifel volcanic region and the last volcanic eruption in his homeland was a mere 11,000 years ago. From a purely statistical perspective, the next eruption there is long overdue.

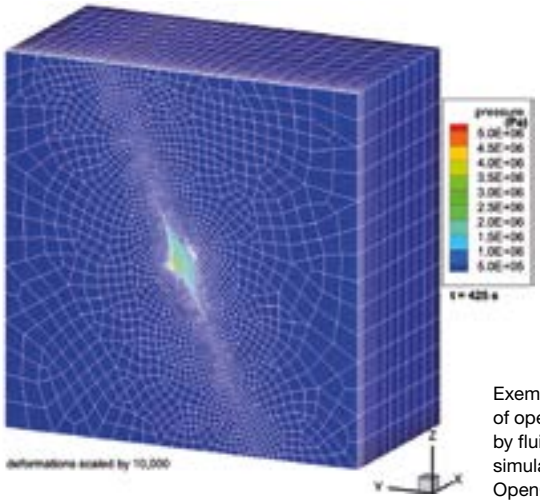
"However, in order to make qualitative statements about possible future magmatic developments in Germany, even in these well-researched volcanic fields, we need a better understanding of the overall process. Among other things, this requires looking back further and not just looking at the Quaternary volcanic fields explicitly mentioned in the Site Selection Act", says the geologist. If he and other experts have their way, then (Tertiary) magmatism extending back 50 million years must also be considered in these forecasts.

According to an initial assessment, around 25 different phenomena, processes and properties may be associated, as indicators, with magmatic processes and provide information on future activity. May and his team hope to use the combination of various indicators to identify regions where eruptions seem more likely than others. These indicators are based on findings that can be derived, for example, from the lavas and ashes of past volcanic eruptions, earthquake records, seismic subsurface surveys and recent gas escapes, as well as magma development models and rock investigations in the laboratory. Together with external experts, the team in the BGR's *Magmatism* research project is developing methods to facilitate spatially differentiated statements about the possibility of future volcanic activity in Germany. Here, the current state of research on magmatism will be amassed and evaluated in interdisciplinary working groups. The results are intended to help in the site selection process to improve the justifications for excluding unsuitable areas. ■

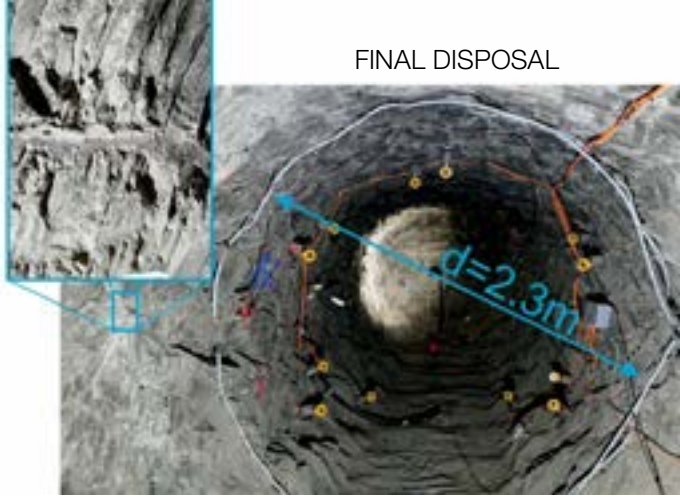
The *Laacher See* volcano last erupted 12,900 years ago. The volcanic cinder cones of the *Hochstein* and *Hochsimmer* can be seen in the background.

**Dr. Franz May**
B3.1 Resource Potentials of the Geological Subsurface

✉ Franz.May@bgr.de



Exemplary analysis of opening a fracture by fluid injection; simulated using OpenGeoSys.




Desiccation cracks in the Opalinus Clay at an excavation in the Mont Terri rock laboratory.

# THE NUMERICS OF ROCK FRACTURES

## Fundamental research on geomechanics in host rocks: BGR is investigating the nature of fracture formation with national partners – from experiments to complex computational models and into practice.

If you ask Dr.-Ing. Jobst Maßmann about the applications of numerical modelling, he answers fourfold. Firstly, model projections are indispensable when searching for a final disposal site for which one has to look very far into the future. Secondly, models are needed to address specific problems, such as analysing stability of a newly excavated mine. Thirdly, laboratory and field measurements can be simulated in advance and optimized with respect to their sensor settings and locations. Finally yet importantly, there is a more fundamental aspect that plays the key role in Maßmann's team: modelling can improve overall system understanding, since numerous rock stability problems remain unanswered. For example: under which conditions does deep rock fracture? How does the overall system alter if parameters such as permeability, heat or load vary? How can the physical and mathematical methods be used to describe processes and make predictions? The collaborative project *GeomInt* searches for these answers both in real scale underground (also see *Research in the heart of the mountain*) and in laboratory scale experiments. With a predominant focus on experimentally based numerical modeling and analyses, Maßmann's team investigates how fissures, fractures and joints develop in claystone. Such "discontinuities" weaken the rock and could open unwanted pathways for fluids. These risks must be calculated to ensure safe storage of radioactive waste or operate storage caverns. Although that sounds easier said than done, project coordinator, Maßmann's, explains: "The core challenge is to develop the mathematical-physical model. The thermal, mechanical and hydraulic processes raise very complex problems and there is no software available to deal with them – we have to develop it ourselves or have it developed for us." His project lies at the interface between code development and application. "Together with an expertise in numerics, we also need to be aware of the practical context within the underground rock mass and in laboratory scale." Understanding a system through modelling is similar to piecing a puzzle. You simulate different processes, couple them, design experiments, compare the results and continuously improve the software.

It is therefore essential to collaborate closely with the environmental informatics department at the Helmholtz Centre for Environmental Research (UFZ) in Leipzig, which is responsible for developing the *Open-GeoSys* open source code. There is also a lively exchange with the other national partners: on one hand, BGR distributes core samples for laboratory testing to Kiel's Christian-Albrechts University (CAU) and the *Institut für Gebirgsmechanik GmbH Leipzig* (Institute of Geomechanics). On the other hand, the partner institutions develop their own coding and compare their simulations. And that is also the intention: "A variety of methods for translating processes into numerical models exists", explains Maßmann. "One of GeomInt's goals is to employ and compare these different approaches." After all, codes may be flawed, so their reliability must be ensured in final disposal research. "It is a great achievement if different groups arrive at the same result", sums up Maßmann, who is continuously fitting the pieces of the puzzle of the nature of the fractures together with his colleagues in BGR and the national GeomInt network partners. ■

**Dr.-Ing. Jobst Maßmann**
B3.5 Geotechnical Safety Analyses

✉ Jobst.Massmann@bgr.de

BGR and swisstopo employees installing a geoelectric probe to observe changes in the rock mass when excavating a drift.

# RESEARCH IN THE HEART OF THE MOUNTAIN – EXPERIMENTS UNDER REAL WORLD CONDITIONS IN MONT TERRI ROCK LABORATORY

Underground experiments provide research findings on final disposal and fluid storage. In the renowned Mont Terri rock laboratory in Switzerland, BGR works closely with international partners to investigate the suitability of claystone as host rock.

Parallel to the busy Swiss A16 motorway tunnel heading towards France, lies a special underground world in the heart of Mont Terri mountain. Two restricted access security gates only allow admission to those who are allowed to borrow a key – they include Dr. Dorothee Rebscher and Dr. Markus Furche. The BGR team waits in an eerily illuminated security chamber for the second gate to open. Then the *clicking* snap of the second lock gate announces the opening of the portal to the international rock laboratory in the heart of the 800 metre high mountain. "That click – that's the typical sound of Mont Terri when entering the rock laboratory", says physicist Dorothee Rebscher, for whom it is always exciting to arrive, just like her physicist colleague Furche. After a quiet journey through the two-kilometre safety tunnel, they both look forward to the brightly lit, widely branched network of tunnels and the work underground. The rock laboratory, the tunnel walls of which are mostly clad with shotcrete to enhance stability, extends within a layer of clay several hundred metres thick that stretches throughout Mont Terri. 300 metres below its surface, it is a pleasant 17 °C and very quiet outside of the laboratory – with the exception of the occasional dripping from a sometimes wet rock ceiling. But when the drills roar again in the busy rock laboratory itself, it is at times louder than on the A16. The dust is then everywhere and everybody wears a helmet, ear protection and protective mask. There is almost no dripping water here, because the all-encompassing claystone does not normally allow water to penetrate.

Claystone is one of Germany's potential host rocks for the permanent disposal of radioactive material, because of its excellent barrier with regard to fluids – including for other applications such as gas storage in the deep subsurface (also see *Hydrogen reactions in high pressure reactors*). In the Mont Terri project, a representative study of all underground claystones will be carried out to determine the extent to which they can be used for safe storage to protect humanity and the environment. There are no sites in Germany where claystone's properties and interactions can be investigated *in-situ* underground in such an international environment. The pure research laboratory in the heart of the Swiss mountain is therefore regarded as the *non plus ultra*, as Furche puts it. In particular because this laboratory is one of the best equipped in the world – at least as far as clay testing is concerned. Although the sporadic underground work has become routine for the physicist after almost 10 years, he always finds it exciting down here.

The Mont Terri ammonite species *Leioceras Opalinum*. It is the namesake of the Opalinus Clay due to its shimmering, opalescent surface.

Celebratory breakthrough to a new tunnel in the rock laboratory.

The rock laboratory continues to develop: here, the BGR team continuously encounters new boreholes, experimental setups and people. Dorothee Rebscher has also been coming here regularly for years and, as a project partner of the rock laboratory founded two years earlier, BGR has even been researching since 1998. Today the Mont Terri research group consists of 22 equal partner institutions from nine nations. Dorothee Rebscher is the BGR delegate. The Mont Terri consortium has already successfully completed 100 experiments, 50 more are ongoing, BGR is currently involved in 22 of them.

Not only the close and exceptionally good collaboration between the international institutions is remarkable here, enthuses the BGR delegate: "Everyone here is highly committed to the broad range of topics covered, in order to enable politics and society to make fact-based decisions in the field of safe storage of radioactive waste". The topics are interdisciplinary and require many different types of expertise, which come together here and serve to support everyone involved.

For example, if someone from the Mont Terri network needs an expert in what is known as electrical resistivity tomography (ERT), they ask for Markus Furche. "The principle is simple: you place several electrodes in certain configurations, one generates a current field and the other measures the resulting voltage drops", explains the physicist and adds: "But the practical implementation, as well as the analysis and interpretation are complicated and time-consuming."

The ERT expert has further adapted this method for use underground and has been employing it successfully for years in boreholes and tunnels in the rock laboratory. With ERT he can, among other things, indirectly map the moisture inside a rock, because water in a rock influences the specific electrical resistivity. The internal moisture in turn is responsible, among other things, for the shrinking and swelling of claystone, and this influences important properties such as stability and permeability. Because claystone is intended to represent a barrier for radionuclides, it is precisely such characteristics that must be investigated more closely. Changing conditions such as seasonal fluctuations and extended periods of time need to be evaluated. "This is the only way we can understand the physical processes that we numerically model", explains Furche (also see *The numerics of rock fractures*).

Dorothee Rebscher explains: "In addition to the in-situ activities in the rock laboratory, small-scale laboratory work is carried out at BGR, as well as extensive computer-aided modelling of the complex processes involved." Improvements in process understanding on the one hand, and the characterisation of claystone as a potential host rock on the other, also represent the primary focus of further Mont Terri experiments. In addition, the projects aim to explore the technical barriers and carry out demonstration experiments. For example, specimen canisters equipped with heating elements were enclosed in niches to simulate the hot radioactive waste. BGR accompanies such experiments with monitoring, among other things, in order to record the effects on the surrounding claystone.

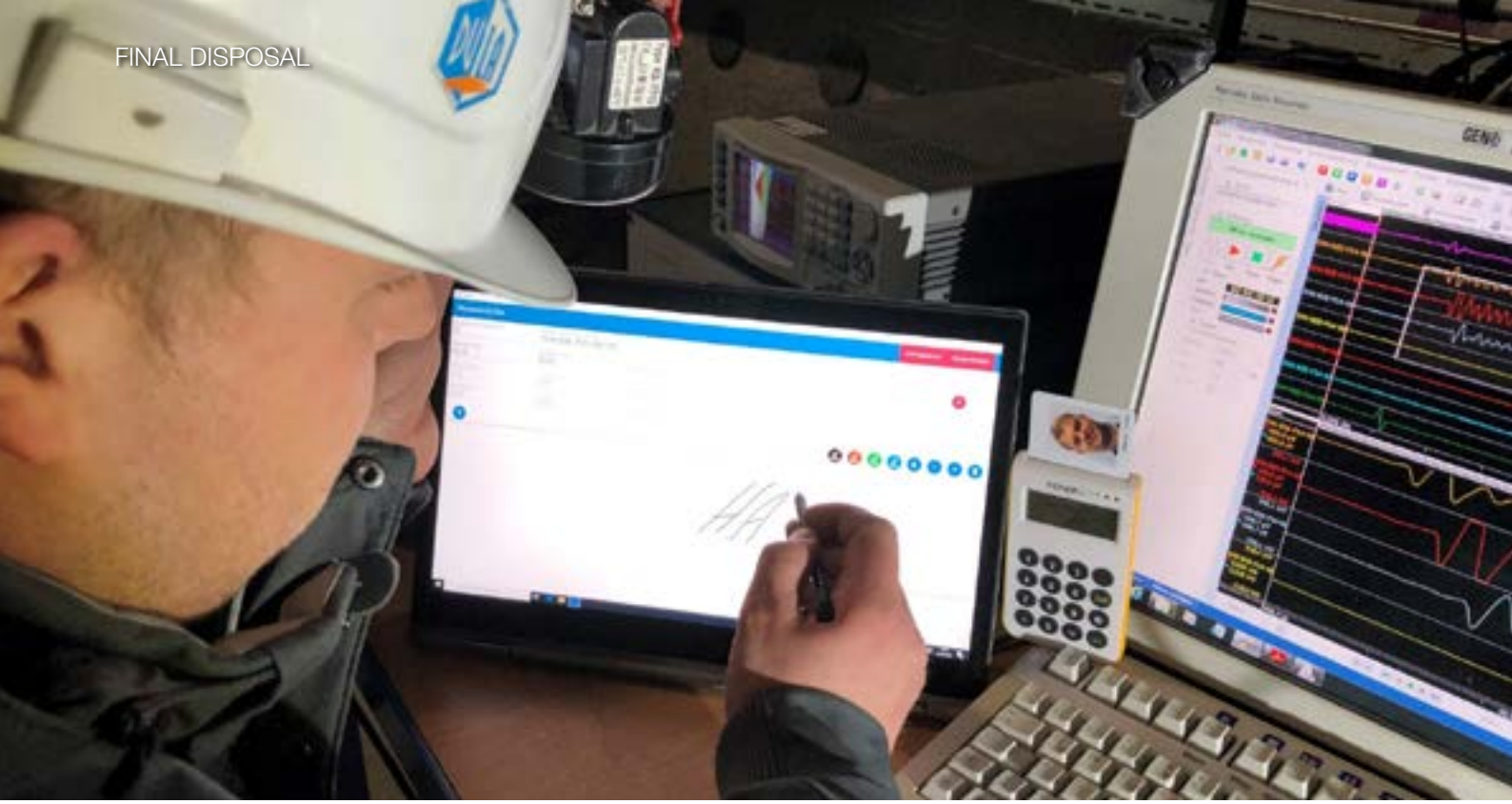
Although a multitude of valuable answers have already been found in Mont Terri, a number of new, relevant questions have already arisen. A lot of research remains for everyone in the heart of Mont Terri. ■

**Dr. Dorothee Rebscher**
B3.1 Subsurface Use

✉ Dorothee.Rebscher@bgr.de

**Dr. Markus Furche**
B3.2 Geological-geotechnical Exploration

✉ Markus.Furche@bgr.de



Logging a survey in a rock laboratory (in-situ) using the INIS app and a signature card reader.

# QUALITY ASSURANCE IN FINAL DISPOSAL RESEARCH

BGR creates transparency in final disposal research. It guarantees permanent quality by means of new digital developments, accreditation and long-term archiving that preserves evidence.

Identification of a final disposal site for high-level radioactive waste has always been, and is likely to remain, controversial. However, precautions can be taken against one point of contention: the questions of transparency and quality of the research results in this context. Little time remains until the officially targeted 2031 decision date to transparently document all previous research results and specify the quality of current data acquisition and storage. "We must have the capability to seamlessly document all our work", says physicist Dr. Johanna Lippmann-Pipke, one of the disposal research department heads.

"Following generations must be capable of understanding exactly what we did, which data and reports were created, how and where. This would not be technically possible without the systems that we are currently developing here."

A few years ago the physicist and her team therefore began to thoroughly reorganise the final disposal laboratory research quality management. The aim was to have the BGR's rock mechanics laboratory accredited as a *testing laboratory*. This means that the German Accreditation Service (*Deutsche Akkreditierungsstelle – DAkkS*) issues its seal on the basis of independent, external reports and thus confirms high measurement quality compliant with DIN standards. In Germany, this special award can only be given, or taken away, by DAkkS. This is because every two years each accreditation is re-audited to ensure that all experimental activities continue to meet the *testing laboratory* standards.

It has been official since the rock mechanics laboratory received its accreditation in 2018: BGR organises and documents all work processes in the rock mechanics laboratory based on defined, high quality standards. "The new management system seamlessly describes all activities: from sampling pieces of drill core underground, transporting the material to the laboratory, characterising the material in the laboratory to processing and documenting the results", explains Johanna Lippmann-Pipke. One may imagine that a work order is issued to a specialist for each process in this chain. This specialist documents the process and the results of their work step and forwards the sample on to the next person. At the same time, they assess the work of the previous specialist using a satisfaction survey. "This means that it is always possible to trace who was involved in which project and when, before the results are written down in reports", explains the department head.


Confirmation of the quality management system compliant with KTA1401 and DIN/ISO EN 9001 by BfS and with DIN/ISO 17025 by DAkkS.

However, accreditation is only one aspect of quality management. Another is digitisation and long-term archiving: "What was still completely documented on paper two years ago has now been entirely replaced by digital methods", says engineer Hendrik Albers, who works in IT project management for geophysical site investigations. In parallel to Johanna Lippmann-Pipke's accreditation project, he coordinated a new BGR digital development that practically manages quality autonomously: INIS. Or more precisely: the in-situ information system, which centrally manages and administrates raw and metadata obtained in-situ (on-site) from final disposal projects, and also has integrated handwriting recognition software. A special highlight, because it simplifies many processes.

"In the past, handwritten notes and logs were used because, especially in the field, taking notes with a mouse and keyboard would often have been more time-consuming compared to writing them down quickly in the field record book", explains Albers. In order to maintain this advantage, handwritten notes and sketches can be made in INIS, which are then interpreted in graphic form. "The electronic pen is an important way of facilitating the workflow for many colleagues who have long been used to notes and ballpoint pens", explains Albers. For the IT expert it was challenging to reconcile all these elements: "We wanted a system with which everyone could, in principle, identify and exploit for their own benefit, in order to generate a significant improvement. A system that can be used equally for numerous fields, methods and people. "For example, 67 measurement methods from the fields of geomechanics, geohydraulics, geophysics and borehole characterisation are currently combined in a single package in INIS. All of the information required to enable the measurement results to be reproduced is stored here.

The survey data and notes are linked to one another by a string of metadata. For example, it includes the exact place and time of each data point, changes to a measured variable, parameter settings, etc., each of which is provided with a time stamp and a qualified electronic signature of the person responsible when entered. "The signature card replaces the signature. This means that it is always possible to trace who recorded the data, so that plausibility and confidentiality are ensured and the completeness of the survey data is confirmed", says Albers.

With INIS and the accreditation of the rock mechanics laboratory, quality assurance at BGR with regard to site selection consulting and research is currently at the highest possible level. Johanna Lippmann-Pipke is convinced: "Transparency is only possible if you also lay the technical foundations for it, allowing it to be lived and to show work that was completed many years ago."

This also includes the maintenance of legacy data, i.e. digitisation of legacy analogue survey data and logs in paper format, their incorporation into the existing system and their long-term storage. For the engineering geologist Benjamin Paul, this is the greatest challenge. Together with Albers, he leads the INIS project and is responsible for both data management and data analysis. He knows the pitfalls that lurk in long storage durations: "As technology advances, there are constant updates and data formats change", explains Paul. "Certificates will expire at some point, so we must keep up-to-date with the best available technology, especially over long periods of time."

Last year the team started to make data from decentralised computers and notepads available to everyone and to process them according to the FAIR principle (also see *The nerve fibre of BGR's research and consulting services*). In December 2019, BGR arrived at an administrative agreement with the Federal Archives, the service provider for the highest federal authorities with regard to digital data, for the secure storage of geoscientific data and their long-term verifiability. The Federal Archives offers a centralised long-term storage system, guaranteeing legally secure storage as well as integrity, authenticity and completeness. The ideal place, then, to transparently immortalise BGR's research results and processes. This represents another important step towards quality assurance for BGR's quality management in final disposal research. ■

**Dr. Dipl. Phys.**
**Johanna Lippmann-Pipke**
B3.3 Characterisation of Storage and Barrier Rocks

✉ Johanna.Lippmann-Pipke@bgr.de

# 60 YEARS OF TECHNICAL COOPERATION WITH JORDAN

From the pioneering work in establishing Jordan's geological survey to capacity development in resource conservation in one of the world's most arid countries.

Today Jordan is seen as an anchor of stability in a region that has been shaped by crises and conflicts for decades. BGR has been involved in projects in Jordan for more than 60 years on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ). BGR is currently supporting Jordan in the conservation and management of groundwater resources, because groundwater here is dwindling at a breathtaking pace. In the following double interview, landscape ecologist Alexander Jokisch and hydrogeologist Dr. Falk Lindenmaier discuss the critical drinking water situation and the special role of BGR in Jordan.

**Mr. Jokisch, Dr. Lindenmaier, BGR, at that time still known as *Bundesanstalt für Bodenforschung*, began its cooperation with Jordan in 1959, just a few years after it gained independence. What has changed since then?**

The country we support today has little in common with the country of 60 years ago. In the past, fewer than a million people lived there; today it is over 10 million. Its structures and needs have transformed dramatically. Once characterised by subsistence farming and nomadism, the country now has large industries and cities. This has led to a shortage of drinking water and other problems. There are therefore good reasons for Germany, and thus the BMZ as our client, to continue supporting Jordan.

**You have both been working for several years in BGR projects in Jordan and travel there several times a year. What exactly are you doing there?**

BGR is intensely active as a cooperation partner to the Jordanian Ministry of Water and Irrigation. We provide capacity development on resources such as groundwater reserves, and their quality and distribution in the subsurface. The job of the six seconded experts of BGR staff, who live there with their families, together with five local project employees, is on-site project management and daily consultations with our Jordanian partners. These projects can only function with experts on-site, and additionally with the committed colleagues from our Jordanian partner Ministry. We support and coordinate technically and strategically from Hannover. In Jordan, we hold talks with the government and the team, and organise project workshops and public events.

**Seen holistically: to what extent does past technical cooperation condition the current situation?**

Our current work systematically builds on the previous work carried out in Jordan. Early in the collaboration, BGR geologically surveyed the country and established the then geological survey of Jordan. At the end of the 1960s, the first groundwater resource studies followed with the help of the maps created. Since then, the collaboration has focused on hydrogeological work and training of the project partners. Using new methods, BGR carried out an initial comprehensive assessment of groundwater resources in the 1990s and realised: protecting groundwater against pollution is a crucial factor in securing the drinking water supply. The focus of work therefore shifted to water resource conservation. Together with the Jordanian Ministry of Water and Irrigation, BGR worked on the fundamentals of conservation zone designations for the most important drinking water sources, and trained its employees. Now we are jointly developing management plans for the remaining groundwater resources.

The Wadi Rum in the extreme south-east of Jordan. The Ram Group sandstone in the background contains an important aquifer with fossil groundwater.

BGR vehicles in the Jordanian desert geological exploration in 1959.

BGR vehicle during a joint inspection of springs together with the Jordanian ministry in the Jordan valley in 2019.

**You supported the Ministry of Water in publishing a *Water Yearbook*. It informs the population of Jordan about their current and future drinking water situation. What was your specific role in creating it?**

The Jordanian Ministry of Water is both competent and open, and has the ambition and the will to communicate the critical supply situation to the Jordanian population. Because we've been there for so long, we have a good and trustful relationship. BGR always attempted to listen to the needs in the country and to make a professional contribution – over time, this built up a great foundation of trust. We can easily point out problems and warn that water resources will run dry if the way they are used does not change.

**Disregarding the increasing demand due to rapid population growth and urbanisation – what are other pressures on Jordan's groundwater resources?**

Very clearly the increase in irrigation required by large scale agriculture intended for export. Groundwater resources must meet the majority of Jordan's water demand, but have now been overexploited since the 1980s. Numerous wells have already fallen dry, and an annual groundwater drawdown of 5 metres, up to greater than 10 metres locally, is not uncommon. Groundwater resources have been dwindling at this breathtaking rate for some years now.

**What are the consequences of the dwindling availability of groundwater?**

Over the last few decades, groundwater abstraction has increasingly shifted to the east and into the fossil (i.e. non-renewable) aquifers in the south. In the final reckoning, this constitutes a race between industrial agriculture and the public water utilities for the last reserves. The often illegal water abstraction by agriculture also exacerbates the conflict.

**To what extent does the population already feel the effects of potable water scarcity in everyday life?**

The public water utilities must apply restrictions: water is not available all day, but for only 8 hours on a weekly basis in towns. All over the country, people store potable water in large tanks that are refilled every few weeks. If this is insufficient, or if the supply fails, the water is privately delivered by expensive tanker trucks.

**What other technical cooperation measures is BGR planning with Jordan?**

In the coming years we will be studying the economic aspects of groundwater abstraction together with the Jordanian Ministry of Water and Irrigation. After all, drinking water production accounts for an estimated 15 % of energy consumption in Jordan. In the mid-term, groundwater will remain the backbone of Jordanian drinking water supplies; meaning its abstraction should be energy-efficient and therefore cost-efficient. For deep wells with a pumping height of more than 200 m, this includes very fine coordination between well development and pump settings. Because poorly developed wells lead to high energy consumption and high operating costs – which in turn reduces the investment capital available for better wells. ■

**Alexander Jokisch**
B4.1 International Cooperation, Asia & Oceania Section

✉ Alexander.Jokisch@bgr.de

**Dr. Falk Lindenmaier**
B2.3 Groundwater Resources – Quality and Dynamics

✉ Falk.Lindenmaier@bgr.de


Top:
A soil is jointly described and classified in a training programme.

Bottom:
Profile of a Plinthosol soil in the municipality of Ngong.

# SOIL INFORMATION FOR CAMEROON'S SPATIAL PLANNING

## BGR supports Cameroon in determining and securing baseline pedological data.

If a nation aims at structuring its land use, it should consider the different interests in a process referred to as spatial planning. For example, is it more appropriate to protect a particular natural resource than to use it economically? Or: which agricultural land use is best suited for the specific area? Such considerations require information and "spatial planning works better with quality-assured data than without", says geographer Thomas Rehmann, who coordinates a BGR project in Cameroon in the context of Technical Cooperation (TC).

Spatial planning can create a balance before conflicts of interest arise, but this is an issue that has long been neglected in Cameroon's politics. Here, the Cameroon Ministry of the Economy, Planning and Regional Development (MINEPAT) therefore initiated an innovative process and cooperates with the German Federal Ministry for Economic Cooperation and Development (BMZ). "Together with our partners in Cameroon, BGR provides soil information in order to better protect the local rural population from the negative effects of land use conflicts and resource overuse", Rehmann explains the aim of the project, which is funded by BMZ.

The geoecologist Lisa Heise adds: "We support the nation's geoscientific authorities in collecting and providing harmonised and quality-assured soil data and maps." Together with the Cameroonians, the BGR team planned and carried out scientific studies dealing with soil mapping and groundwater quality. They went into the field together. In a 4,000 hectare pilot zone in a water catchment area in Ngong Township, data was acquired and samples taken from 22 soil profiles. The team classified these according to the WRB soil classification system (World Reference Base for Soil Resources 2014). This international system is fundamental for all further data collection, emphasises Heise's colleague, the geoecologist Dr. Daniel Rückamp: "Because this allows Cameroon to also make international comparisons with regard to its land use options."

The field data formed the basis for large-scale mapping of the water catchment area: Cameroon's first WRB 1:25 000 scale *Draft Soil Map* was created on the basis of international mapping and laboratory standards. The precarious

Colleagues from Cameroon being trained in BGR's soil chemistry laboratory.

security situation in a second pilot zone in the south-west prevented further activities such as field campaigns in this region, but the partners were still involved in training activities.

Lisa Heise and Daniel Rückamp's team trained their colleagues from Cameroon based on the "train-the-trainer" principle.

The aim of the two geoecologists in the BGR team was for their Cameroonian partners to independently design training modules in the future and then carry out further training autonomously as trainers. For example the Cameroonian Zocpé Elisabeth. "First, the BGR colleagues digitised the existing maps, then Elisabeth did it, and now she's showing her compatriots how it works", says Rückamp.

Digitisation of the information content of a pedological map is more complicated than one might think. Within soil science, fundamentally different systems for classifying soils exist. This makes uniform classification difficult. "The Cameroonians know exactly which soil is suitable for which crops", explains Rückamp, "but how it is classified internationally is more difficult. No algorithms exist for transferring the old French or American systems, for example, into the international WRB, says the BGR geoecologist. His colleagues therefore came up with new strategies for harmonising the old stock of maps with the WRB system.

This quality-assured digitisation is only one aspect of the technical cooperation, because BGR has been empowering its Cameroonian partners in a large range of topics since 2015. The training measures also included the fields of *free and open source* geographic information systems, statistical data analyses, archiving existing data records and maps, and the design and utilisation of reference management databases. A special aspect of the collaboration for Rückamp was the laboratory work, in which the samples were jointly analysed for soil chemistry and physical parameters. While the visit to the BGR laboratories in Hannover was a highlight for the soil experts from Cameroon, Rückamp was enthusiastic about the laboratory skills of the partner IRAD in Cameroon: "Some of our Cameroonian colleagues use basic methods that I know from the literature but have never used myself, because we use automated instruments", says the soil scientist. "The Cameroonians do a lot of things themselves using robust chemical methodologies that are perhaps more time-consuming, but by no means worse than ours. It was very exciting to follow that."

The first major step has been taken: joint data collection, analysis and archiving have contributed to soil data harmonisation and improvements in quality. Now the next phase follows. "The objective now is to bridge the gap between the experts and the people who use the data, the planning people and people in politics", explains project coordinator Rehmann. "We have to make it clear why the data is so important and how it can be used". Ultimately, this information should serve the Cameroonian ministry as a basis for decision-making in the future when planning compensatory measures and sustainable land use. ■

**Thomas Rehmann**
B4.1 International Cooperation, Africa Section

✉ Thomas.Rehmann@bgr.de

**Dr. Daniel Rückamp**
B2.4 Soil as a Resource – Properties and Dynamics

✉ Daniel.Rueckamp@bgr.de

Installation of pile foundations in Dhaka.

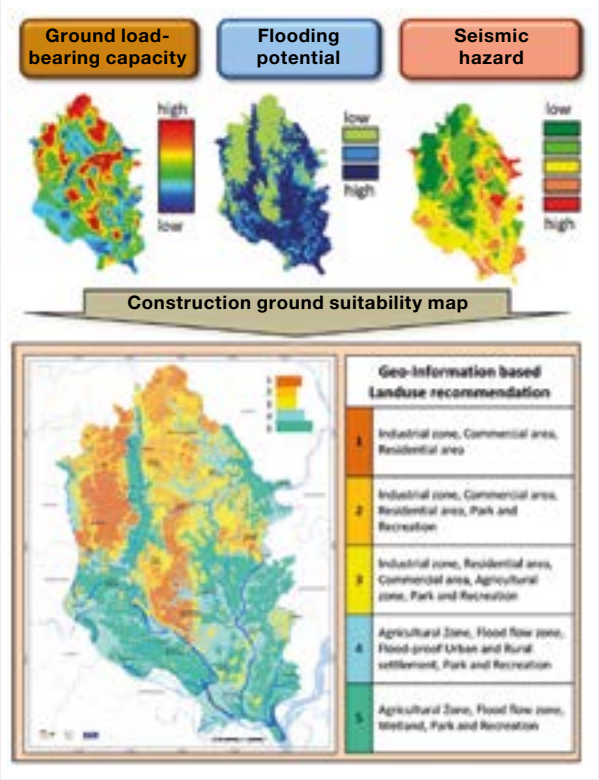
# BANGLADESH: WHERE URBAN DEVELOPERS NEED RELIABLE GEOINFORMATION

## Flooding, earthquake hazards and ground instability: as a component of technical cooperation, BGR helps to identify geohazards for the city of Dhaka.

From the capital Dhaka it is only 120 kilometres north to the workshop in Sirajganj, to which Annette Lisy travels on well-developed roads that run on embankments. However, Bangladesh is one of the most densely populated countries in the world, and traffic is always heavy. The BGR project team with Annette Lisy therefore crisscrosses the countless rivers and fields strewn with ponds for almost five hours. Apart from the flora of the hot, humid tropical climate, the landscape is reminiscent of a German marshland, says Annette Lisy. During the heavy monsoon rains, the water can only drain off slowly and remains on the fields as ponding. "You can't drive five kilometres here without having seen water", the geoscientist remarks, "and the ponds are not blue, but green by water hyacinths".

Annette Lisy is just as enthusiastic about the country and its people as for the work that she is allowed to do in mutual cooperation with colleagues in Bangladesh. As a trained project manager for international cooperation, the geographer coordinates projects at BGR on behalf of the Federal Ministry for Economic Development and Cooperation (BMZ). In particular, the aim is to reduce recurring losses in towns and cities resulting from geohazards and the negative effects of climate change in the long term. Experts predict that Bangladesh may lose a fifth of its land mass in the next 30 years and that up to 50 million climate refugees may be anticipated in the next 50 years. However, heavy precipitation and flooding, sea-level rise, groundwater salinisation and an increasing number of storms already impact the country today. Land subsidence and poor infrastructure planning exacerbate these problems – especially in urban areas.

"With the help of improved urban planning based on reliable geoinformation, we can reduce climate-related risks for the population", explains Annette Lisy. This is why BGR supports its partner, the National Geological Survey of Bangladesh (GSB), in collecting reliable geoinformation relating to ground stability, earthquake hazards, subsidence and inundation caused by floods. The team of experts tested how this successfully works in the 20 million strong capital, one of the fastest growing mega-cities in the world. "Dhaka actually had a master plan for strategic spatial planning until 2024. However, when we presented the hazard potentials and construction ground suitability maps together with our partner, the plan was adapted in accordance with the new geoinformation", explains Dr. Andreas Günther, BGR expert in the field of engineering geology. To this end, GSB and BGR carried out extensive data collection and analysis in three fields: engineering geology enables the load-bearing capacity of the ground to be determined by drilling 30 m deep boreholes in a tight grid across the city. With the help of geophones located in these boreholes and across the surface, active seismic methods are used to characterize the strength of the subsurface materials and the potential seismic hazard induced by earthquakes. In remote sensing, analysis of satellite images of the maximum flooding of recent decades and their comparison with Dhaka's ele-




Concept for creating the construction ground suitability map: the individual geofactors (load-bearing capacity of the ground, flood potential, seismic hazard) are overlaid and the resulting map is divided into five construction ground suitability classes.

vation profiles allows to estimate the flood hazard in specific areas. "Our concern was to improve the partner's ability to survey, manage, analyze and interpret geo-information necessary for spatial strategic urban planning", says Günther. They equipped the GSB geological survey with supplementary IT, trained its staff and introduced analysis and documentation standards. The result is an extensive *atlas* of validated geoinformation relating to Dhaka – a groundbreaking product for urban development.

"This winter, our *Atlas on Urban Geo-Information of Dhaka Metropolitan Region* is going to print for the interested public", says Günther. "Of course, we had communicated the information intensively to the urban planners and decision-makers in advance."

Communication at all levels has always been easy for Annette Lisy and is a key to success. She calmly permutates in her functions as an organiser, moderator, mediator and consultant between the geological survey, the BGR team of experts on site and in Hannover and also with the BMZ, for example when it comes to specific national supporting strategies. The broad dialogue between the professional groups involved is also very important in this project. For example in the cross-topic workshops in the six new pilot areas, for which reports and maps are now being created.

After driving for hours, Annette Lisy finally arrived at the workshop with project manager Rüdiger Ludwig, the BGR project leader located in Dhaka. There, a young urban planner has a lively discussion with the BGR experts, the mayor, representatives of the local planning authorities, the GSB geological survey, the German Society for International Cooperation (GIZ) and the *Kreditanstalt für Wiederaufbau* (KfW). The urban planner demands diverse high-quality and functional geoinformation in order to be able to incorporate it in urban planning. "It's a mutual coordination and adaptation process", explains Annette Lisy. "Any user should receive valid information from the geological survey in such a way that it can be utilised. Only enhanced methods to implement geo-information will improve sustainable spatial urban planning. This is what our technical cooperation aims at." A very committed, professional discussion takes place, an experience the project team here constantly makes.

"It is evident that BGR also expands mental spaces", she describes BGR's mediating and catalysing role. "Because open discussions are often made more difficult by cultural idiosyncrasies such as hierarchy or power politics."

One of the current technical discussions concerns remote sensing. The next step is to facilitate monitoring ground motion (such as subsidence processes) in order to be able to identify potential geohazards at an early stage – as is the case with the new Ground Motion Service Germany (see cover feature: *Where Germany's ground is in motion – now online!*). In Bangladesh, BGR equips its GSB partner with the relevant hardware and software, trains project counterparts in radar interferometry methodology and also addresses remote sensing challenges: the space-born radar sensors, for instance, cannot recognise the surfaces of water bodies if they are covered by water hyacinths. The experts on site therefore need to identify backscatter data from the *green* water bodies in order for them to be integrated in the analysis algorithms. On the way back from the workshop, passing the green fields of water, Annette Lisy was happy to see both: the magic of a landscape that appeals to her and the geoscientific duties still waiting for the team. ■

**Annette Lisy**
B4.1 International Cooperation,
Asia & Oceania Section

✉ Annette.Lisy@bgr.de

**Dr. Andreas Günther**
B2.2 Basic Information
Groundwater and Soil

✉ Andreas.Guenther@bgr.de

# SUSTAINABLE ALTERNATIVES TO ILLEGAL SMALL-SCALE MINING

In Indonesia, BGR succeeded in establishing a pilot cooperation project to recultivate former tin mining areas.

Every smartphone, television set or computer contains some: tin. The metal is needed for soldering electronic components, but also for manufacturing tin plating, chemicals, medicines and packaging. Demand is increasing globally – and globally, Germany is one of the largest importers of refined tin. This implies that we need to think about the sustainability of tin mining.

"Sustainability in mining impacts the entire cycle, from exploration and production, to renaturation or recultivation", explains BGR economic geologist Dr. Philip Schütte. Fine soil particles are washed out when the tin ore is mined from the placer deposits. Aftwards, the soil left behind has a sand-gravel texture and suffers from long-term damage to soil functions. It is *degraded*, as BGR soil scientist Dr. Andreas Möller calls it professionally, and "the consequence is infertility". In order to make the degraded soil usable again, for example for agriculture, it must be recultivated. This is exactly what the BGR colleagues Schütte and Möller attempted using the innovative approaches of two BGR departments on Bangka, one of the Indonesian *tin islands* east of Sumatra*.

Indonesia is currently the world's second largest tin producer after China. The centuries-old mining activity in this region is an important source of income for the local population. However, proper recultivation is not carried out, leaving behind large-scale crater landscapes with infertile soils. The situation is exacerbated by small-scale mining. After the end of industrial production, the residual tin left behind continues to be mined, mostly illegally, using simple methods, thus degrading the soil even further.

Reports of the extensive destruction on the Indonesian tin islands already received international attention a number of years ago. In the interests of sustainable supply chains, responsible companies in Germany that purchase Indonesian tin or products made from it should ask themselves: how can we mitigate the negative impacts associated with tin mining?

The two BGR experts Schütte and Möller can provide an answer, because they have achieved two things in their successful pilot project: on the one hand, they demonstrated on an area of 18 hectares that crops can grow again on the degraded soil by adopting experimental soil improvement and sophisticated erosion control measures. On the other hand, they took the local population on board right from the outset in order to develop beneficial alternatives to illegal small-scale mining for the future.

In Bangka the lights are now set to green – with the backing of the Indonesian Mining Ministry, the state-owned mining operator PT Timah as a project supporter, the local government and civil society. And with the help of science.

"In particular, the enthusiastic specialists from the universities of Bogor and Bandung made crucial scientific contributions", says soil expert Möller with respect. "Because they knew precisely what would grow best on which soil. We also learned a lot ourselves", enthuses the soil scientist, who particularly appreciated the intensive, partnership-based dialogues during the many multi-day workshops.

"Right from the outset, we considered knowledge transfer to be an important part of our project", adds Schütte. BGR brought science, politics and the local population together around one table or even, on one occasion, in a local WhatsApp group. As an independent third party with partners in the ministry, BGR was able to accelerate some processes, notes Schütte.

It became apparent that the previous recultivation measures were unsustainable. Planting the former mining areas in accordance with the legal minimum

* Also see the project video on YouTube in the BGR GeoChannel *Rekultivierung im indonesischen Zinnabbau* (Recultivation in Indonesian tin mining).

*"Sustainability in mining impacts the entire cycle, from exploration and production, to renaturation or recultivation."* Dr. Philip Schütte

The recultivation project on the Indonesian tin island Banka.

standards resulted in little benefit for the broad local population. Suitable crops for the BGR pilot project were therefore selected by the Indonesian experts and endorsed by the local community. The new recultivation plans were then rapidly implemented: with the support of BGR, the islanders cultivated aubergines, tomatoes and pineapples on various test areas – including special *soil ameliorants*. Because compost is both expensive and rarely available in sufficient quantities, the BGR team experimented with alternative soil additives: chicken manure, rice husks, clay and biochar from charred oil palm fruit stands. A stabilising drainage system was also installed on the pilot area in order to avoid erosion of fine soil particles during the rainy season. After many months, the efforts bore so much fruit that even Möller was astonished: "We could hardly believe how well everything worked."

Based on the lessons learnt from the project, the project partners developed a handbook of recommendations for recultivation in Indonesian tin mining and published it in English and Indonesian. "The manual is now available locally and is intended to serve as a basis for discussion", says Schütte proudly. "It provides guidelines for local mining operators and the local government in order to facilitate perspectives for economic development once mining has ceased." In addition, the experience gained in this pilot project is also important for BGR, he explains: "We have acquired extensive knowledge of the costs and challenges associated with recultivation in Indonesia. We can utilise this knowledge in other projects worldwide."

Möller believes that the recultivation of former mining areas is a field that has still not received sufficient attention in many countries. Soils around the world are threatened by degradation and "next to water and air, the soil is our most precious resource on earth", warns the soil scientist (also see *Our soils: the changing foundation of life*).

During their project in Indonesia, Schütte and Möller found the social interactions to be particularly exciting and work with the committed local partners very relaxed: "The many different parties involved all pulled together. This created a positive overall dynamic. "The BGR team will keep in contact with those involved." The project area was officially handed over in 2019 and PT Timah, the state-owned mining operator, will manage it from now on. The local village administration has committed to maintaining the recultivated pilot area for the next three years.

"This is a first milestone. We have demonstrated that sustainable alternatives to illegal small-scale mining can work", say the two BGR scientists. ■

**Dr. Philip Schütte**
B1.2 Geology of Mineral Resources
✉ Philip.Schuette@bgr.de

**Dr. Andreas Möller**
B2.4 Soil as a Resource – Properties and Dynamics
✉ Andreas.Moeller@bgr.de

# WHAT CHALLENGES DOES BGR FACE?

## Interview with the Board of Trustees Chair, Prof. Dr. sc. Antje Schwalb

**As the Chair of the Board of Trustees, you and experts from science and business advise BGR and the Federal Ministry for Economic Affairs and Energy (*BMWi*) on BGR's technical and organisational orientation. How does the Board of Trustees support BGR in its tasks?**
In its two annual meetings, the Board of Trustees catches up on BGR's scientific, technical and business-related consulting activities, as well as on important organisational and personnel issues. We discuss current scientific topics, deal with the future fields of action of a resources research institution, advise BGR on questions of national and international networking, in the fields of expertise and institutions, or discuss aspects of public relations. Here, the Board of Trustees and its members from research institutions, universities, industry and government ministries can shed light on issues and problems from a variety of perspectives. In this way, we support BGR in its continuous process of reflection on strategic alignment and in defining priorities, and can introduce recommendations for action.

**The pressure to exploit earth's natural resources is constantly increasing. What are the consequences for BGR's work?**
Our lives are increasingly affected by global developments, above all by global population growth – accompanied by increasing urbanisation and migration – by the globalisation of economic cycles, the switch to renewable energies and the effects of climate change. BGR faces these challenges. The Board of Trustees emphatically supports the BGR's approach to developing strategies and standards for the sustainable use of the earth's resources, in order to limit the environmental impact of the development and use of natural resources to a minimum or, wherever possible, to entirely avoid those impacts. In this

**PROF. DR. SC. ANTJE SCHWALB**

- Head of the Institute for Geosystems and Bioindication, Technische Universität Braunschweig (since 2012)
- Member of the BGR Board of Trustees (since 2015), Chair (since 2019)
- Habilitation, Universität Göttingen (2002)
- Docteur ès Sciences, Université de Neuchâtel (1992)
- Graduate in Geology/Palaeontology, Universität Göttingen (1987)

*"Rapidly growing volumes of data constantly challenge geosciences, but they also offer great opportunities."*

Prof. Dr. sc. Antje Schwalb

manner, BGR makes an important contribution to securing our own livelihoods and at the same time supports developing and emerging countries in building prosperity.

**With its new *BGR 2025+* action strategy, BGR pursues the goal of addressing urgent future tasks much more equitably. How can BGR continue to provide research and consulting at the highest level?**

In order to bolster its scientific capabilities, BGR has defined a new thematic focus, which at the same time allows responsibilities to be addressed across fields even better than previously. I think it's important that BGR intensifies its efforts in improving forecasting techniques in order to be able to assess the effects of human interventions in the subsurface even more precisely. Simultaneously, suitable science-based monitoring technologies and follow-up measures are being developed. Here, BGR benefits from its already excellent infrastructure with state-of-the-art laboratories, highly specialised methods and excellent scientific networking based on many years of national and international cooperation. As a university lecturer, I am particularly pleased that the supplementary measures to bolster academic performance include, for example, the recognition of university teaching by BGR colleagues and joint appointments with universities. Research collaborations with universities and non-university research institutions are equally as important. This reinforces networking in Germany's geolandscape, as well as with other countries – in turn creating the preconditions for further innovative research projects in the future.

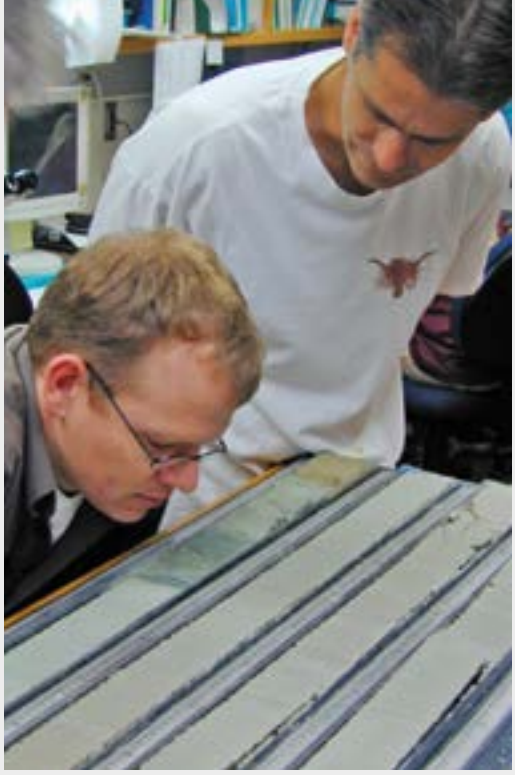
**At the beginning of the year, BGR hosted a highly recognized international conference on the subject of *Big data and machine learning* at BMWi. What does the future of applied geosciences look like?**

Rapidly growing volumes of data constantly challenge geosciences, but also offer great opportunities. Satellites provide data that can be utilised to assess the effects of climate change and natural disasters, as well as anthropogenic impacts, for example. Intelligent linking between the different data sets can contribute to managing geohazards or be employed in sustainable land use, for example. It opens up decision-making aids in oil exploration and production or in the exploration of groundwater resources. With the cross-scale combination of observation technologies and intensive professional networking, BGR is already setting new standards in earth observation.

**BGR addresses issues of high socio-political relevance. What are the key criteria for successful science communication?**

In order to increase public acceptance of geotechnologies, it is critical to communicate scientific data, facts and evaluations in a transparent and traceable manner, as well as to explain the need for the accompanying research. BGR makes a particularly important contribution to this goal. The aim is to make consumers even more cognizant of the sustainable use of our georesources. This means, for example, that we broaden our knowledge of the origins of the natural resources that are essential in manufacturing our everyday objects. In addition, it is important to raise societal awareness of the environmental and social conditions under which these natural resources are extracted. With the increasing pressure to exploit natural resources, platforms for the exchange and transfer of knowledge will increasingly be a necessity in the future to enable a critical and controversial, but above all constructive discourse with and in society. ■

Jochen Erbacher during field work in the Harz Mountains.



The BGR scientist (left) and a colleague examine a core sample that was taken from the Atlantic off Suriname.

Jochen Erbacher investigates a quartz sand pit near Uhry in Lower Saxony, Germany.

# RESEARCH, TEACHING AND GEOMANAGEMENT – JOCHEN ERBACHER COMBINES THEM ALL

For almost 15 years, Prof. Jochen Erbacher has been coordinating the German contribution to the international IODP research programme, in addition to his duties as BGR head of the stratigraphy and collections section. At the same time, he teaches as an honorary professor at the University of Heidelberg and is the editor of a specialist scientific journal.

"As a departmental research facility, BGR offers me a broad range of opportunities to perform scientific work and simultaneously pursue my diverse interests", says the geologist.

Jochen Erbacher's scientific career began in 1991. After studying geology and palaeontology at the Eberhard-Karls-University of Tübingen, Erbacher authored his dissertation on the development of radiolarians (unicellular, silica-shelled planktonic organisms) in the Cretaceous oceans. To this end, he conducted research in Italy and on cores from the Ocean Drilling Program (ODP), which would later develop into the International Ocean Discovery Program (IODP). As a *post-doc*, Erbacher continued his work in this field with a project in south-east France. Several expeditions on research vessels followed, including an ODP expedition off Florida. During this time he also accepted a teaching position (micro-palaeontology, mapping courses) at the University of Tübingen.

Erbacher arrived at BGR in 1997. He initially started out as an employee in a third-party funded project in which he supported the German coordination office for the ODP research programme, which was then part of the BGR. There, in what was formerly the Marine Geology section, the young geologist finally gained a foothold three years later when he successfully applied for a permanent position.

Following this, the aspiring scientist's career at BGR quickly picked up speed. In 2003 Erbacher led his first expedition. On what was then the largest research vessel in the world, the JOIDES Resolution, he investigated the effects of extreme greenhouse climate conditions during the Cretaceous as part of the ODP programme off Surinam, as well as the formation of petroleum source rocks. In 2006 Erbacher took over as head of the German coordination office for the IODP successor programme, the organisation of which had also been entrusted to BGR by the German Research Foundation (DFG). "With their work in the global IODP project, scientists from 23 countries are researching previously inaccessible regions of the ocean floor", says Erbacher, describing the task of the international programme.

Erbacher himself was involved in five expeditions. He is now primarily a programme manager. Erbacher: "Together with my team in the IODP office we organise the participation of German scientists in the programme's expeditions and projects, and are also responsible for the annual reports, maintaining lists of publications and hosting colloquia and workshops."

He can easily combine his work for the IODP with his principal duties at BGR. After Erbacher had, in the mean-

The BGR scientist (left) on board the research ship FS Heinke in the German North Sea.

*"As a departmental research facility, BGR offers me a broad range of opportunities to perform scientific work and simultaneously pursue my diverse interests."*

Prof. Dr. Jochen Erbacher

time, been entrusted with the establishment of a German collaborative project to investigate the geopotentials of the German North Sea, as well as with the establishment of the national core archive in the Spandau area of Berlin, under the leadership of BGR, he took over as head of section of BGR's stratigraphy and collections in 2008. "For example, our roles include curating the collections and core archives in Hannover, Spandau and Grubenhagen, as well as implementing stratigraphic research drilling", he says.

As a BGR department head and – since 2009 – deputy department head (*Geoinformation, Stratigraphy*) and IODP coordinator, Erbacher is primarily in demand as a researcher and geo-manager. As editor of the specialist journal *Newsletters on Stratigraphy* (since 2008) and a member of numerous scientific committees, the geologist is an integral part of the international scientific community. "For me, professional networking is an essential element of successful research", emphasises Erbacher.

However, he continues to have a scientific passion for teaching. The BGR official has been volunteering at the University of Heidelberg since 2014 – initially as a lecturer and since 2018 as an honorary professor at the Faculty of Chemistry and Earth Sciences. Erbacher: "I want to pass on my knowledge to younger generations." ■

**THE INTERNATIONAL OCEAN DISCOVERY PROGRAM (IODP)**

The *International Ocean Discovery Program* is a deep-sea drilling programme in which scientists from 23 countries explore inaccessible areas of the ocean floor. The IODP coordination office responsible for Germany is located at BGR. On behalf of the German Research Foundation (DFG), it organises the participation of German scientists in expeditions and projects of the international programme and is also responsible for the annual reports, lists of publications and hosting colloquia and coordination meetings. BGR has been the German implementation organisation for IODP and its predecessor programmes since 1975.

The IODP was launched in October 2013. It builds on previous scientific ocean drilling programmes.

The scientific objectives of the drilling programme have been summarised in the science plan *Illuminating Earth's Past, Present, and Future*. It defines four main areas of research emphasis: *Climate and Ocean Change, Biosphere Frontier, Earth Connections and Earth in Motion*.

**Prof. Dr. Jochen Erbacher**
B4.2 Geoinformation, Stratigraphy

✉ Jochen.Erbacher@bgr.de

First meeting of the early career scientists from the new *Early Career Scientists Club* with the Geozentrum management

# SKILLS OF TOMORROW – THE EARLY CAREER SCIENTISTS NETWORK

Continuously striving to meet the demands of scientific excellence in the present day and the future, BGR attaches a special importance in nurturing the next generation of academics. BGR proudly supports the work of early career researchers and scientists (ECS) at the *doctoral club*, now reshaped as the Geozentrum Hannover's *Early Career Scientists Club*. The club equally welcomes scientists of early career stages from *Landesamt für Bergbau, Energie und Geologie* (LBEG) and the *Leibniz Institute for Applied Geophysics* (LIAG). The club aims, but is not limited to, providing a platform for networking, collaboration, discussion of scientific topics and (PhD) support. More than 25 early career scientists, including both home and international researchers, currently belong to the ECS network at the Geozentrum Hannover. Among them are the two spokespeople of the Early Career Scientists Club, Dr. Sarah Weihmann and Konstantin Kühnel.

For the past year, **Dr. Sarah Weihmann** has been working as a post-doctoral researcher at BGR in the field of geotechnical stability analysis. Her field of research plays a vital role in determining a solution for high-level radioactive waste in Germany. Working at BGR enables her to directly apply her doctoral thesis in geomechanics (fluid flow in fractures) and qualify for a professorship in this field. "Here (at BGR), I can expand my technical knowledge and skills through interdisciplinary contact", explains Dr. Weihmann. Over the next few years, she aims to gain further experience necessary for scientific advancement.

"In addition to my project work at BGR, I will teach at the university, take responsibility for the acquisition of third-party funding and focus on publishing in high-ranking peer-reviewed international journals", Dr. Weihmann continues.

**Konstantin Kühnel** works at BGR in the *Geology of Mineral Resources* department as a research assistant. He is also pursuing his doctoral degree at the Technical University of Berlin. For his doctorate, he is addressing how to guarantee a sustainable supply of mineral resources.

"I was already able to gain insights into this topic during my previous studies in mining engineering", says Kühnel. BGR offers him the opportunity to participate in scientific discussion on sustainability in the extraction of natural resources. He also is participating in international conferences and gains experience through interdisciplinary exchanges with scientists in the geo, resource and environmental sciences. "All of this constitutes input into my doctorate thesis. As a result, I feel well positioned to publish my research in recognized journals, which is a requirement to achieve my doctorate", explains Kühnel. ■

**Early Career Scientists Club**
✉ ECS-Club@bgr.de

# APPRENTICES – DIVERSE TRAINING OPPORTUNITIES AT BGR

BGR currently offers training opportunities in seven different professions, including, among others, the fields of office management, chemistry, IT, geomatics and motor vehicle mechatronics.

**David Schlecht** (photo) is one of a total of 12 apprentices currently at BGR. As a prospective office management clerk, he is in his second year of training. In the course of his training, he goes through several different stations within the administrative and organisational departments of the authority. "This allows me to learn a large number of core skills for my future career", says David Schlecht. In addition to extensive training, BGR also attaches great importance to the independence of its apprentices. The apprentices learn to work on and solve tasks independently. In addition, the apprentices can always count on honest and constructive feedback. "I really like working with the trainers. They are competent, you always get an answer immediately if you have any questions and the atmosphere at work is good", says David Schlecht. After completing his training, he wants to expand his knowledge further. "I would like to continue my education, maybe start studying", says David Schlecht about his future.

**Alana Zimmer** (photo) is completing her second year of training as a chemical laboratory technician. She is also involved in BGR's youth and trainee representation. When choosing the institution to train with, the direction of research was very important to her. "I wanted to do my apprenticeship in an institution that covers several fields and does not specialise in just one", Alana Zimmer reports. She appreciates the different objectives of her training. "I come into contact with almost all aspects of chemistry, get to know a large number of devices and processes that help in substance analyses", says Alana Zimmer. In addition to vocational college, she also receives lessons at BGR – here the theoretical content is explained in more detail and open questions are answered. "This should not be taken for granted and I am very grateful for it", says Alana Zimmer. After completing her training, she would like to stay at BGR to gain professional experience. A degree would then also be an option for her. "I would like to get a foothold in forensics one day", adds Alana Zimmer.

**APPRENTICESHIPS AT BGR:**

- Chemical laboratory technician (3½ years)
- Office management clerk (3 years)
- Media and information services specialist (3 years, dual)
- IT specialist (3 years)
- Precision mechanic (3½ years)
- Geomatician (3 years)
- Motor vehicle mechatronics technician (3½ years)

**Youth and trainee council (JAV)**
JAV-BGR@bgr.de

# BGR

## BGR offices


## BGR employees

**735**

**+ 22 APPRENTICES**

| | |
|---|---|
| Employees | **507** |
| Civil servants | **228** |
| Permanent employees | **546** |
| Temporary employees | **141** |
| Women | **281** |
| Men | **454** |
| With academic qualification | **438** |
| Without academic qualification | **297** |
| Doctoral/post-doc students/Scientific Temporary Contract Act | **20** |

Valid as of: 01/07/2020

## 2019 budget

Income (third-party funding)

**21,811,782.88 €**

Expenditure

**99,661,999.95 €**

Expenditure for orders from other federal agencies and third parties (in particular BMZ)

**20,379,565.41 €**

# CONSULTING

BGR is the central geoscientific authority providing advice to the Federal Government in all geo-relevant questions. Its core tasks include advising and informing the Federal Government, German business and the general public, particularly on the issues of securing the supply of natural resources and energy in the Federal Republic of Germany over the long term, the final disposal of radioactive waste and sustainable georesource management. On the basis of research and development and with the involvement of institutional and scientific networks, BGR advises and informs at national, European and international levels. The addressees also include actors in the partner countries involved in development cooperation. BGR publishes studies, opinions and communiques. Their experts provide scientific expertise in lectures and at other events. They appear as experts in parliamentary committees, answer questions from the German Bundestag (lower house) and support institutions such as the United Nations, the EU Commission, the World Bank and the *Kreditanstalt für Wiederaufbau*.

## Examples of BGR advisory responsibilities

### DERA

The German Mineral Resources Agency (DERA) at BGR advises German companies on the sustainable and secure supply of raw materials. In the years 2018 and 2019, seven studies and reports were published as part of the *DERA Rohstoffinformationen* publication series, including raw material risk assessments on magnesium (metal), tantalum and cobalt, as well as a study on the cooperation potential for German companies in the Canadian commodities sector and the 2019 DERA commodities list. Results are presented at DERA's in-house industry workshops and discussed with relevant stakeholders from companies and trade associations, inluding its study on Chinese raw materials. DERA's newsletter „Rohstoff-Trends", published quarterly since 2019, aims to give an overview of market developments and is the latest addition of regular DERA publications.

### SECTOR PROJECT EXTRACTIVES & DEVELOPMENT

BGR's "Extractives and Development"-project provides policy advice to the Federal Ministry for Economic Cooperation and Development (BMZ) and supports the Ministry in international dialogues as well as in initiatives (e.g. the European Partnership for Responsible Minerals), events and publications. Among other things, it was involved in setting up a stakeholder network on the responsible procurement of gold from artisanal and small-scale mining and developed the Local Investment Opportunities in Natural Resource Projects tool (LION). The aim of LION is to make better use of the potentials of resource-rich countries for broad economic development. By modelling the procurement demand in natural resource projects, LION identifies the procurement categories with the highest demand in the mining industry. The knowledge gained from this data helps to inform local suppliers and decision makers of the investment opportunities in the mining sector and thus increase the share of local content in order to contribute to local value addition and economic development. LION has so far been implemented for Gold mining in West Africa and Copper/Cobalt in the Copperbelt in the DR Congo and Zambia.

### SECTOR PROJECT POLICY ADVICE GROUNDWATER

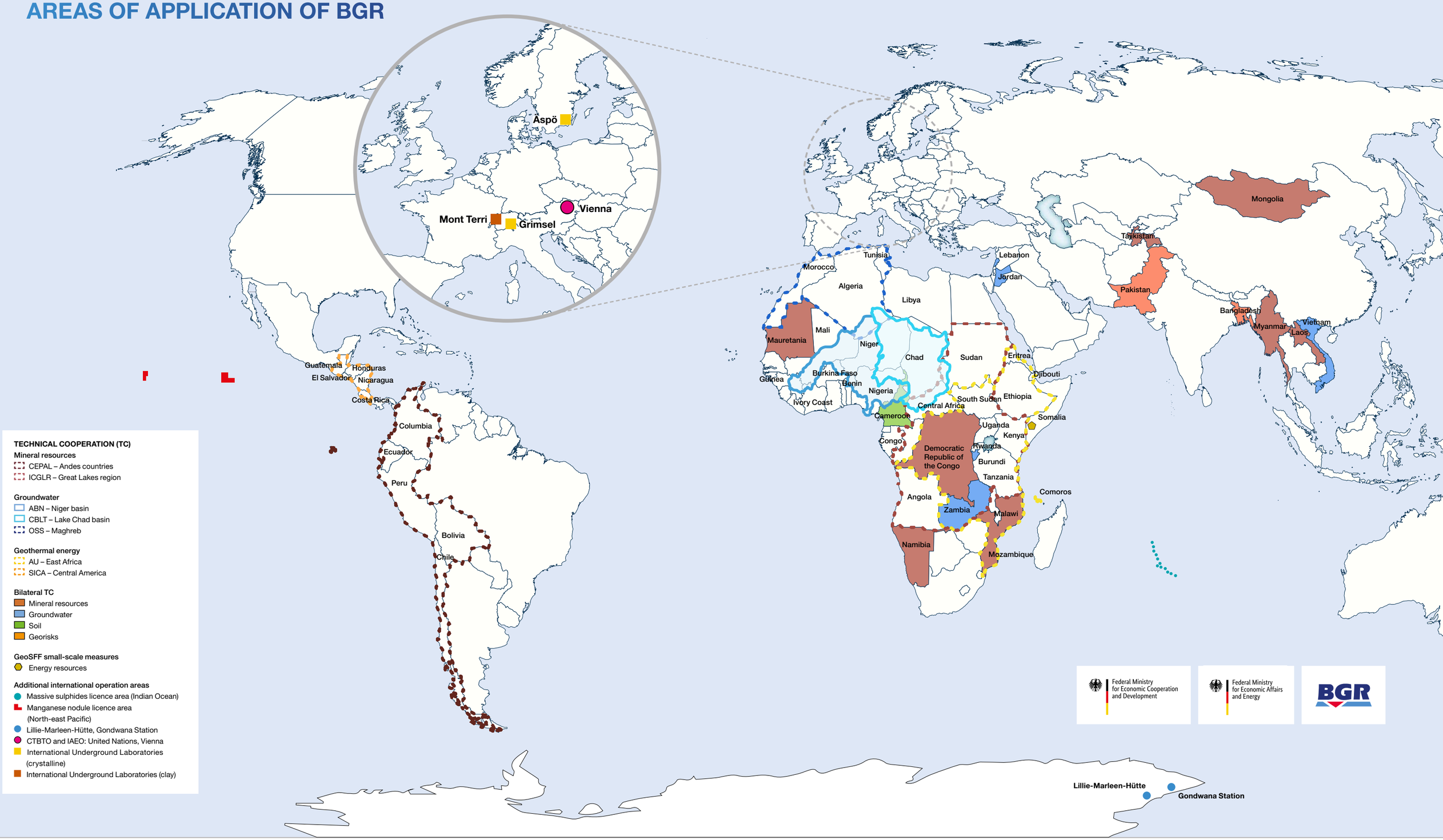
Population growth, economic development and climate change put an increasing pressure on the world's groundwater resources, especially in the world's arid regions. BGR's sector project *Policy Advice Groundwater* supports BMZ in direct advice and develops strategies and concepts for sustainable groundwater management in German and international development cooperation. The project provides contributions for sectoral policy conferences, moderates dialogues and supports international and regional initiatives to bring a sustainable groundwater management on the political agenda. In this context the sectoral project is currently supporting the African Ministers Council on Water (AMCOW) in setting up the AMCOW Pan-African Groundwater Programme (APAGroP).

### FINAL DISPOSAL

BGR advises the *Federal Company for Radioactive Waste Disposal – BGE (Bundesgesellschaft für Endlagerung mbH)* on the basis of a collaboration agreement in the field of site selection and federal final disposal sites. It carries out geoscientific and geotechnical investigations commissioned by BGE and evaluates them for the current federal final disposal sites *Schacht Konrad* and *Morsleben repository*, as well as for Asse II mine. In addition to the underground investigations in parts of the *Asse II* mine, BGR supervises the above-ground seismic surveys on behalf of BGE. With the help of the data obtained, BGR makes an important contribution to the characterisation of the salt structure there.

FACTS & FIGURES

# AREAS OF APPLICATION OF BGR




**TECHNICAL COOPERATION (TC)**

**Mineral resources**
- CEPAL – Andes countries
- ICGLR – Great Lakes region

**Groundwater**
- ABN – Niger basin
- CBLT – Lake Chad basin
- OSS – Maghreb

**Geothermal energy**
- AU – East Africa
- SICA – Central America

**Bilateral TC**
- Mineral resources
- Groundwater
- Soil
- Georisks

**GeoSFF small-scale measures**
- Energy resources

**Additional international operation areas**
- Massive sulphides licence area (Indian Ocean)
- Manganese nodule licence area (North-east Pacific)
- Lillie-Marleen-Hütte, Gondwana Station
- CTBTO and IAEO: United Nations, Vienna
- International Underground Laboratories (crystalline)
- International Underground Laboratories (clay)

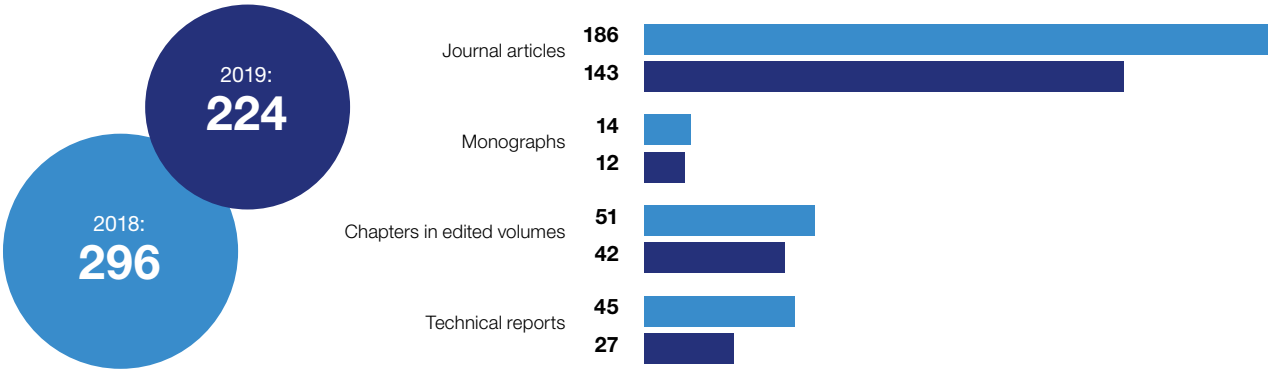
Federal Ministry for Economic Cooperation and Development

Federal Ministry for Economic Affairs and Energy

BGR

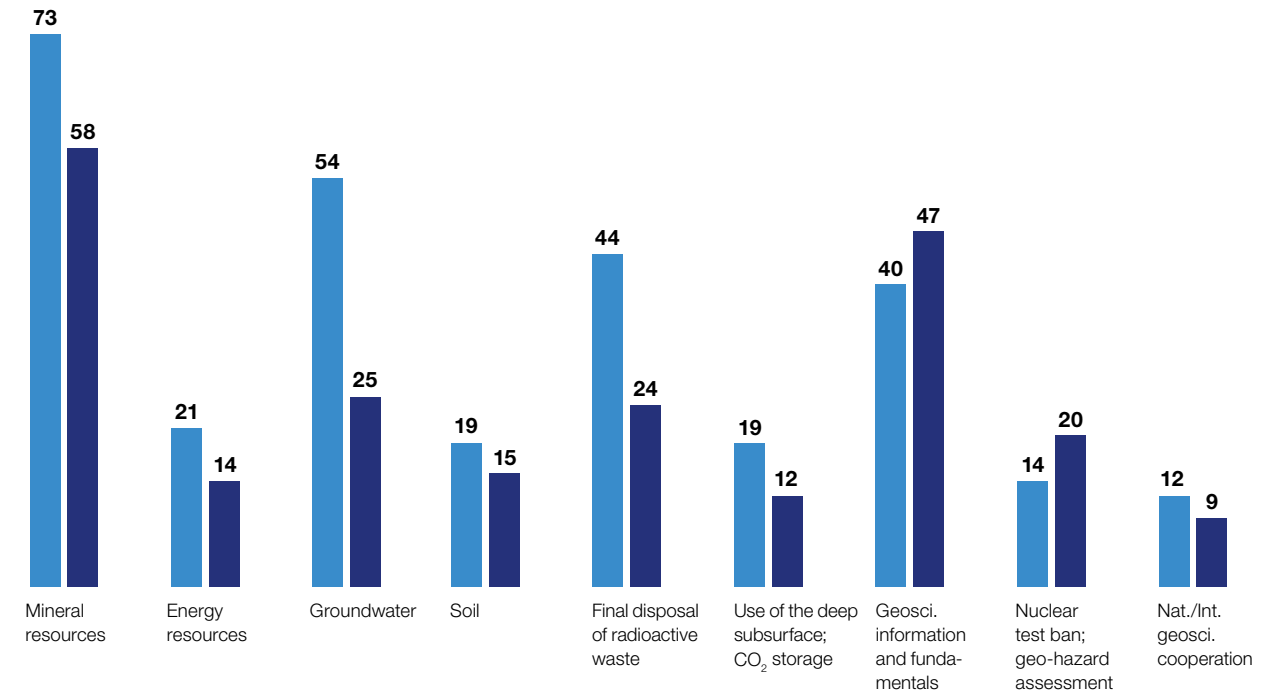
# PUBLICATIONS

## BGR's scientific publications[1)]




[1)] Either the first author or one or several co-authors are affiliated with BGR.

## Publications according to topics[2)]




[2)] Total includes closed and open access publications.

# PRODUCT CENTRE

BGR's digitally available specialist information can be accessed via the product centre on the BGR website. The product centre currently encompasses around 600 geoscientific and resource management thematic datasets, in particular maps (sheets).[1)] The latter are continuously updated. In addition, BGR is increasingly adapting its national map series to the technical requirements of uniform European maps under the directive for a European geospatial data infrastructure (INSPIRE).

## National thematic datasets (selection)

### SOIL

Soil quality rating for cropland in Germany 1:1,000,000 (SQR1000)
Soil map of Germany 1:250,000 (BÜK250)
Heavy metal and trace element background values in German Soils 1:1,000,000 (HGW1000)
Potential soil erosion risk on arable soils in Germany 1:1,000,000 (PEGWASSER1000)
Potential risk of wind erosion on arable soils in Germany 1:1,000,000 (PEGWIND1000)
Field capacity of German soils (FK10dm1000_250)

### GEOLOGY

The General Geological Map of the Federal Republic of Germany 1:250,000 (GÜK250)
Geological Map of Germany 1:1,000,000 (GK1000)
Geoscientific Map of Germany 1:2,000,000 - Geology (GK2000 Geologie)
Salt structures in Northern Germany (InSpEE-Salzstrukturen)
Horizontal cross-section maps of Northern Germany (InSpEE-Niveauschnitte)

### GEOPHYSICS

German Earthquake Catalogue (GERSEIS)
Helicopter-borne Electromagnetics (HEM)

### HYDROGEOLOGY

Groundwater Yields of Germany 1:1,000,000 (ERGW1000)
Groundwater Background Values of Germany (HGW)
Hydrogeological Map of Germany 1:250,000 (HÜK250)
Mean Annual Groundwater Recharge of Germany 1:1,000,000 (GWN1000)

### RAW MATERIALS

Map of Mineral Resources of Germany 1:1,000,000 (BSK1000)
Map of Mining and Storage Operations of the Federal Republic of Germany 1:2,000,000 (BergSP)
Map of the raw materials close to the surface in the Federal Republic of Germany 1:200,000 (KOR200)

## Global and European datasets (selection)

EMODNET Seafloor Geology - Pre Quaternary (EMODnet4-PreQ)
Global Groundwater Vulnerability to Floods and Droughts (WHYMAP GWV)
Groundwater Resources of the World (WHYMAP GWR)
International Geological Map of Europe and the Mediteranean Regions 1:1,500,000 (IGK1500)
The 1:5 Million International Geological Map of Europe and Adjacent Areas (IGME5000)
International Hydrogeological Map of Europe 1:1,500,000 (IHME1500)
Marine Seismic Survey Profiles (MSSP)
Soil Regions of the European Union and Adjacent Countries 1:5,000,000 (EUSR5000)
Global Distribution of Precambrian Rocks (Precam)
World-wide Hydrogeological Map Information System (WHYMIS)

[1)] The datasets accessible via the product centre were collected by BGR in collaboration with the state geological surveys of the federal states or at the European level, or they were developed through the standardisation and harmonisation of datasets of the federal states.

# BGR

The Federal Institute for Geosciences and Natural Resources (BGR) advises and informs the Federal Government and German business on all issues relating to geosciences and natural resources. As the German Centre of Excellence for geoscience, BGR's work focuses on ensuring that natural resources are used in a way that is economically and environmentally sound and thus in the interest of humankind. BGR is a higher federal authority. It is subordinate to the Federal Ministry for Economic Affairs and Energy (BMWi) and is part of Germany's scientific and technical infrastructure. As Germany's Geological Survey, BGR undertakes a large number of international duties. In Germany, its main task is to act as a coordinator. Together with the State Authority for Mining, Energy and Geology (LBEG) and Leibniz Institute for Applied Geophysics (LIAG), BGR forms the GEOZENTRUM Hannover.

◀ Organisational Chart of the Federal Institute for Geosciences and Natural Resources

**BGR Report**
Download as PDF

www.bgr.bund.de/Report2020_en

# Organisational Chart of the Federal Institute for Geosciences and Natural Resources


**Federal Institute for Geosciences and Natural Resource**
Postal address: Stilleweg 2, 30655 Hannover
PO Box 510153, 30631 Hannover, Germany
Telephone: 0511 643-0 or extension
Telefax: 0511 643-2304

**German Mineral Resources Agency/Berlin Office**
Postal address: Wilhelmstr. 25-30, 13593 Berlin
Telephone: 030 36993-0 or extension
Telefax: 030 36993-100
Internet: http://www.bgr.bund.de
Email: Poststelle@bgr.de


**PRESIDENTIAL STAFF[4], PRESS OFFICE**

C. Blume 2835
Press Officer:
A. Beuge 2679

**PRESIDENT**

Prof. Dr. R. Watzel 2101

**VICE PRESIDENT**

Dr. V. Steinbach 2352

**INTERNAL AUDIT**

K. Krämer 3840

**GERMAN INSPECTION BODY FOR EU DUTIES OF CARE IN NATURAL RESOURCE SUPPLY CHAINS (DEKSOR)**

M. Baier 2069

**Data protection officer**
A. Schenk 3688

**Occupational safety specialist in acc. with § 5 ASiG**
D. Reinert 2248

**Equal opportunities officer**
R. Altmann 2340

**Person of trust in acc. with Section 3.5 of the rules for safe-guarding good scientific practice**
Dr. U. Lanzendorf 2312

**Staff Council**
Chair:
K. Kruse 3036

**Person of trust for the severely disabled**
U. Fabel-Schulz 2876

**DEPARTMENT Z[1]**
**Central Affairs**

F. Sieling 2494
Deputy: C. Jahn 2155

Department Controlling
A.-C. Woodyard 2279

**SECTION Z.1**
**Personnel**

K. Fischer

**SECTION Z.2[1]**
**Technical Equipment, Internal Services**

R. Schwier 3042

**SECTION Z.3**
**Organisation, Central Controlling**

G. Lopez Wismer 2156

**SECTION Z.4**
**Budget and Financial Management**

F. Lichtenberg 2303

**SECTION Z.5**
**Procurement, Materials Management**

C. Jahn 2155

**SECTION Z.6[1]**
**Central Information Technology**

H.-G. Möws 3181

**SECTION Z.7[1]**
**Library, Archive**

N. N.

**SECTION Z.8**
**Publications**

N. N.

**DEPARTMENT 1**
**Energy Resources, Mineral Resources**

Dr. V. Steinbach 2352
Deputy: Dr. H. Wilken 2362

Department Controlling
Dr. I. Heyde 2782

**DEPARTMENT 1.1**
**German Mineral Resources Agency (DERA)**
Dr. P. Buchholz 030/36993228
Deputy:
Dr.-Ing. S.-U. Schulz 030/36993235

**DEPARTMENT 1.2**
**Geology of Mineral Resources**

Dr. H. Wilken 2362
Deputy: Dr. G. Franken 2370

**DEPARTMENT 1.3**
**Geology of Energy Resources, Polar Geology**

Prof. Dr. C. Gaedicke 3790
Deputy: Dr. D. Franke 3235

**DEPARTMENT 1.4**
**Marine Resource Exploration**

Dr. C. Müller 3129
Deputy: N. N.

**DEPARTMENT 1.5**
**Resource Geochemistry**

Dr. K. Beckmann 2053
Deputy: Prof. Dr. A. Schippers 3103

**DEPARTMENT 2**
**Groundwater and Soil Science**

Prof. Dr. T. Himmelsbach 3794
Deputy: Dr. U. Meyer 3212

Department Controlling
Dr. S. Costabel 3489

**DEPARTMENT 2.1**
**Geophysical Exploration – Technical Mineralogy**

Dr. U. Meyer 3212
Deputy: Dr. B. Siemon 3488

**DEPARTMENT 2.2**
**Basic Information – Groundwater and Soil**

Dr. J. Reichling 2366
Deputy: Dr. E. Eberhardt 3733

**DEPARTMENT 2.3**
**Groundwater Resources – Quality and Dynamics**

N. N.
Deputy: Dr. G. Houben 2373

**DEPARTMENT 2.4**
**Soil as a Resource – Properties and Dynamics**

Dr. habil. E. Fries 2814
Deputy: Dr. F. Stange 3071

**DEVELOPMENT STAFF**
**to establish the Post-Mining Landscapes Research and Development Centre**

N. N.
Dr. habil. C. Neukum[3] 2223

**DEPARTMENT 3**
**Underground Space for Storage and Economic Use**

G. Enste 2442
Deputy: N. N.

Department Controlling
N. N.

**DEPARTMENT 3.1**
**Resource Potentials of the Geological Subsurface**

Dr. G. von Goerne 3101
Deputy: N. N.

**DEPARTMENT 3.2**
**Geological-geotechnical Exploration**

N. Schubarth-Engelschall 2436
Deputy: N. N.

**DEPARTMENT 3.3**
**Characterisation of Storage and Barrier Rocks**

Dr. J. Lippmann-Pipke 2848
Deputy: N. N.

**DEPARTMENT 3.4**
**Long-term Stability**

Dr.-Ing. J. R. Weber 2438
Deputy: S. Mrugalla 3764

**DEPARTMENT 3.5**
**Geotechnical Stability Analyses**

Dr.-Ing. S. Fahland 2584
Deputy: N. N.

**DEPARTMENT 4**
**Geoscientific Information, International Cooperation**

Dr. C. Bönnemann 3134
Deputy: N. N.

Department Controlling
Dr. S. Donner 3904

**DEPARTMENT 4.1**
**International Cooperation**

N. N.
Deputy: Dr. A. Hoffmann-Rothe 2651

**DEPARTMENT 4.2**
**Geoinformation, Stratigraphy**

T. Wodtke 3455
Deputy: Hon.-Prof. Dr. J. Erbacher 2795

**DEPARTMENT 4.3**
**Federal Earthquake Service, Comprehensive Test Ban Treaty**

Dr. L. Ceranna[2] 2252
Deputy: N. N.

**DEPARTMENT 4.4**
**Geo-Hazard Assessment, Remote Sensing**

Dr.-Ing. T. Lege 3001
Deputy: Dr. D. Balzer 2742

[1] also responsible for the LBEG on the basis of the administrative agreement as of 01.01.2021
[2] provisional/on probation
[3] entrusted with the conduct of business
[4] responsible for risk management

Dated: 16.02.2021

**www.bgr.bund.de**

Federal Institute for Geosciences and Natural Resources
Stilleweg 2
30655 Hannover
Telephone: +49 (0)511 643 0
Email: info@bgr.de

BGR is a higher federal authority. It is subordinate to the Federal Ministry for Economic Affairs and Energy (BMWi) and is part of Germny's scientific and technical infrastructure.