BGR Report

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Decarbonisation brings major challenges for commodity markets

Imprint

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

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

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Editorial

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

Dear Readers,

BGR was first-time host of the German event to celebrate World Soil Day when loess soil was presented as "Soil of the Year 2021". Due to the Covid-19 pandemic, the event was hosted in a hybrid format for the first time, with a minor number of guests attending live and the majority joining online. The article starting on page 6 shows why it is so important to value soils as an essential basis for our lives.

The use of new technologies is just as relevant as the protection of essential georesources. From page 22 we report how BGR uses artificial intelligence and machine learning in various research areas, enabling us to use ever larger data volumes in a purposeful way and develop solutions for specific research tasks.

The path out of the fossil fuel age is leading to a boom for numerous high-tech metals. The increasing need for climate-neutral energy technologies will transform commodity markets for decades to come. The cover story of this Report describes from page 16 how the German Mineral Resources Agency, DERA, which is part of BGR, prepares forecasts for future demands.

In another field, BGR is addressing direct effects of the fossil fuel age. Lignite mining has left lasting marks in the coalfield regions. BGR is currently setting up a new research and development centre in Cottbus to develop new concepts for mitigating the effects of mining with regard to groundwater and post-mining landscapes. This knowledge will also be of interest for international projects, as you can read from page 20.

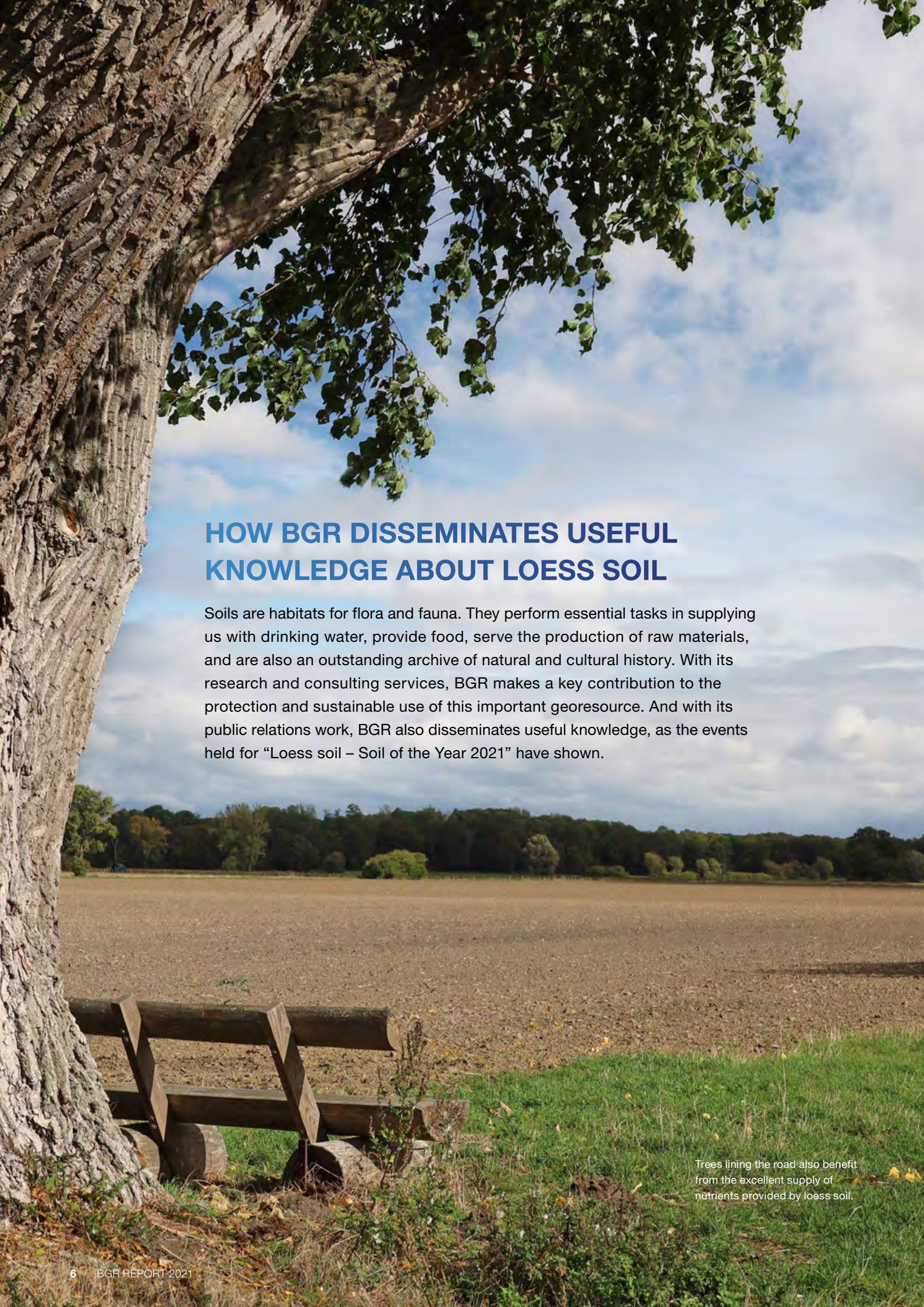
The safe long-term disposal of heat-generating radioactive waste from nuclear power plants is a major topic in Germany and other countries, which is why we have seen greater networking of repository research at the European level. From page 34, you can read about BGR's participation in scientific engagement in international projects and programmes.

BGR has been a valued partner of the Federal Government in development cooperation for decades. With a new strategy, BGR aims at more efficiency and sustainability in cooperation projects. For the first time governance studies have been carried out in the groundwater sector, specifically in Jordan and Zambia. Read from page 36 why a sound understanding of the political structures of partner countries contributes to project success.

I hope you will find this BGR Report an enjoyable read!

HOW BGR DISSEMINATES USEFUL KNOWLEDGE ABOUT LOESS SOIL

Soils are habitats for flora and fauna. They perform essential tasks in supplying us with drinking water, provide food, serve the production of raw materials, and are also an outstanding archive of natural and cultural history. With its research and consulting services, BGR makes a key contribution to the protection and sustainable use of this important georesource. And with its public relations work, BGR also disseminates useful knowledge, as the events held for “Loess soil – Soil of the Year 2021” have shown.



Trees lining the road also benefit from the excellent supply of nutrients provided by loess soil.

Left: BGR President Ralph Watzel attending the "Soil of the Year 2021" event at Geozentrum Hannover.

Below: Prof. Dr. Tamás Harrach gave the official speech celebrating the soil of the year.

Every day, soil is lost – because of building developments, for instance. It is washed away by water and eroded by the wind. To protect this most important basis for our lives, we need a new perspective on the threat to soils and greater appreciation for soil. This is why BGR has supported the "Soil of the Year" campaign right from the start. The Advisory Board Soil of the Year has been awarding the title since 2005. The campaign aims to raise awareness of the key role soils play in the environmental balance.

Celebrating a special soil

When loess soil was presented as "Soil of the Year 2021" on World Soil Day in December 2020, BGR was the first-time host of the event alongside the Advisory Board Soil of the Year. Because of the Covid-19 pandemic, it was held in a hybrid format, with a small number of guests attending at Geozentrum Hannover and about 200 others joining online.

BGR President Prof. Dr. Ralph Watzel also welcomed Elisabeth Winkelmeier-Becker, Parliamentary State Secretary to the Federal Minister for Economic Affairs and Energy, at the event. "I'm hoping to promote greater public awareness for soil protection and a responsible use of soils", said Ms Winkelmeier-Becker at the event celebrating the "Soil of the Year 2021", of which she is the patron.

"With its wide range of functions, loess soil in particular makes important contributions to agriculture, food security, and groundwater conservation", she emphasised in her address.

In his speech celebrating the soil of the year, Prof. Dr. Tamás Harrach highlighted the unique character of loess soil. Harrach, who has worked on loess soils throughout most of his career as a scientist, spoke about the special qualities of this type of soil: loess soil performs many of the functions of a soil particularly well, such as storing water and important nutrients. Thanks to this excellent storage capacity, the soil also retains harmful substances, so they cannot be easily absorbed by plants or leached into the groundwater. These attributes result from a mostly homogeneous composition of loess. Loess is a more or less calcareous, homogeneous, pale yellow to grey, largely silt-sized sediment, i.e. with grain sizes between 0.002 and 0.063 mm. This gives the soil a large surface area that can adsorb substances, while the pores between the silt particles can retain water against the Earth's gravity.

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Studies on the transport of water and matter in the loess soil of the Cologne Lowland.

Loess dolls found in trenches excavated for the soil of the year.

Loess – a product of the last glacial period

Most loess soil formed during the last glacial period, around 115,000 to 13,000 years ago, when large parts of Germany were covered by ice. Rock had been broken down by a combination of glacier activity and frost weathering. Often, all that was left was mineral dust. This would then be swept up into the air by dry cold fall winds descending from the glaciers and usually be deposited on the leeward slope of a ridge.

Depending on the climate, it developed into black earth, Luvisols and Haplic Retisols. In humus-rich black earth, a dry climate and cold winter temperatures delayed the decomposition of organic matter. The humus of the topsoil was transported to lower areas of the soil by soil fauna, resulting in thick dark coloured soil horizons.

Luvisols formed in areas where clay was transported by seepage water into the subsoil. Where leaching was so intense that the topsoil was bleached, Haplic Retisols would form. The formation of all these soil types starts with the leaching of lime. When environmental conditions change, the soil solution may become supersaturated with lime and lime precipitation will occur. This leads to the formation of hard concretions with irregular shapes measuring up to several centimetres in length, so-called loess dolls, particularly in deeper areas of the soil. They were given this name because they often have a figure-like shape or are reminiscent of animals or plants.

In Northern Germany, loess soils can be found in the fertile börde belt north of the Central Uplands. This includes, for instance, the Jülich-Zülpich Börde and Soest Börde in North Rhine-Westphalia, the Calenberg Loess Börde and Hildesheim Börde in Lower Saxony, the Magdeburg Börde in Saxony-Anhalt, and the Leipzig Basin in Saxony. In Southern Germany, loess soils occur in areas north of the gravel plains of the Alpine rivers, in the Upper Rhine Plain, and in the wide valleys and basins of the Central Uplands.

The origins of the term “loess” are not entirely clear. It may be a variant of the Alemannic dialect word “lösch”, meaning loose.

An all-rounder

Soils in the loess börde areas are very fertile and productive, making them highly suitable as arable land. “They are loose, well aerated and contain sufficient nutrients. Loess soil pores have just the right size so plants can make the best use of the water stored in them”, explains BGR soil expert Dr. Florian Stange. The pore size also provides relatively good water conductivity. These properties combined result in an excellent delivery of water to the plants thanks to capillary rise from the area without roots. “This is why loess is the soil of choice for water-intensive crops such as sugar beets”, says Stange.

But that is not all: with its high sorption capacity, loess soil also retains many harmful substances, thus making an important natural contribution to groundwater conservation. “All these qualities make loess soil a real all-rounder”, says BGR soil expert Stange.

Sugar beet is a major crop in loess soils.

Erosion of a loess soil caused by water.

BGR exhibition on loess soil, the Soil of the Year 2021 with entrance to the soil tunnel.

Even the earliest farmers about 7,500 years ago knew about the excellent properties of fertile loess soils with stable yields. It was around that time in human history when they first built settlements, cultivated fields and reared animals.

The other side of the coin

But there is another side to this soil type. Loess soils are highly prone to wind and water erosion whenever they lack a vegetation cover to protect them. Soil loss through erosion can, however, be prevented if suitable action is taken. During winter, for instance, the soil should not be left uncultivated, as catch crops can protect it from erosion.

Another problem remains. Because of the building of houses and roads, many good soils, including loess, are still irretrievably lost.

But there is also good news. When lignite extraction in West German mining areas had come to an end, the loess soil that had previously been removed was restored, so whole areas could be reclaimed as arable land. ■

THE SOIL EXPERIENCE

With its exhibition on the “Soil of the Year 2021”, BGR has addressed many aspects related to loess soil. Because of the Covid-19 pandemic, the exhibition was initially open to virtual visitors only, on the Internet. But even the online format brings to life the special qualities of these soils. Comprehensive information is available on many informative posters. Real soil profiles in the form of lacquer peels provide unique insights into the world of loess soil. And a soil tunnel offers completely new perspectives, inviting visitors to a tour of the “soil of the year” that reveals its composition, structure and life below our feet.

The soil display will be on show as a travelling exhibition throughout 2021.

Scan this code for direct access to the online exhibition and other useful information about the “Soil of the Year 2021”, including dates:

Rare-earth open-cast mining at Mount Weld, Australia.

INFORMATION AND ADVICE TOWARDS MORE SUSTAINABILITY IN RAW MATERIAL PRODUCTION

"Sustainability Information" is a new series of publications in which the BGR provides the basics for understanding the economic, environmental and social impacts of the production of raw materials. This is particularly relevant to the question of whether the supply chains for these raw materials are reliable, ecologically sound and socially just. The publications are intended for business, politics, society and the public.

German industry is very much dependent on commodity imports, including the high-tech metals needed for the transition to a more sustainable economy. So far, companies used to be interested primarily in securing their supplies via complex supply networks on the global market. Today, in addition to security of supply, another key criterion in building supply chains is sustainability. Guidelines such as the OECD guidance on due diligence in mineral supply chains, the EU Parliament's legislative initiative on this issue, or the Supply Chain Act recently adopted by the German parliament are only some drivers of this development. Investors, commodity exchanges and, last but not least, the public are also increasingly mindful of where and how the raw materials for products are sourced.

"More and more small companies in particular tell us that due diligence in supply chains is being addressed increasingly, so they need to know about environmental and human rights risks", says Dr. Gudrun Franken, head of the unit *Mining and Sustainability* at BGR. Unlike for some large corporations, this is new ground for most of these companies. For them, the commodity publications on sustainability by BGR can provide important basic information. "In our series, we started with the commodities that are particularly relevant for the energy transition and for digitalisation", explains Gudrun Franken. So far, studies on copper, cobalt, rare earths, tantalum, aluminium, lithium, nickel and tin have been published. Each publication includes a section on governance, which addresses general governance framework in the producer countries as well as international initiatives. The studies thus offer a first overview to German companies, industry associations and politicians.

They are, however, also useful for the producer countries. In view of international due diligence regulations, the supervisory authorities themselves have an interest in the sustainability of raw materials production. BGR already provides support in this area as part of its technical development cooperation. "We provide advisory services to mining authorities on environmental standards or occupational health and safety, e.g. related to small-scale mining", says Gudrun Franken.

Franken's team are also active in international panels and organisations, such as in the OECD working group on due

Soil erosion and slumps in Burundi caused by small-scale tantalum mining.

Washing tantalum-tin pegmatite ore in Rwanda.

Flotation plant for the production of rare earths, Mount Weld, Australia.

diligence in mineral supply chains. Together with the German Environment Agency, BGR is currently providing valuable support in the preparation of an OECD handbook on the practical implementation of environmental due diligence. General OECD guidelines that call for a risk assessment of environmental standards to be included in the supply chain already exist. "But it is not entirely clear how these should be applied in practice", says Gudrun Franken. The handbook will be a source of practical advice on this. ■

INTERVIEW ON DUE DILIGENCE WITH GUDRUN FRANKEN, HEAD OF THE MINING AND SUSTAINABILITY SECTION AT BGR.

What does sustainability mean in the context of raw material production and supply chains?

Gudrun Franken: Initially it sounds like a contradiction in terms. But we understand sustainability in the extractive industries to mean that the production and use of resources can contribute to sustainable development, while social and environmental risks have to be kept to a minimum. We will continue to need raw materials, such as for the energy transition or for digitalisation, and we will continue to need to mine a certain share of them, because recycling alone will not be enough.

What does that mean in concrete terms?

Primary raw material production without land disturbance is clearly not possible. Mining will always involve disturbing the land, the ecosystems and the environment of local communities to some extent. Sustainability always concerns all three areas: economic, social and ecological aspects. Economic means that local communities benefit economically from such projects. At the same time, social and environmental risks have to be kept to a minimum. It is important, for instance, that adequate reclamation takes place and that income opportunities exist for the time after mining has ended. You also need to look at the whole life cycle of raw materials: smelting of alumina to aluminium by nature is a process that requires a large amount of energy. On the other hand the use of aluminium for lightweight construction in the transport sector, for instance, saves a lot of energy.

What should companies focus on?

To make sure their products comply with environmental and social standards, companies need to ensure the raw materials in their supply chains are responsibly sourced, even if they're just manufacturing companies. Some large companies have already come a long way in that. Small companies could engage in international initiatives to exert an influence. One such initiative is the Aluminium Stewardship Initiative (ASI), which sets requirements, for instance, related to companies' greenhouse gas emissions. As such, there are no "good" or "bad" commodities, but a wide range of production conditions and technologies. There are, of course, red lines such as human rights violations. The ILO core labour standards, for instance, should be met. And areas with very high biodiversity should be protected. Today, pressure no longer comes only from the public or legislators. Investors and finance providers also increasingly include sustainability. They expect both the mining sector and the major buyers of raw materials, such as the automotive industry or the information and communication industry, to comply with and audit against internationally recognised environmental and social standards.

How can these requirements be met?

It is, of course, a burning question how much information they can get about their global supply networks. For some countries – China, for instance – much less information is publicly available on the sustainability aspects of production than for some English-speaking countries or Latin America. The same applies to artisanal and small-scale mining versus industrial-scale mining. Since supply chains are global, it is important that businesses work together and that governments and international organisations promote transparency and due diligence in supply chains.

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POTENTIAL RESOURCES OF NATURAL HYDROGEN IN THE GEOLOGICAL SUBSURFACE

While hydrogen is seen as a beacon of hope for an energy economy based on renewable sources, the natural occurrence of this reactive gas in an unbound state is rare. Nevertheless, occurrences of natural hydrogen have recently attracted the attention of scientists, also at BGR.

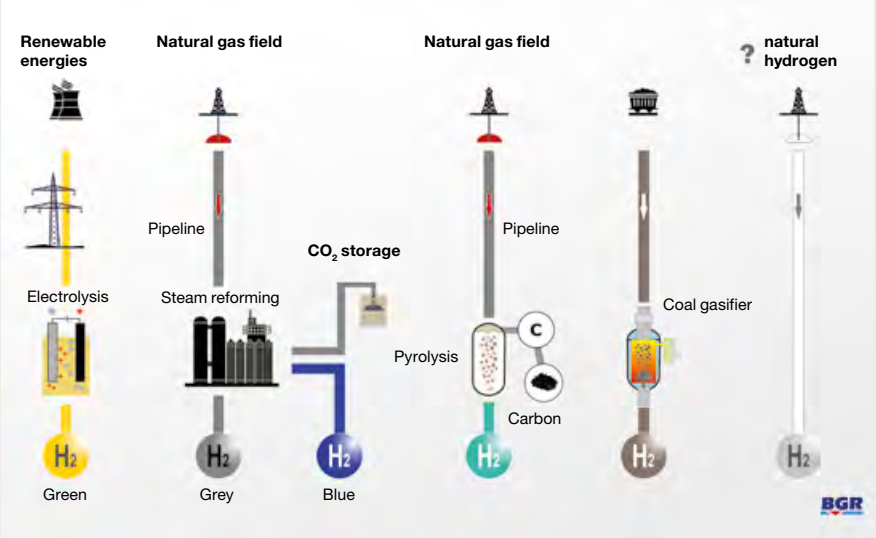
For the Federal Government, hydrogen is a key element in the decarbonisation of the country's industry. Germany currently consumes 20bn m^3 annually, primarily for industrial purposes. If hydrogen was also used in transport and to heat buildings, demand would multiply. A basic requirement for future use is that it needs to be produced without releasing greenhouse gases.

However, hydrogen also forms continuously in a range of geological processes. The development of such potential resources could therefore be of considerable interest for the future energy supply.

The most significant of these sites is probably Bourakebougou in Mali, West Africa. Hydrogen was found there while drilling for drinking water. "The gas drove an engine that temporarily supplied electricity to the village", says Martin Pein, an economic geologist at BGR in the sub-department *Geology of Energy Resources, Polar Geology*. Bourakebougou is on the margins of the Taoudeni Basin, the largest sedimentary basin on the West African Craton. Major accumulations of natural hydrogen might be concentrated in such sedimentary basins within a craton.

Research in the field of natural hydrogen has intensified since. BGR has completed a study on the presence of hydrogen in the geological subsurface. "But research is in its infancy", emphasises Martin Pein. "We understand the formation processes and can therefore localise the areas where hydrogen is likely to occur. But whether hydrogen can accumulate in the subsurface, and under what circumstances, is not yet clear." That is because hydrogen has a very high diffusivity, which makes permanent preservation in the subsurface unlikely in many geological formations. It is a highly reactive molecule that can easily be altered on mineral surfaces or metabolised by microorganisms. "Our studies are also looking at the flow rates of hydrogen outgassing from the surface structures concerned", says Pein.

Hydrogen can form by various processes, one of the most important being serpentinisation. This refers to the transformation of rock containing olivine to serpentinite,



Depending on how it is produced, hydrogen can have different colour labels. Green hydrogen is produced without the release of CO_2. Grey hydrogen is produced from fossil fuels, generating carbon dioxide that is released into the atmosphere. Where the CO_2 is captured and stored underground, the label used is blue hydrogen. There are also trials involving pyrolysis, the direct thermal decomposition of natural gas into turquoise hydrogen and solid carbon. This article discusses whether natural hydrogen can be produced from underground reservoirs like natural gas.

Distribution of Precambrian rock at the Earth's surface (blue) and units containing Precambrian rock (grey). These areas extend across an even larger area below the sedimentary cover. The circles mark sites in the subsurface of the continents with more than 10 volume percent of hydrogen: orange circles mark hydrogen occurring in Precambrian rock, yellow circles in ophiolites.

which occurs in hot ambient temperatures of between about 200 and 300 °C and under contact with water, releasing hydrogen. Fields in Oman are said to emit 150 m^3 of hydrogen per square kilometre per day. In Germany, a large serpentinite body can be found near Leupoldsgrün in Upper Franconia (Northern Bavaria). The radiolysis of deep groundwater is another major process by which hydrogen is formed. Water dissociates because of the natural radioactive decay of uranium, thorium or potassium. Natural hydrogen can therefore occur in places where these elements are found, such as in the surroundings of uranium deposits or salt domes.

In its study, BGR has identified 16 regions around the globe where natural hydrogen occurs. "But to date, no evidence has been found of accumulations of hydrogen in the geological subsurface that would come even close in size to commercially exploited natural gas fields", says Pein. ■

Picture at top: sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community; Bouysse, P. et al. (2010) Geological Map of the World. Commission for the Geological Map of the World (CGMW, Paris). Map by Federal Institute for Geosciences and Natural Resources (BGR), Hannover (Asch, K. & Radke, M, 2020).

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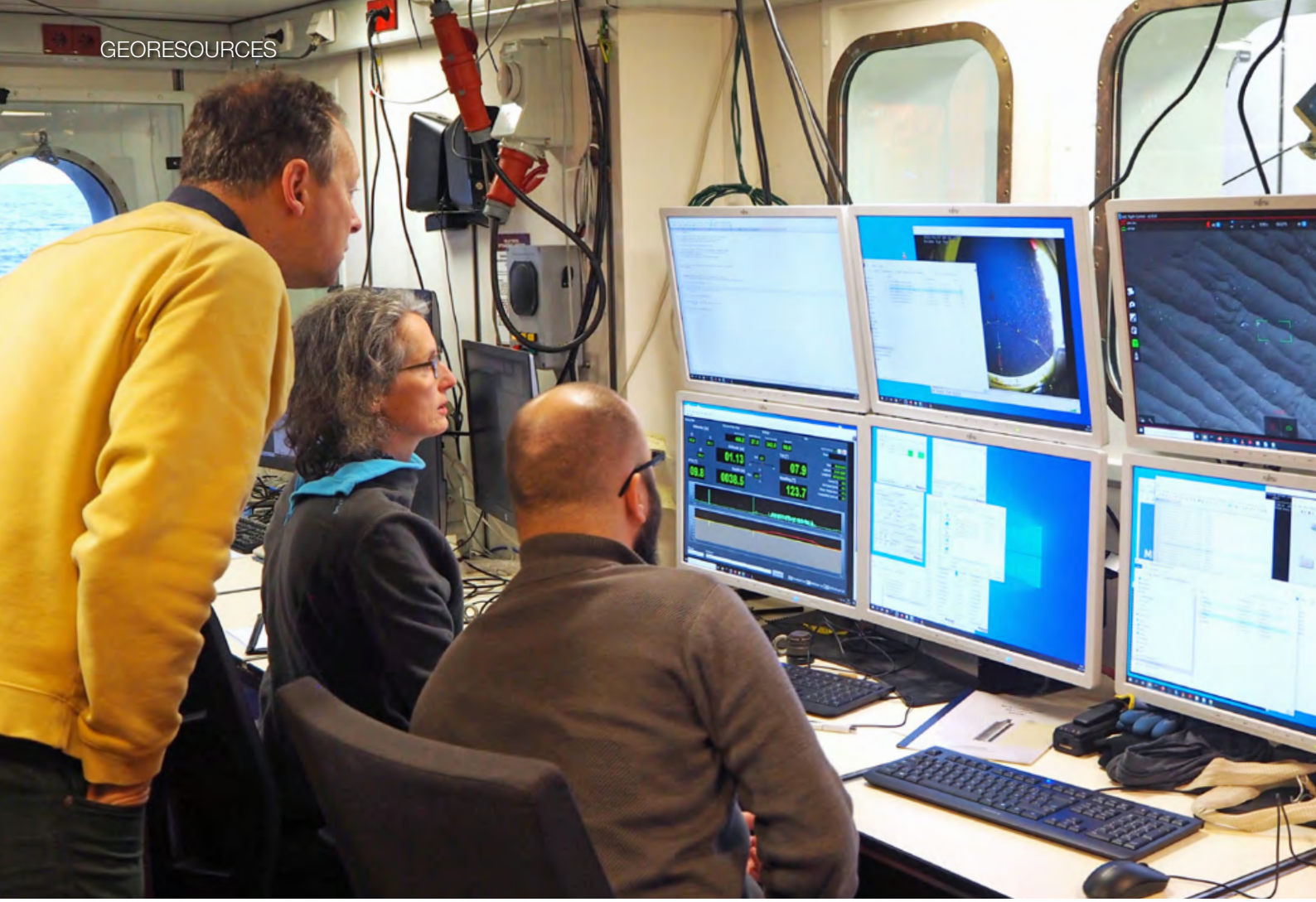

Control station for GOLDEN-EYE, BGR's own marine sensor system.

METHANE EMISSIONS IN THE PRODUCTION OF NATURAL GAS

Natural gas, the fossil fuel with the lowest CO_2 emissions, is considered a bridging technology for the energy transition. Lately, however, the use of natural gas has been criticized because leakage of methane, the second most important greenhouse gas, during production and transport are considered too high. BGR is currently investigating this issue.

Despite heavy weather, the BGR team on board the research vessel Maria S. Merian successfully completed its North Sea expedition as part of the Varioseep project in early 2021. During their two-week trip, the scientists, including Martin Blumenberg, who heads the unit *Organic Geochemistry and Gas Geochemistry* at BGR, carried out their full programme of measurements. "We have come closer to our aim of better understanding methane emissions from the North Sea seafloor", says Blumenberg.

Methane is the main constituent of natural gas and a powerful greenhouse gas: according to the Intergovernmental Panel on Climate Change (IPCC) its global warming impact is 84 times that of carbon dioxide over a period of 20 years. Yet, its residence time in the atmosphere is only twelve years, compared to hundreds of years for CO_2. Although power plants fueled by natural gas emit 40% less greenhouse gases than those fuelled by hard coal and even 50% less than lignite fired power plants, even small, yet unidentified methane emissions during production, transport, and storage question the climate balance of natural gas as a bridging fuel during the energy transformation towards renewables.

How high are these methane emissions? That is the question BGR is trying to answer in research projects such as Varioseep, which investigates natural gas seeps in the North Sea –

View from the Maria S. Merian research vessel during the Varioseep North Sea expedition in January 2021.

MARUM's ROV (BlueROV2) for sampling and observation of natural gas emissions in the North Sea.

"We have come a little closer to our aim of better understanding methane emissions on the North Sea floor."

Martin Blumenberg

Europe's major oil and natural gas province. The data complement an extensive literature survey, which compares different datasets for methane emissions from oil & gas developments.

"Here's the problem: there are significant differences in the way emissions are reported – between individual countries and in the methods applied", says Stefan Ladage. His team from the unit *Energy Resources* at BGR analysed the data. Looking at, for instance, natural gas imported from Norway or the Netherlands to Germany, relatively low emissions rates are reported for these supply routes. They are considerably higher for natural gas from Russia, partly because of the long distance transport. Thanks to ESA's latest Copernicus satellite mission, it is now possible to identify methane leaks along the intercontinental pipelines connecting Siberia with Europe. "Those are snapshots at the moment. It still remains a challenge to accurately quantify emissions from space – but the methods are continuously improving", explains Ladage.

In a modelling simulation just published, he and his team have nevertheless tried to establish whether emissions in Germany would be lower if coal power stations were replaced by gas power stations. The result: looking at greenhouse gas emissions, it would still be better to use natural gas rather than coal for power generation during the transition phase, even with leakage rates as high as 4.9%. Yet, the lower the methane emissions in the natural gas supply chain, the better. ■

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DECARBONISATION BRINGS MAJOR CHALLENGES FOR COMMODITY MARKETS

As we are heading towards the end of the fossil fuel age, demand for many high-tech metals is soaring. The necessary focus on climate-neutral technologies will transform commodity markets for decades to come. The German Mineral Resources Agency (DERA), which is part of BGR, aims to forecast future developments.

Large parts of the world are facing a major shakeup: decarbonisation and the goal of carbon neutrality will drive structural changes that are going to affect all sectors of the economy and leave lasting marks on society. According to the International Energy Agency (IEA), the countries worldwide who have pledged to become net-zero by 2050 together account for around 70% of current emissions. They include the EU and the United States. China, at present the world's largest producer of greenhouse gases, has pledged net-zero for 2060. The IEA has warned that speed is of essence if this goal is to be reached.

In July, Brussels presented its ambitious "Fit for 55" legislative package, which stipulates that EU member states have to reduce their greenhouse gas emissions by 55% from the 1990 level by 2030. Measures to reach this goal include a ban on the sale of new cars with an internal combustion engine (ICE) from 2035; an increase in the share of renewable energies to 40% EU-wide; and extending the emissions trading scheme to include industries such as shipping and the trade in fuel. "This will be quite a transformation, but that is what's needed if we want to achieve the climate goals", says Siyamend Al Barazi, who heads the unit *Mineral Economics* at DERA.

But how to shape such a transformation in just a few decades? It will be particularly radical in the energy supply and transport sectors, which account for more than 60% of emissions worldwide. According to IEA information, it is quite clear what changes will look like in these industries. These are the forecasts: in private transport, there is no alternative to e-mobility; fuel cells are expected to predominate in heavy goods vehicles, synthetic fuels in air transport, and ammonia fuel cells in shipping. Electricity will then become the dominant form of energy, with 250% growth in generation by 2050 compared to today covering a share of around 50% of the total energy requirement. Ninety percent of this electricity would by then come from renewable sources, which for the IEA – but not Germany – include nuclear power. Wind and solar would be the major sources in this segment, accounting for a share of 70%.

These goals can only be achieved with a dramatically accelerated expansion of wind and solar power. The IEA has called for an increase in new installed annual capacity to 390 gigawatts for wind power and 630 gigawatts for photovoltaics by 2030 – four times the figures for the previous record year 2020. It will have a considerable impact on commodity markets. "The next decade will be very exciting for us, with the growing raw material demand from low-carbon technologies such as photovoltaics or wind power", says Johannes Perger, a commodity economist at DERA. The IEA thinks that the gigantic expansion scheme will result in a massive boost in demand for mineral resources such as copper, nickel, manganese, cobalt, lithium and rare earths. It is expecting sevenfold growth of the aggregate market volume by 2030.

Scenarios such as these have been analysed from a range of perspectives for years, making an impact on commodity markets. "The dynamics of prices on these markets in recent months and years have created a challenging situation for all commodity buyers", explains Michael Schmidt, a commodity analyst and lithium expert at DERA. This volatility is likely to continue, as individual countries' decarbonisation plans take shape. In view of the dynamics that can be expected on both the supply and demand sides, the monitoring and analysis of commodity markets play a crucial role. The raw materials monitoring by DERA as part of its consulting activities for the German government helps German businesses prepare for rapidly changing commodity markets and develop adaptation strategies.

Published in July 2021, the commissioned study "Raw materials for emerging technologies 2021" looks further into

the future. It is an analysis by the Fraunhofer Institutes for Systems and Innovation Research ISI and for Reliability and Microintegration IZM of how future raw material demand could develop for selected emerging technologies until 2040. This is the third study of its kind, with updates published every five years. "The new analysis looks at technology clusters representing the three major emissions sectors power generation, transport and industry, and at two cross-sectional clusters representing network and circular technologies", explains DERA project coordinator Viktoriya Tremareva. The study concludes that, for 33 emerging technologies considered, raw material demand for 11 of the 19 metals identified could exceed current production volumes.

According to DERA experts, power generation and the transport sector in particular will dominate demand for individual high-tech metals on commodity markets in the coming years and decades. In the medium term, they currently see only one dominant issue: "At the moment, it's all about batteries for e-mobility" says DERA commodity analyst Schmidt talking about his day-to-day consulting work. "The focus at present is particularly on the transport sector, which pushes the energy storage of renewable electricity, another important topic, into the background", he adds.

While the EU Commission's goal is to have no vehicles with ICEs registered from 2035, car manufacturers apparently have even earlier dates in mind: Fiat and Volvo want to sell only electric cars from 2030, the Volkswagen Group and Mercedes-Benz are planning their exit from ICE vehicles between 2033 and 2035. However, the move towards electric vehicles involves more than switching from petrol pumps to wall sockets. The IEA has calculated that, in terms of quantity, an electric car contains around six times more high-tech metals than a comparable conventional vehicle.

The study commissioned by DERA breaks down this additional consumption. Depending on the motor rating and technology, an electric drive unit contains, for instance, between two and 24 kg of copper. The necessary magnets, varying by vehicle class and motor technology, weigh between one and three kilos, of which the rare-earth metals neodymium and dysprosium account for roughly one third. Even in the study's medium development scenario for 2040, demand for neodymium/praseodymium and dysprosium/terbium exceeds 2018 global production by about 100 and 590% respectively.

A similar picture emerges for the metals used in electric car batteries. Today, it is expected that lithium-ion batteries will still be the storage technology of choice in 20 years' time, so demand, certainly for lithium and nickel, is going to rise dramatically. Researchers at the Fraunhofer Institutes forecast 40 and 50-fold increases in demand respectively for the medium development scenario. The transport sector would thus require almost 80% of the nickel currently produced globally, and more than 300% of lithium. Although the trend in the use of cobalt is towards reduction and in the long term elimination, forecast demand in the transport sector for this metal in the medium development scenario increases more than 20-fold in less than 20 years – twice the 2018 global production volume.

Where low-carbon energy systems are concerned, the focus has shifted a little. For cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) thin-film solar cells, which have for some time been recognised as having great potential, material efficiency and cell efficiency have improved, resulting in a reduced use of gallium, indium, selenium, cadmium and tellurium per watt peak. Although silicon wafer solar cells currently dominate the photovoltaics market, with more than 96% of modules sold, thin-film solar cells have technological advantages. The commodity demand for thin-film solar cells is even below the 2018 level, at least in the medium development scenario. The crucial factor here are sales figures, which are expected to be low. Only when the expansion of photovoltaics using thin-film solar cells gathers pace too, will the demand for gallium and indium rise more. However, there should be no shortage of supply in these raw materials. The situation is different for tellurium used in cadmium telluride modules. In an accelerated expansion of photovoltaics, it could become scarce, since the solar power sector alone would consume 35% of the 2018 production volume in 2040.

The second pillar of regenerative power generation is wind power. A faster expansion would lead to a rise in demand particularly for rare-earth metals. Even in the medium development scenario, most of the 2018 annual production volume of dysprosium and terbium would be needed to meet demand in the wind power sector. For >

Wind and solar power – the most important renewable energy sources after hydropower.

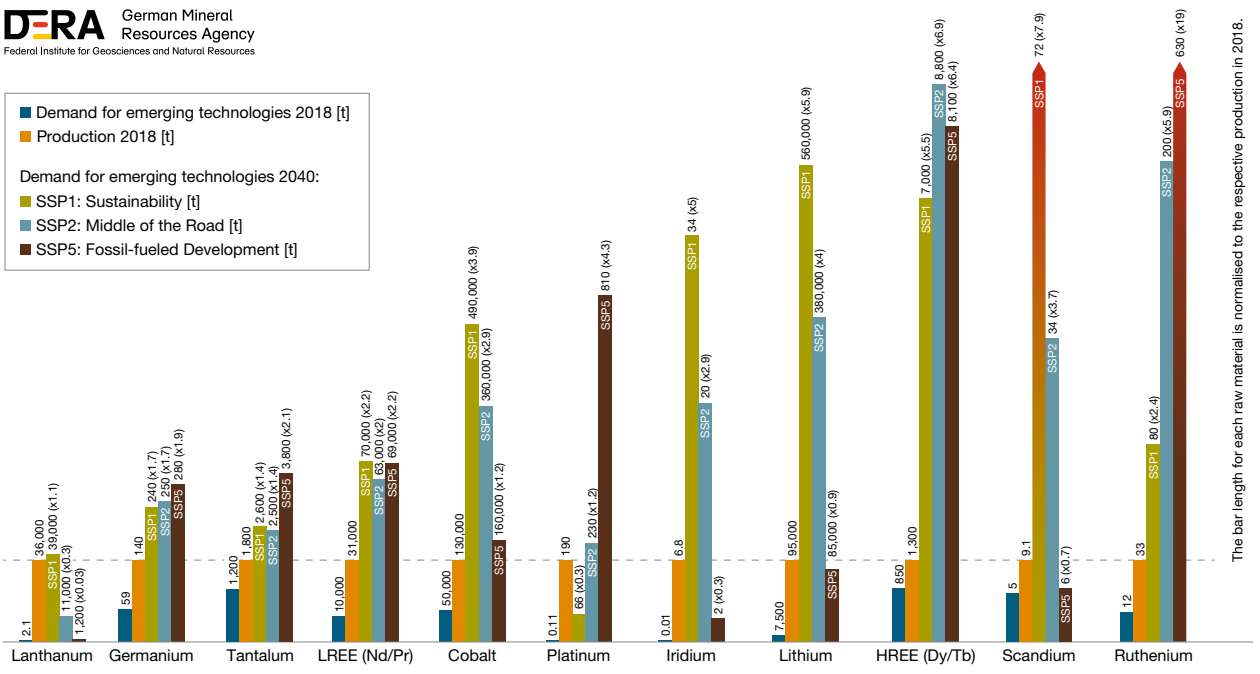
Automotive industry in transformation – towards e-mobility.

praseodymium and neodymium, the shares would also be considerable.

Another factor in the decarbonisation of the economy is the use of hydrogen and its production without the release of CO_2. This is why the study commissioned by DERA also included water electrolysis technologies. Shortages should, however, only be expected for iridium and scandium. Scandium is needed for solid oxide fuel cells and solid oxide electrolysis, so both these hydrogen technologies could increase demand pressure.

Even experts have no easy answer to the question of how raw material producers will respond to this development. "We can model future demand, but future supply depends on many factors, and particularly on the development of commodity prices", admits DERA commodity analyst Schmidt. The fluctuation in market prices is just one element that makes long-term planning for new projects difficult for both mining companies and finance providers. The entire mining sector is facing a major transformation, because decarbonisation does not stop at primary production. This development is driven by international investors and financial institutions, for whom sustainability is becoming an increasingly important decision criterion. And customers themselves are also passing on as much decarbonisation pressure from their domestic markets as possible. "The carbon footprint from primary production is passed on downstream", says DERA expert Al Barazi and adds: "To produce low-carbon or even carbon-free products, you need low-carbon raw materials".

Recycling will gain in importance as a raw material source alongside primary production. Germany is already on the right track for major bulk minerals, achieving rates above 40% for aluminium, crude steel and copper. According to DERA, that must also be achieved with many other commodities for emerging technologies. "In the medium term, it will be extremely important for Europe that the raw materials we use today to produce energy technology can be



Demand for different raw materials for 33 emerging technologies in 2018 and in three scenarios for 2040 compared to primary production in 2018 (source: study "Raw materials for emerging technologies 2021").

ECONOMIC INTERDEPENDENCE: STANDING MORE ON OUR OWN FEET AGAIN

Today's global economy is characterised by a division of labour and interdependence. Many supply chains extend across the globe. These close ties have brought great wealth to many countries. However, the Covid-19 pandemic was not the first time we saw that globalisation has not only benefits for all sides.

The economic dependence of the Western industrialised nations on Far Eastern countries is increasingly evident. In the commodity sector, China has been a dominant player for some time, and Europe also depends on certain products from Asia for major e-mobility components. "In view of the complex value chains and the impact of the Covid-19 pandemic on the availability of certain goods, you really must ask whether Germany, Europe and the United States should not start building up manufacturing capabilities again for selected products and components, to be more independent", says Siyamend Al Barazi, who heads the unit *Mineral Economics* at the German Mineral Resources Agency (DERA), which is part of BGR.

In fact, both sides currently appear to be reassessing their economic relations. China is also striving for greater economic and technological independence. The country's leadership is steering the economy more towards a domestic market focus, not least with the goal of sustainability. The West is working to rebuild entire sectors of industry, from battery manufacture to the production of drugs. In addition, Europe has put the development of its own resources back on the agenda. There are not only strategic reasons for establishing a raw material base in your own or at least a neighbouring country.

"Not having to transport commodities over distances of 20,000 km and more considerably reduces their carbon footprint as well", says DERA's lithium expert Michael Schmidt.

recovered and reused", explains Dr. Britta Bookhagen, who heads the new unit *Secondary Raw Materials* at DERA. "And for that purpose, we need innovative recycling technologies", she adds. Because there will be large numbers of batteries and drives from end-of-life electric vehicles, and photovoltaic modules.

The potential recovery of raw materials from cadmium telluride photovoltaic modules is already at 95% today. And in pilot trials on CIGS modules, a recovery rate of 90% has been achieved for gallium and indium. The recycling of lithium-ion batteries currently focuses mainly on the recovery of cobalt, nickel and copper, but there are also plans to recover lithium.

These approaches make sense not just in terms of climate protection. "The recycling potential should be developed and used more, also with a view to a more sustainable supply with raw materials, to make Europe less dependent on imports", says DERA commodity economist Perger. Experts agree that Europe urgently needs to address supply security of commodities. Particularly for many high-tech metals, China has in recent years acquired an influential, even dominant position. With its 14th Five-Year Plan, the country's party and state leadership is steering the economy slightly away from exports. The consolidation of production represents a supply risk for the high-tech industries in the West. "The capacity controls of high-energy metal sectors in China that we have seen in recent years will continue", says Al Barazi. Using secondary raw materials from recycling could therefore be a mitigation strategy for the German industry. ■

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SUSTAINABLE SOLUTIONS FOR POST-MINING AREAS: RESEARCH FOR NEW LANDSCAPES

As decided by the German Bundestag, coal mining in Germany will be phased out by 2038. That will end a chapter of industrial history spanning many decades and contributing significantly to the rebuilding of industry in post-war Germany. Lignite mining, however, has left lasting marks on the land. The rehabilitation and creation of sustainable post-mining landscapes will be the focus of an international research centre that BGR is currently setting up in Cottbus.

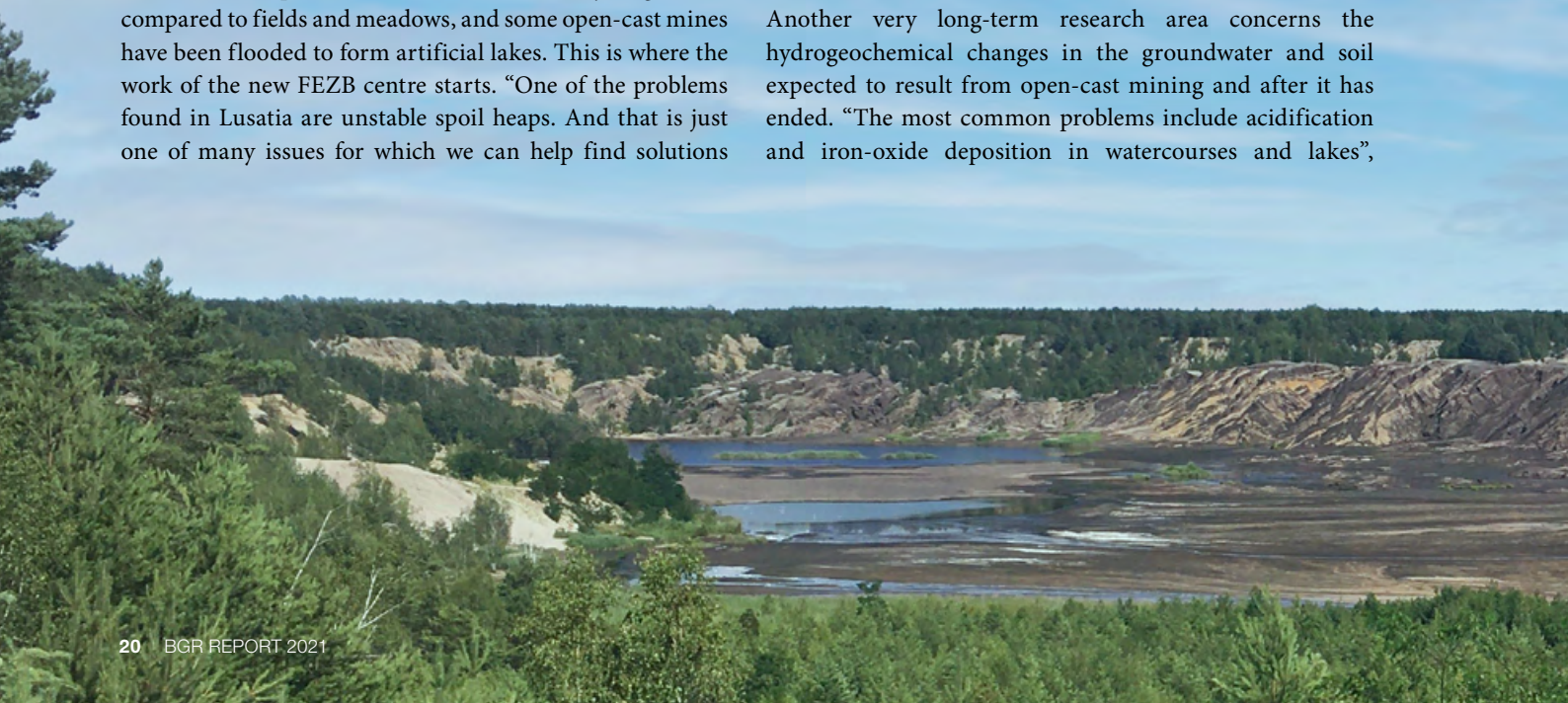
Lignite mining means an invasive alteration of the natural environment. Large-scale open-cast mining involves moving and changing the soil and entire landscape features, as well as the destruction of villages. These alterations often also have a permanent effect on the hydrology and water quality of the regions concerned. Mining law requires the reclamation of these sites, so they are not left as industrial wasteland. Which is why the end of mining anywhere in Germany always marks the beginning of a new chapter: post-mining reclamation, rehabilitation of the landscape. On behalf of the German government, BGR is supporting this process with its new Research and Development Centre for Post-Mining Areas (FEZB) in Cottbus.

As in all brown coalfields in Germany, major structural changes are ongoing in the region of Lusatia. Since the fall of the Berlin wall, 80,000 lignite mining jobs have already been lost in the border area between the German states of Brandenburg and Saxony. Only a relatively small number of the people employed right up to the end will be kept on to work in reclamation.

Vast new landscapes have already been created in Lusatia. Woodlands in particular now cover relatively large areas compared to fields and meadows, and some open-cast mines have been flooded to form artificial lakes. This is where the work of the new FEZB centre starts. “One of the problems found in Lusatia are unstable spoil heaps. And that is just one of many issues for which we can help find solutions using our knowledge”, says the head of the FEZB Implementation Task Force at BGR, Dr. Christoph Neukum.

BGR has the necessary geoscientific knowledge in the areas soil, groundwater, environmental monitoring and geotechnical engineering. “New rehabilitation and monitoring technologies have to be developed and research carried out into forecasting tools for the safe and environmentally sound reclamation and rehabilitation of former mining areas”, explains Neukum. In future, 34 employees will be working on these tasks at BGR’s FEZB in Cottbus. They will carry out their projects within a network of partners such as Brandenburg University of Technology Cottbus-Senftenberg, Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH (LMBV), Wismut GmbH and other local businesses. “BGR will be responsible for research tasks that the rehabilitators could previously not consider or implement without scientific support”, says Neukum. They include issues related to geotechnical safety, which can be a problem in post-mining landscapes. In March 2021, for instance, the slope of a shoreline collapsed at the artificial Lausitzer Knappensee lake, causing a 1 m high wave.

Another very long-term research area concerns the hydrogeochemical changes in the groundwater and soil expected to result from open-cast mining and after it has ended. “The most common problems include acidification and iron-oxide deposition in watercourses and lakes”,



Measures to stabilise the shoreline of an artificial lake as part of the rehabilitation of a decommissioned open-cast mine.

The BGR helicopter takes off from the Welzow airfield for an airborne geophysical exploration around the Finsterwalder Restlochkette decommissioned mine pits.

explains Neukum, a hydrogeologist. For the open-cast mining of lignite, the groundwater table had to be lowered considerably for decades. "Whereas the soil and subsurface had previously been saturated and oxygen-free, air could now get in, oxidising the iron sulphide contained in the sediment. Iron hydroxides formed as a result, and will continue to do so for decades to come, producing the characteristic ochre colour in the water – and ultimately sulphuric acid. This can't be neutralised in the groundwater, since young deposits in Lusatia contain very little lime", says Neukum.

Subsequent iron-oxide deposition can be observed in the Spree and other rivers, caused by iron minerals that precipitate when they come into contact with oxygen. Another slow and invisible process is the acidification of rivers and lakes, which in some places is countered by adding large amounts of limewater. These are the issues facing people, both in post-mining landscapes and well beyond them. Since the Spree river passes through the region, pollution could also affect Berlin's water supply.

The FEZB has already started work. In summer 2021, for instance, BGR surveyed the subsurface of the "Finsterwalder Restlochkette" decommissioned open-cast mine pits about 60 km southwest of Cottbus by helicopter, using a probe. "Airborne geophysical methods can help answer major question such as these: How low is the groundwater table? Are there layers of clay in the subsurface? How much salt does the groundwater contain?" explains Neukum.

The knowledge acquired at the FEZB in Cottbus will be relevant even beyond Lusatia. There are already contacts with the Rhine brown coal district, which will be intensified once the start-up phase of the FEZB is complete. And Neukum also thinks there are opportunities for international cooperation. Although not all methods can necessarily be transferred, "Lusatia is not the only place where post-mining effects have to be overcome; the knowledge generated here may be of interest for Asia, Africa or the Americas in the context of international cooperation projects." The great hope is that, one day, the huge invasive alterations of the natural landscape will no longer be visible – because a new landscape will have been given back to nature. ■

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Post-mining landscape in Lusatia.

Dr. Dieter Rammlmair in the x-ray fluorescence laboratory, analysing drill core sections from the Bushveld Igneous Complex in South Africa, the world's largest platinum deposit.

ARTIFICIAL INTELLIGENCE AT BGR – ALGORITHMS FOR THE DATA OVERLOAD

With the use of new technologies comes a wealth of additional data. Artificial intelligence (AI) and machine learning can help put the ever larger volumes of data to productive use, also in geoscientific research. At BGR, several projects are currently testing the application of computer systems.

In the laboratory of the BGR unit Mineral Residues, state-of-the-art methods are available for scanning one-metre long drill cores at maximum resolution in just a few minutes – or hours, for more complex tests – revealing information about, for instance, their mineralogical composition. "Interpreting the data collected is actually the largest part of research work", says Dr. Dieter Rammlmair, who heads the unit. And clearly, that takes time and background knowledge, adds the mineralogist. Thousands of samples are analysed in his laboratory to find answers to a wide range of geoscientific questions. "In our internal AI project, we are creating databases that permit something like an automated analysis, to channel the abundant data even more efficiently for research", explains Rammlmair.

Using this as a basis, his unit also combines the information generated by the application of different analytical methods to a single sample. Rammlmair's team then analyses the fused data using AI techniques such as deep learning, to detect higher-level patterns in the samples. "This lets us test how efficient the individual methods are and gain new insights", he explains.

The project in Rammlmair's unit is one of several at BGR using artificial intelligence. AI is also an important topic in the geoscientific community as a whole. The conference "Big data and machine learning in geosciences", organised by BGR in Berlin in early 2020, attracted great interest. It was attended by 150 participants and hosted at the Ministry for Economic Affairs' grand Oak Room. "We could have easily welcomed twice or even four times as many guests", remembers Dr. Stefan Broda, head of the unit *Spatial Information on Groundwater* at BGR. He was one of the conference organisers and also uses AI in his unit.

The aim of the event was to connect geoscientific actors in government authorities, research and industry more closely for the use of big data and the continued development of machine learning methods. Scientists from Google, Fraunhofer-Gesellschaft, the University of Minnesota and other organisations reported on the current state of AI

Prof. Dr.-Ing. Christian Bauckhage of the Fraunhofer Institute for Intelligent Analysis and Information Systems reports on the growing influence of machine learning in everyday life.

BGR President Prof. Dr. Ralph Watzel (4th from left) and the speakers on day 1 of the conference (left to right): David Osimo (European AI Alliance), Sören Sonnenburg (TomTom), Ed Parsons (Google), Xiaoxiang Zhu (DLR) and Vipin Kumar (University of Minnesota).

research. Experts from the German Aerospace Center, the European AI Alliance and TomTom outlined the capabilities and challenges that the geosciences present for artificial intelligence applications. On day 2, industry experts from North America and Europe reported on specific AI applications in the geosciences.

BGR uses artificial intelligence in many of its projects and is among those who benefit from the experiences shared by other AI experts. In addition to mineralogy, areas include earthquake monitoring, repository research, commodity monitoring and hydrogeology. Though the areas may differ, the challenge is the same: to search through large data volumes quickly to identify previously unknown relationships. “This is so-called weak AI: systems more or less autonomously identify patterns within data sets and solve specific problems”, explains groundwater expert Broda.

Broda’s unit uses artificial intelligence for tasks such as groundwater level forecasting. Indications are that, in future, water shortages will become more severe in Germany. The summers of 2018, 2019 and 2020 were already among the driest in the past decades. “Germany’s groundwater can easily survive two dry summers”, says Broda, “but a longer series of droughts would be critical for some parts of the country.”

This is why Stefan Broda’s team is planning to develop a groundwater level forecasting service for all of Germany, which would be able to predict the development of water levels over weeks, months and even years. The groundwater experts at BGR already relied on artificial intelligence to find out which of the time series coming from about 14,000 groundwater monitoring wells made available by the German states are representative of larger areas. “We had to reduce the number of monitoring wells to be used for forecasts to a reasonable level, not least because we couldn’t equip all data loggers for remote data transmission, which would be a prerequisite for an operational service”, says Broda. Based on the readings available and the regional distribution, the AI calculated that around 200 wells would be needed as a basis for a national forecasting service. Using historical monitoring data, the tool’s reliability in modelling the development of groundwater levels has already been demonstrated. The service is currently being put into operation and will soon be available for actual forecasts.

Providing a better service to the public is also the focus of the SEIGER cooperative project by the BGR sub-department *Federal Seismological Survey, Nuclear Test Ban*. This project uses AI techniques around two geothermal power plants, at Landau and Insheim in the Southern Palatinate region of southwest Germany. So-called induced seismicity events related to the functioning of the plants keep recurring there. “We want to make an assessment of which area of the surface could be affected within seconds of such a tremor”, says BGR expert Dr. Andreas Steinberg.

Based on the data provided by the 15 seismometer stations of the Südpfalz research network in the region, a self-learning neural network will determine the properties of an >

Use of big data in the real-time monitoring of commodity supply chains.

earthquake almost in real time. To ensure the system is fast enough, BGR scientists have trained it using data from 100 million artificial earthquakes. They used three different subsurface models for the region simulating the earthquakes. "That teaches the system to handle uncertainties and make reliable assessments regarding the impact of an earthquake", says Steinberg.

Researchers in the ITERATOR project, another area where BGR uses artificial intelligence, are hoping for a consistently reliable analysis of rock samples. Algorithms are to be used to help detect the frequency, size and shape of pores in samples based on scanning electron microscopy images. This is important in areas such as repository research, because the pores in a reservoir rock determine its hydraulic permeability in the event of a liquid flowing into it. The aim is that a self-learning neural network will bring permanence and consistency to the analysis as its analytical experience grows and corrections are made by the experts. "At the moment, it very much depends on the person handling the analysis", says Christoph Schettler, a geoinformation scientist in the *Geoinformation, Stratigraphy* unit at BGR. "We want to know whether a reliable reference basis can be created using artificial intelligence", he explains. The suitability of available neural networks is currently being tested. "There are many networks from current research projects and some of them have been trained with millions of images. We hope that it'll take relatively little effort to train them for our application", says BGR engineer Marco Brysch.

The German Mineral Resources Agency (DERA), part of BGR, is currently developing an early warning system for supply risks on mineral raw material markets for the German industry. Big data tools monitor the abundant sources of information, filter out and rate relevant information, and thus provide a picture of specific supply situations for up to 60 mineral resources. "We process a wide range of indicators, from standard weather data and economic indicators to information about political crises, wars, social tensions, and other sources that could be relevant for disruptions of the supply chain", explains DERA expert Arne Schumacher. Proven geoinformation systems and the entire spectrum of online resources serve as sources of information.

Much of the test run will be done in-house at BGR, because the DERA experts need to carefully check the quality of the information compiled by the computer system. "But the more the system learns and the clearer it becomes which sources of information are reliable, the more we will start partially automating the process of evaluating and distributing information", says Schumacher. A beta version of the tool for testing the concept should be available by 2024. ■

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B2.2 Basic Information – Groundwater and Soil

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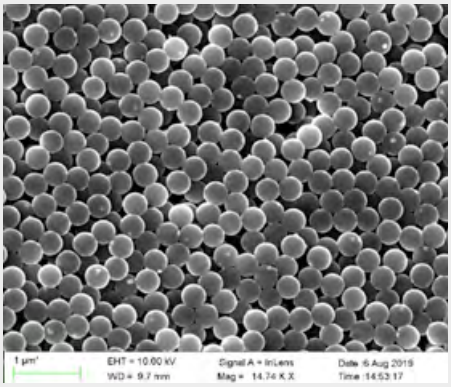
Plant tests at the Fraunhofer IME using different polystyrene particles produced at BGR. The image shows oat plants after seven weeks of growth.



Synthesis (left) and characterisation (right) of polystyrene particles at BGR.

TRACKING PLASTICS IN SOIL

Today, microplastics and nanoplastics can be found everywhere in our environment. For a long time, research in this area focused on oceans, lakes and rivers, while soils did not feature. That is changing and BGR is among those researching plastics in soil.

Soil pollution from microplastics and nanoplastics is a global challenge. According to a 2016 estimate for the EU, up to 430,000 tons of microplastics annually end up on arable land. That compares with up to 236,000 tons in the surface water of the oceans reported by another study.

In Europe, sewage sludges are a major source of plastic particles in soils. Somewhat more than a quarter of sewage sludges in Germany are applied on land as fertiliser. "While its fertilising effect ends, the concentration of plastics in the soil is still significantly increased even years after sewage sludge was last applied", explains BGR soil scientist Dr. Martin Hoppe.

Soils are complex systems of minerals, humus, water, microorganisms and other living organisms. There is a lack of data to answer questions about the impact the tiny plastic particles have on the necessary environment for plants, such as whether plastics end up in the groundwater or whether they are harmful to the microorganisms in the soil.

In collaboration with the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and Leibniz University Hannover, BGR is working to develop scientifically sound testing methods. An example: BGR has developed test particles consisting of polystyrene, a plastic that is widely used every day. "Soil has a high concentration of carbon, which is the main constituent of plastic. We therefore had to first of all find a way of marking plastics in order to draw any conclusions about their impact or retention", says BGR expert Hoppe, describing the approach, which uses so-called doping. This involves marking plastic particles with silver or palladium. These metals are rare in arable soil, which makes them suitable for the purpose.

There are plans for laboratory experiments on soil columns into which doped particles are introduced. Says Hoppe: "We intend to find out how many particles are translocated through the soil columns. That will give us basic information about the mobility of these particles in the environment."

Field trials are equally important. In an ongoing experiment, sewage sludges enriched with doped particles have been applied to a test field. The area has been prepared with cylinders that are open at the top, sunk into the earth and filled with soil cores and seedlings. The containers are closed at the bottom, so seepage water can be caught and measured.

"This enables us to test whether plastic particles are present in the root or in the aerial parts of the plants", explains Hoppe. He and the rest of the team are hoping to gain insights that will advance the research. Because reliable data are essential for risk assessments required by laws and regulations. ■

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B2.4 Soil as a Resource – Properties and Dynamics

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Rockfall in the Kirnitzschtal near Bad Schandau (Saxon Switzerland) – displaced volume approx. 120 m³. The enormous rock is 3.7 m high.

RECOMMENDATIONS FOR THE ASSESSMENT OF GEOLOGICAL HAZARDS

In Germany, the federal states are responsible for maintaining public order and security, but there are considerable differences in hazard assessment between them. A joint federal and state project has elaborated recommendations for a standard national methodology for the assessment of geological hazards such as landslides or rockslides.

Germany's potential for geological hazards is relatively low. Earthquakes can occur in only a few areas and the risk from volcanoes is even more restricted geographically. Landslides and rockslides (rockfalls), on the other hand, are a hazard in many places. "The hazard is particularly high in the low mountain ranges and in the Alps, of course, but also on steep coasts", says Dr. Dirk Balzer, who heads the unit *Geological Engineering Hazard Analysis* at BGR. In Germany, the geological surveys of the federal states are responsible for localising and regionally assessing geological hazards.

In the states concerned, more or less sophisticated tool sets exist for recording and assessing geological hazards on their respective territories, differing in terminology, scale,

classification and level of detail. However, since natural hazards are not bound by state borders, difficulties arise whenever an area under investigation spans the territories of two or more states. “The Harz mountains, for instance, occupy an area of 110 x 40 km on the territories of Lower Saxony, Saxony-Anhalt and Thuringia. And each state's hazard map indicating mass movements on its respective territory looks different”, says Balzer.

“We looked at which methods are suitable for modelling which type of mass movement under current conditions, and which are not.”

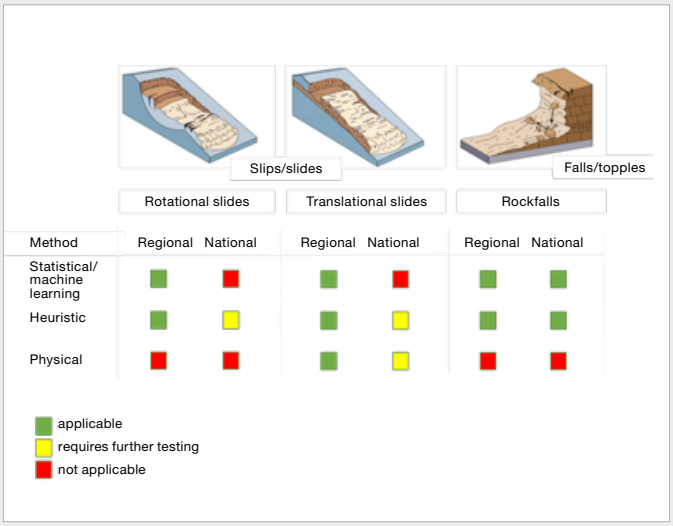
Dr. Dirk Balzer

This was the background for the joint federal and state project Mass Movements in Germany (MBiD), which studied the different risk assessment methods and made recommendations for a national approach. BGR was responsible for the project coordination, specifically Dr. Michael Fuchs in Balzer’s unit. “The aim was to draw up common methods for all states. As a federal organisation with EU-level links, we were able to make important contributions to this standard approach”, says Fuchs. The project involved, for instance, preliminary work on a standard hazard map indicating landslides and rockslides on German territory. “We looked at which methods are suitable for modelling which type of mass movement under current conditions, and which are not“, explains section head Balzer. The map itself will be prepared in the medium term.

Alongside BGR, the state geological surveys of Bavaria, Baden-Württemberg, North Rhine-Westphalia and Saxony participated in the project. Each of the 14 detailed case studies analysed several methods, which were based on the statistical evaluation of historical records, physical models, or expert assessments. “It is generally preferable to have detailed physical data or extensive records of events, but you obviously need a contingency plan for cases where no such information exists”, says Fuchs.

The case studies tested all methods regarding their suitability for forecasting. Each method had to be able to designate zones where landslides or rockslides had occurred with maximum accuracy. “If a model captures about 80 percent of known events in zones with the highest level of risk, and these zones can be restricted to roughly 20 percent of the total surface, it is considered a good model”, explains section head Balzer.

One result of the thorough method tests was a preliminary division of Germany into hazard zones for rockslides by means of a terrain parameter. Based on a digital terrain model, by applying the slope gradient susceptibilty zones can be designated using a gradient greater than 45 degrees for overview representations. The precise susceptibilty classification depends on the geology.



Methods used in the project for regional and national modelling and their applicability on a validity scale of 1: 250k.

Landslides and rockslides are not the only hazards in Germany, however. Therefore, in a follow up project the experts will deal with the sinkhole hazard, which is subject to completely different geological factors. ■

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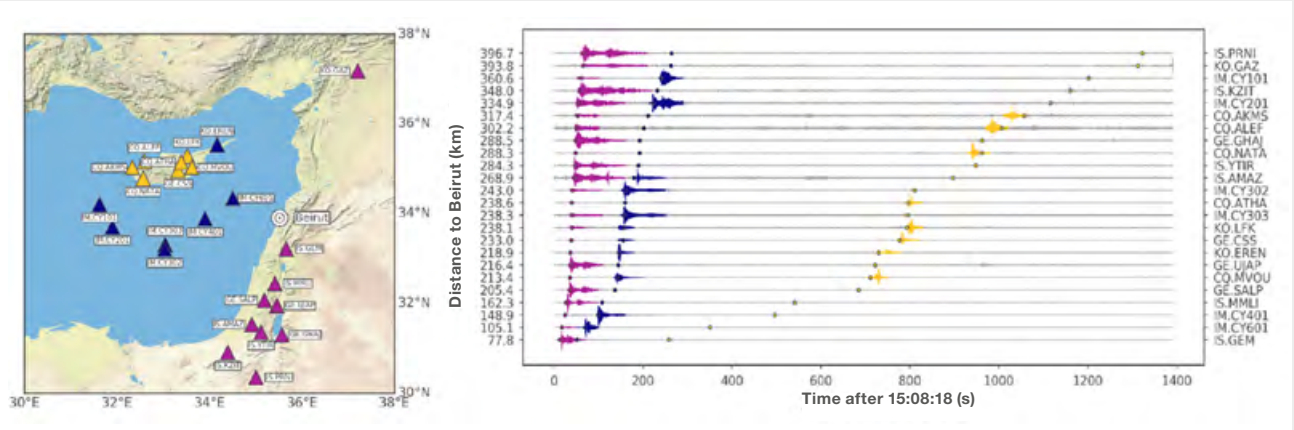
BEIRUT EXPLOSION: INFRASONIC SIGNALS USED TO ESTIMATE EXPLOSIVE YIELD

The huge explosion in the Port of Beirut in August 2020 was recorded by the monitoring stations of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). Scientists led by BGR, who operates stations of the CTBTO international monitoring system, used infrasonic signals to estimate the force of the blast.

It took less than three seconds on 4 August 2020 to reduce the Port of Beirut and surrounding areas of the city to rubble. Following a fire in a port warehouse, a huge explosion occurred at 18:08 local time, with the blast wave felt across the city. More than 200 people were killed and 6,500 injured. The property damage is estimated to amount to billions.

The cause of the disaster was soon identified: 2,750 tons of ammonium nitrate, a fertiliser, had exploded in the warehouse, after fireworks also stored there had been set off by a fire. The blast, which left a 43 m deep crater with a 124 m diameter in the port area, was detected as far away as 6,000 km by high-sensitivity geophysical measurement instruments that are part of the CTBTO network. This comprises a total of 321 infrasonic, seismic, hydroacoustic and radionuclide stations, four of them operated by BGR: two seismic and two infrasonic monitoring stations, in the Bavarian Forest and the Antarctic. The shock waves from the blast in the Port of Beirut were transmitted through earth, under water and in the air. Seismometers in Israel and Turkey were the first to detect the seismic waves. Then stations on the seafloor of the Eastern Mediterranean picked up hydroacoustic signals caused by the explosion close to the sea. After these regional sensors, infrasonic CTBTO stations located in Europe and Africa also registered the blast. This was not until several hours later, since acoustic waves propagate with the speed of airborne sound.

Scientists at BGR, the German Research Centre for Geosciences in Potsdam, and Kiel University focused on analysing these data to estimate the explosive yield of the blast in Beirut. Infrasonic waves can travel thousands of kilometres, because they bounce off the Earth's surface and the upper stratosphere multiple times on their path without losing much of their intensity. The team of researchers used infrasonic data from the closest stations west of Beirut: the site operated by BGR in the Bavarian Forest, and locations in Tunisia and Ivory Coast. Stations in the West were chosen because, at the time of the explosion, stratospheric winds were blowing from the East, carrying the infrasonic waves westward.



Seismometers (left) in a 400 km radius around Beirut that registered the shock wave caused by the explosion. The colours of the triangles indicate the main wave form type captured (purple: seismic – propagation in solid ground; blue: hydroacoustic – propagation as underwater sound in the ocean; yellow: acoustic – propagation as infrasonic waves in the atmosphere). The transit times of the signals (right) vary depending on the medium.

The blast in the Port of Beirut caused severe destruction to buildings and infrastructure within a radius of several kilometres around the explosion site.

Based on the CTBTO data, the scientists calculated an explosive yield of between 800 and 1,400 tons of TNT, which matches the theoretical explosive potential of 2,750 tons of ammonium nitrate quite well. The Beirut explosion was therefore at a level that CTBTO sensors have to detect under the treaty. "As the German data centre for the nuclear test ban, BGR has to ensure that we can register events of a yield of one kiloton of TNT equivalent", says Dr. Christoph Pilger from the BGR sub-department *Federal Seismological Survey, Nuclear Test Ban*, who took part in the investigation for BGR. To verify and refine the explosive yield estimation from the infrasonic stations, Pilger and the team of researchers included freely available seismological data from earthquake monitoring stations in the Eastern Mediterranean in their investigations. "On that basis, we calculated a moment magnitude of 3.47, which is equivalent to the explosive yield of around 1,100 tons of TNT – right in the middle between the values provided by the infrasonic sensors", says Pilger to explain the result.

Using data from the European Sentinel Earth observation satellites, the team in collaboration with remote sensing scientists were also able to draw conclusions regarding the damage caused by the explosion in the Lebanese capital. Earth observation satellites provide regular high-resolution images of the Earth's surface with or without the consent of the countries concerned. Consequently, they are another independent source for the assessment of heavy explosions. The research group was able to estimate the damage based on an automated comparison of images taken before and after the blast, thus gaining information about the explosive yield of the blast using a novel approach.

The findings, published by the team of researchers as a paper in the Scientific Reports journal from the publishers of the acclaimed science journal Nature, have shown that the international CTBTO monitoring network has lived up to the UN institution's expectations. Whenever a nuclear test is carried out anywhere in the world, in water, on land, or in the air, the high-sensitivity stations of the CTBTO network must be able to detect the signals, whether they are seismic or acoustic waves. "The most important signal is the shock or blast wave caused by the explosion. That's why we were able to estimate the explosive yield of the blast in Beirut just like, for instance, the strength of North Korea's nuclear test in September 2017", says Pilger. Unlike with such internationally banned weapons tests, the explosive yield of accidents like the one in Beirut is generally clear soon. They can therefore be used to check the accuracy of CTBTO readings.

BGR intends to pursue the multi-technology approach tested in the Beirut case for monitoring the test ban treaty. There are also plans to add infrasonic components to the federal seismological survey operated by BGR. This new infrasonic service will provide automated and quality-assured information about events rapidly, just like the seismological data that have been available for decades. ■

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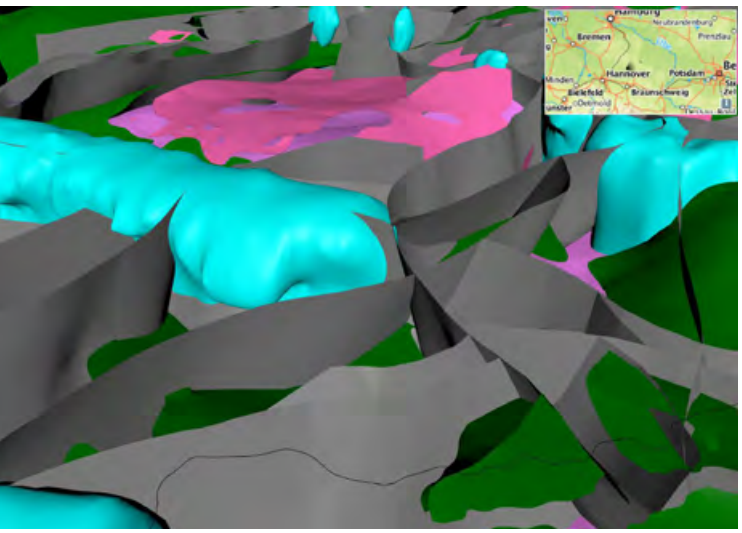
3D MODEL PROVIDES VIRTUAL IMPRESSIONS OF NORTHERN GERMAN SUBSURFACE

A new digital subsurface model available on the Internet shows the geology of the North German Basin in three dimensions. Developed in a joint federal and state project headed by BGR, the 3D model provides virtual impressions of geological horizons, faults and salt structures down to a depth of almost 11 km.

In the TUNB project, the state geological surveys of the Northern German states and BGR have been working on the development of a 3D model since 2015. The model shows the deeper subsurface of the North German Basin including the German part of the North Sea. It can be viewed and searched via the BGR's 3D web viewer – preferably one region at a time. "It takes a while to open the whole model, because of the huge data volume and the computing power required", explains Dr. Gabriela von Goerne, who heads the sub-department *Subsurface Use*, which coordinated the mammoth project.

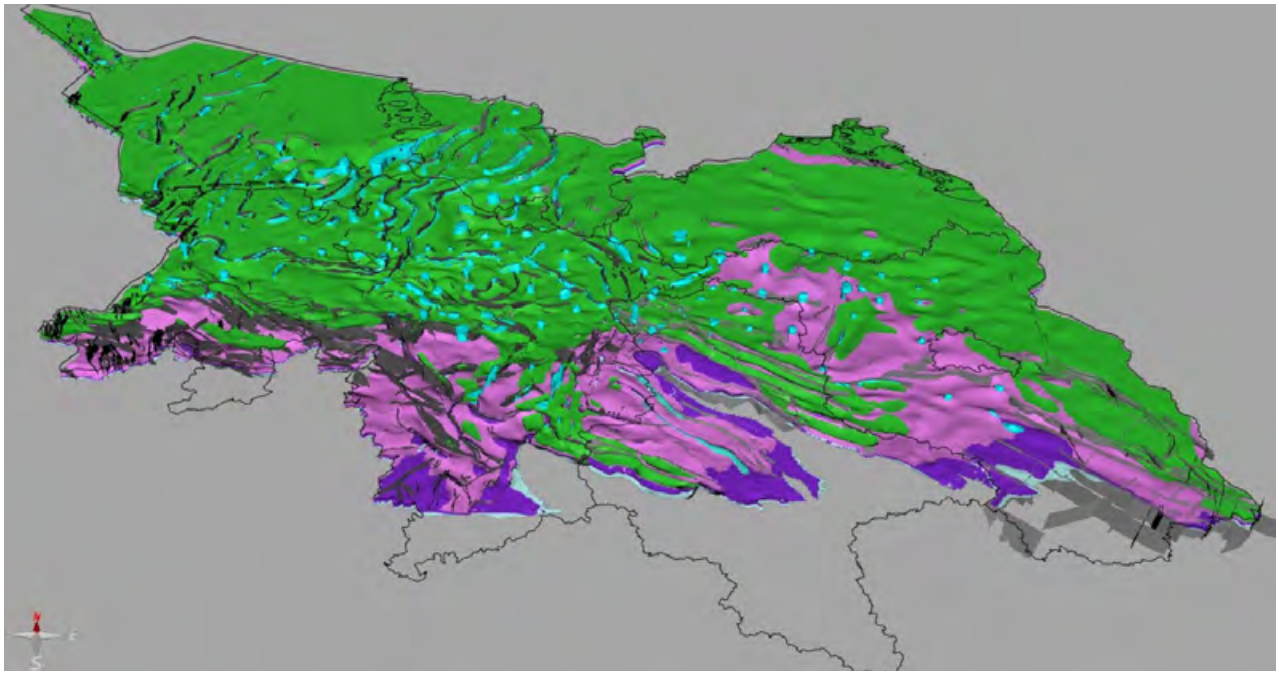
The model maps almost 170,000 km² down to a depth of 10,700 m, of which 138,000 km² or almost a third of German territory are on land. The TUNB model includes a total of 14 stratigraphic surfaces, from today's surface of the Earth to the base of the Zechstein from the late Permian 260 million years ago, as well as 5,331 faults and 273 salt structures piercing the surfaces. Hundreds of thousands of data items were inspected and processed to create the model. The individual parts, prepared by the state geological surveys for their respective territories and by BGR for the sea areas, had to be matched across state boundaries and harmonised. "I don't know of any other model of the deeper subsurface of Europe that comes even close in size", says Gabriela von Goerne.



View of a detail of the TUNB model from the southwest. The different salt structures in light blue and the complex network of displacements (faults) in dark grey are particularly striking. They cause dislocations and divisions in the modelled horizons. Triassic base horizons are shown in pink and purple, the base of the Cretaceous in green.

There is much interest in geological 3D models, as the deeper geological subsurface in Germany is increasingly becoming a space that attracts a lot of attention and is used a great deal. More options for the production and storage of energy sources are needed, particularly as a result of the energy transition and the related demand for storage options, such as for hydrogen. "Because of its resolution, the 3D model created in the TUNB project can only provide an overview for these issues. But it does show you which region might be worth looking at more closely for a specific need", explains Gabriela von Goerne. If, on the other hand, you already know where to look, you can skip the TUNB overview and move directly into site characterisation and detailed analysis, this being essential for any planned subsurface use.

In its current state of development, the model displays the layer boundaries between the stratigraphic units that make up the subsurface. Based on these horizons, you can track sedimentary packages right across the basin: how they were deposited since the Permian, dislocated at faults, domed by rising salt pillows, and in the end partially eroded by Quaternary glaciers. What the model does not show yet are the rocks between the horizons, which will require additional steps. "We're planning to convert the stratigraphic surface model into a volume model", says Gabriela von Goerne. One part of the North German Basin is missing in the model: the Baltic Sea, about whose deeper subsurface very little is known. "We would have liked to include the Baltic Sea in our model. But unlike for the North Sea, we'll first have to get the data", says Gabriela von Goerne. There are hardly any crude oil or gas deposits in the German part of the Baltic Sea, such as those that have advanced exploration of the subsurface of the North Sea, and industrial interest in the area has therefore been relatively low. To overcome the lack of data, new data were collected during a 14-day expedition of the Maria S. Merian



View of the TUNB model from the south. Showing the modelled horizons for the Upper Cretaceous (green), Upper Buntsandstein and Buntsandstein (pink), and the modelled salt structures (light blue) and faults (black).

"Our long-term goal is a 3D subsurface model for the whole of Germany." Dr. Gabriela von Goerne

research vessel, going as far as the Danish island of Bornholm and the Polish coast. These will be used to model the German part of the Baltic Sea, to be united with the TUNB model in future.

Integration of new data sets with the comprehensive model should be quick, as there are now virtually no data conflicts in the stratigraphic framework. Harmonising the stratigraphy, on the other hand, sounds easier than it is: the model of the North German subsurface across the entire basin is in fact a mosaic composed of the eight cooperation partners' submodels. Only with the integrated representation do these submodels become a continuous model of the whole. Harmonising the data it is based on was not always smooth. Complications arose where state boundaries meet, as stratigraphic surfaces were sometimes defined differently, or because the data simply did not match.

The different data sets and definitions of horizons in the former West and East German states remained one of the greatest difficulties. "In the East, horizons were based on seismic reflectors from the seismic reflection maps of the former GDR. In the West, the Geotectonic Map of Northwest Germany with its lithostratigraphic horizons was used as the basis. Horizons in the West used stratigraphic borehole markers as reference points and seismic reflectors were converted to stratigraphic horizons. As a result, there would sometimes be differences in depth of the horizons between one state and another", explains Gabriela von Goerne. It was a painstaking coordination task for the joint federal and state working party to eliminate most of these artefacts. "We're now left with just a handful of places in the surfaces where it wasn't possible to harmonise the data", says Gabriela von Goerne.

For the geologist and her colleagues, the German TUNB model is only a beginning. Talks with Germany's neighbouring states about a harmonisation across national borders of their digital subsurface models have been ongoing for a while. "In the EU project GeoERA, cross-border 3D subsurface models have been newly harmonised between Denmark, the Netherlands and Germany", explains Gabriela von Goerne. After all, the EU is working on common approaches, with at least a long-term prospect of Community-wide common access to the 3D subsurface models.

Within Germany, there are also plans to gradually extend the model southwards beyond the North German Basin. "Our long-term goal is a 3D subsurface model for the whole of Germany", says Gabriela von Goerne. ■

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METHODS DATABASE FOR REPOSITORY SEARCH

On behalf of the Bundesgesellschaft für Endlagerung (BGE), the federal company for radioactive waste disposal, BGR is developing a database to accelerate the search for a suitable repository for high-level radioactive nuclear waste.

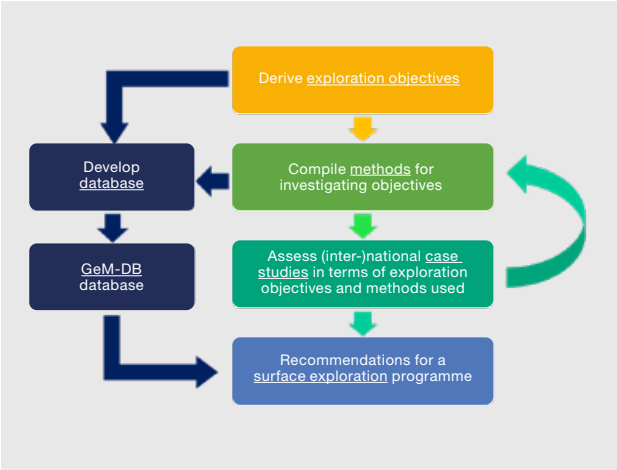
27,000 m^3 of nuclear fuels in about 1,900 containers – that, according to the Federal Office for the Safety of Nuclear Waste Management, BASE, is the result so far of half a century's nuclear power in Germany. A legacy that now has to be stored safely for a million years. After more than four decades of uncompromising debate about a possible site, the German Bundestag and the Bundesrat agreed in 2013 to restart the process, leading to the Site Selection Act (StandAG) in 2017. Its aim is to find the repository with the best possible safety.

The clock is ticking for this search: in 2031, a site recommendation is to be submitted and voted on by the parliament.

The new BGR database is supporting the search for the right site. BGR has been working on its development since 2019. "In this database, we have compiled a catalogue of geoscientific methods for the surface exploration of the three host rocks that can meet the legal requirements, claystone, rock salt and crystalline rock", explains Dr. Thies Beilecke, who heads the unit *Geophysical Site Exploration* at BGR.

To develop an efficient database, the BGR experts started by drawing up so-called "exploration objectives". These incorporated the exclusion criteria defined in the Act, minimum requirements for a repository site, and geoscientific weighing criteria. Added to those were experience and empirical evidence gained by BGR in other exploration programmes and repository projects, providing a broad basis for the future data. The exclusion criterion "active fault zones", for instance, leads to the exploration objective to identify faults and their spatial extension in the geological subsurface. Another example: to establish whether the minimum requirements for a host rock formation are met in a specific place, an exploration has to determine whether the rock area designated to accommodate the repository is located at least 300 m below the ground surface.

"In the database, we have stored the different methods that are suitable for a particular exploration objective", explains Beilecke. A broad range, from geological mapping to geophysical exploration methods such as seismic vibration measurements or geoelectrics, to borehole drilling. Methods are also rated based on experience and assessments in the scientific literature. "For every question, we differentiate levels of suitability", says Beilecke.



The methods database is a key process component in the development of recommendations for a geoscientific surface exploration programme.

Geoscientists working with the database can navigate between the levels, look at the legal text, for instance, compare the exploration methods for their objective, and select individual modules for a surface exploration programme. Everything is linked, to ensure the best exploration strategies can be identified as quickly as possible and developed efficiently. Since its creation, the database has proved an important tool not only for BGE and the repository search: it is also used as a reference work in other fields of activity at BGR. Says Beilecke: "The database simply has additional value that goes beyond its original purpose, which is very gratifying for me personally." ■

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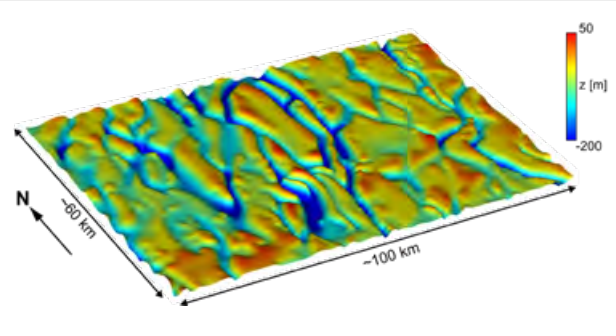
TUNNEL VALLEYS – DEEP CHANNELS IN THE SUBSURFACE

Subglacial tunnel valleys, most of them filled with sediment, are cut into the Northern German subsurface. They are the legacy of the ice sheets that covered the region during the glacial periods of geological history. BGR is studying the formation of these tunnel valleys.

For over 2.5 million years, the Earth has been running in ice-age mode. The Quaternary climate alternates between glacial periods and interglacials, sometimes with quite abrupt changes. There is evidence of at least three major glaciations in Northern Germany. During all of them, glaciers shaped the landscape in what is now Central Europe. The advances of the ice sheets have left lasting marks in the subsurface. The formation of so-called tunnel valleys, which are incised beneath ice sheets, is among the deepest reaching erosional processes. Depths of between 100 and 300 m, in some places even down to 500 m, have been measured in the formerly ice-covered areas of Northern Germany. "Most of them are no longer visible today, because almost all have been infilled", says Dr. Jörg Lang of the sub-department *Long-term Safety*. Only some tunnel valleys from the Weichselian glaciation, the most recent glaciation period in the North, are still evident on the surface. Says Lang: "Examples are the Schlei inlet in Schleswig-Holstein, or many of the lakes in Mecklenburg-Western Pomerania and northern Brandenburg."

The scientist heads a BGR project studying the formation and distribution of tunnel valleys from the Quaternary in Northern Germany. "Our first step will be to create an overview model of the subsurface that shows clearly where the tunnel valleys are, where faults and salt structures are located, and how thick the sediments are", he explains. The project aims to find out what mechanisms and factors play a role in the formation of these tunnel valleys.

There is a concrete reason for these investigations: the search is on in Germany for a repository to accommodate the high-level radioactive waste from end-of-life nuclear power stations. The repository should be located in geologically suitable rock formations, at a depth that will ensure its safety for a period of at least one million years. Since additional glacial periods are at least possible during this time, it is essential that the erosion processes leading to the formation of subglacial tunnel valleys are understood. Currently, the prevailing opinion is that tunnel valleys formed by meltwater that was pushed into the sediment of the subsurface by the enormous pressure of the glaciers and had to find a path to release pressure. "It's the same principle as an artesian well, but at the ice margin", explains Lang. The water shooting up from the glacier forefield leaves the characteristic tunnel valleys in the subsurface.



Detail of a new 3D subsurface model showing tunnel valley sat the base of the Pleistocene succession in Northern Germany (Data from: LBEG).

Many, but not all of them, run parallel to the advance direction of the glacier. However, there are also intersecting or strongly curved tunnel valleys. Says Lang: "It's not clear what happened there." A likely explanation is that the subsurface affected the incision. Maybe it was too hard, so the water changed direction; or maybe it was softer than the surrounding area and therefore the path of least resistance. The project aims to answer these and other questions. ■

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REPOSITORY RESEARCH AT THE EUROPEAN LEVEL: STRONGER TOGETHER

The use of nuclear power has resulted in society having to deal with the disposal of long-lived high-level radioactive waste from nuclear power stations. Alongside Germany, 14 of the 27 EU member states are addressing this issue in joint research projects and programmes, with BGR taking an active role.

More than half of EU countries either operate nuclear power stations or have used nuclear power in the past. They are all faced with the same question: what to do with, in particular, the high-level radioactive materials whose half-lives will likely outlast the human civilisation. There has for some time been a broad consensus regarding the answer: the waste should be safely stored deep underground.

Plans for such deep geological repositories exist in several countries; Finland is already building one. They are sophisticated structures designed to enclose the waste for an inconceivably long time by human standards. In Germany, the law states that radioactive materials must be prevented from entering the groundwater cycle or the biosphere for one million years. The scientific and engineering questions to be solved are the same for many countries, and international cooperation therefore makes perfect sense: to share information and pool resources.

Alongside many bilateral and multilateral initiatives by individual states, the European Union itself is also a major actor in repository research. It has been fostering cooperation on this important issue between the member states via the European Atomic Energy Community EURATOM and, since 2019, with the joint programme EURAD. BGR carries out work under the EURAD programme and in the EURATOM project BEACON. "At the European level, efforts are being made to keep the national states' research programmes at a similar level, in terms of both quality and the state of development", explains Dr. Gesa Ziefle, who is responsible for the EURAD project in the BGR sub-department *Geotechnical Safety Analyses*.

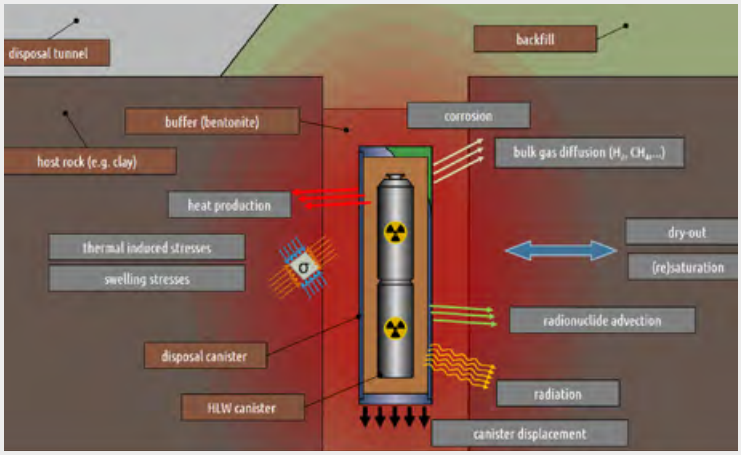
Those are high standards – after all, not all countries in Europe are strong in research and financial resources, with a large scientific and industrial base in nuclear energy. EURAD participants include familiar heavyweights such as France, Sweden, Switzerland and Germany, but also countries such as Lithuania, Romania and Bulgaria. "EU-level research is about promoting exchange and mutual trust. The scientists should not work on their own but share knowledge and solve problems in collaboration with others", says Gesa Ziefle.

The future repositories are planned as systems with multiple barriers that act together to enclose the radioactive material for a long time. All of the European states' repository concepts are multi-barrier systems. BGR maintains a broad repository research base, studying two barrier types at the European level. One is geological barriers. Under the EURAD programme, BGR carries out research on gas transfer in the host rock claystone. The other object of research concerns geotechnical barriers. In the EURATOM project BEACON, BGR is investigating bentonite, intended for use as backfill and sealant in crystalline rock and claystone.

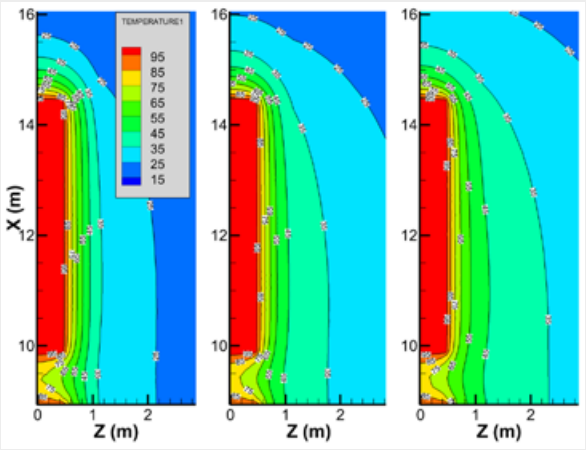
"Bentonite is produced from certain clay minerals. When canisters are emplaced in the future repository, the chambers will be backfilled with this material, which will seal them over time", explains Vinay Kumar, responsible for the BEACON project at BGR. Bentonite is used in the form of a powder, pellets or as blocks. When it comes into contact with water, the material swells – and water is ubiquitous in both claystone and crystalline rock. Over time, the gaps between the bentonite particles will close, resulting ultimately in a homogeneous, very compact solid material. It thus seals the canister, preventing any water leakage, and also ensures the stability of the surrounding rock.

The expansion and sealing processes occur in the first few hundred years following disposal. Compared to the whole period under investigation, that is a short time – but still considerably longer than the periods engineers generally work with for their structures. Numerical models therefore have to fill in the gaps where experiments and empirical

EURAD: This project has received funding from Euratom research and training programme 2014-2018 under grant agreement N°847593.
BEACON: This project receives funding from the Euratom research and training programme 2014-2018 under grant agreement N°745 942.



The disposal of radioactive waste in a repository triggers coupled thermo-hydro-mechanical and other processes. Additionally to the heat generated by radioactive decay, this leads to changes in the stress field and to gas production due to metal corrosion.



Spatial distribution of temperature in bentonite around a heater after approx. 100, 500 and 1,800 days. Simulation results of an in-situ heater experiment in an axially symmetric computational model.

"EU-level research is about promoting exchange and mutual trust." Dr. Gesa Ziefle

evidence cannot deliver sufficient coverage. This is the area that Kumar and his team work on. "We have developed a new material model that describes the mechanical behaviour of bentonite relatively well. It permits better modelling of both laboratory tests, which focus purely on the behaviour of bentonite, and in-situ experiments", explains Kumar's colleague Dr. Steffen Beese.

The BGR model is scheduled to simulate an in-situ experiment in claystone in late 2021. That will show whether the model can be used for the proofs of integrity required for the final disposal of high-level waste.

This links directly with the research carried out by Gesa Ziefle and her team. Her group models gas transport in claystone formations in EURAD. "We're looking at the impact that gas production in the repository has on the integrity of the geological and geotechnical barriers", explains her colleague Michael Pitz. It is a known fact that, depending on the material a repository container is made from, corrosion during the first few hundred or thousand years can lead to the formation of gases, which could increase the fluid pressure on the bentonite casing and the host rock. The question now is whether this gas formation could compromise the barrier effect. "Is it a steady increase", explains Pitz, "or local effects that might suddenly have a major impact at specific points?"

In the end, the modelling approaches for claystone and bentonite have to be brought together, because in a safety analysis, the repository operator has to provide evidence that the system of chosen barriers safely enclose the radioactive inventory. The BGR sub-department has already laid the necessary foundations: both the group in the BEACON project and the EURAD team use the same open-source software, OpenGeoSys. "At the end of the day, both groups also have to answer the same question: whether it can be proven with sufficient certainty that the processes considered have no significant negative impact on the barriers", says Gesa Ziefle. ■

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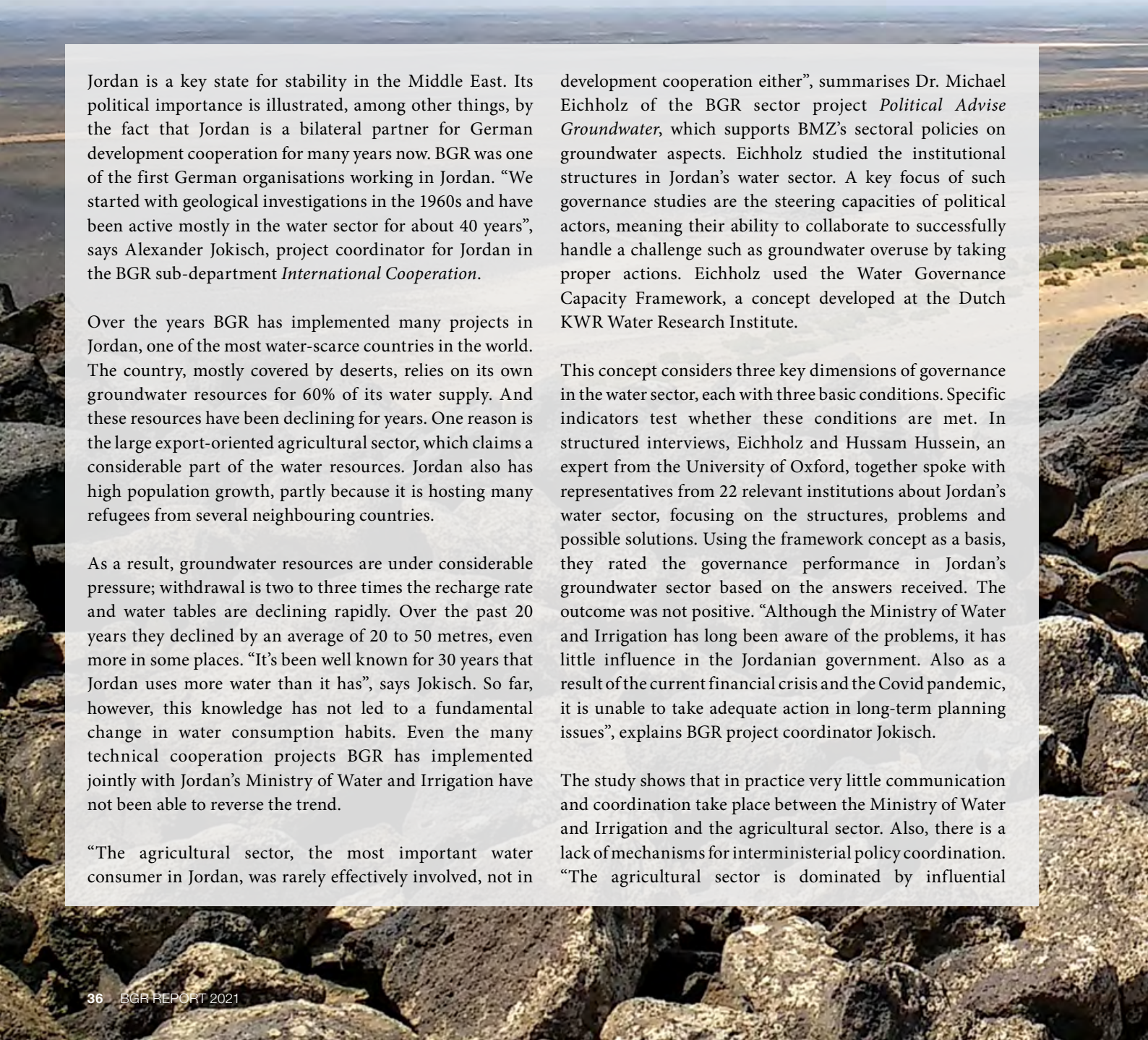
SUCCESSFUL PROJECTS NEED A GOOD UNDERSTANDING OF THE POLITICAL ECONOMY

Technical solutions will only have positive effects in development cooperation if they are embedded in the social, political and cultural environment of the partner country and adapted to the local structures. BGR's work in Zambia and Jordan illustrates the importance of analysing and understanding the local political situation with project goals in mind. On behalf of the Federal Ministry for Economic Cooperation and Development (BMZ), BGR has for many years been working in technical cooperation projects in the groundwater sector in both countries.



Jordan is a key state for stability in the Middle East. Its political importance is illustrated, among other things, by the fact that Jordan is a bilateral partner for German development cooperation for many years now. BGR was one of the first German organisations working in Jordan. "We started with geological investigations in the 1960s and have been active mostly in the water sector for about 40 years", says Alexander Jokisch, project coordinator for Jordan in the BGR sub-department *International Cooperation*.

Over the years BGR has implemented many projects in Jordan, one of the most water-scarce countries in the world. The country, mostly covered by deserts, relies on its own groundwater resources for 60% of its water supply. And these resources have been declining for years. One reason is the large export-oriented agricultural sector, which claims a considerable part of the water resources. Jordan also has high population growth, partly because it is hosting many refugees from several neighbouring countries.

As a result, groundwater resources are under considerable pressure; withdrawal is two to three times the recharge rate and water tables are declining rapidly. Over the past 20 years they declined by an average of 20 to 50 metres, even more in some places. "It's been well known for 30 years that Jordan uses more water than it has", says Jokisch. So far, however, this knowledge has not led to a fundamental change in water consumption habits. Even the many technical cooperation projects BGR has implemented jointly with Jordan's Ministry of Water and Irrigation have not been able to reverse the trend.

"The agricultural sector, the most important water consumer in Jordan, was rarely effectively involved, not in development cooperation either", summarises Dr. Michael Eichholz of the BGR sector project *Political Advise Groundwater*, which supports BMZ's sectoral policies on groundwater aspects. Eichholz studied the institutional structures in Jordan's water sector. A key focus of such governance studies are the steering capacities of political actors, meaning their ability to collaborate to successfully handle a challenge such as groundwater overuse by taking proper actions. Eichholz used the Water Governance Capacity Framework, a concept developed at the Dutch KWR Water Research Institute.

This concept considers three key dimensions of governance in the water sector, each with three basic conditions. Specific indicators test whether these conditions are met. In structured interviews, Eichholz and Hussam Hussein, an expert from the University of Oxford, together spoke with representatives from 22 relevant institutions about Jordan's water sector, focusing on the structures, problems and possible solutions. Using the framework concept as a basis, they rated the governance performance in Jordan's groundwater sector based on the answers received. The outcome was not positive. "Although the Ministry of Water and Irrigation has long been aware of the problems, it has little influence in the Jordanian government. Also as a result of the current financial crisis and the Covid pandemic, it is unable to take adequate action in long-term planning issues", explains BGR project coordinator Jokisch.

The study shows that in practice very little communication and coordination take place between the Ministry of Water and Irrigation and the agricultural sector. Also, there is a lack of mechanisms for interministerial policy coordination. "The agricultural sector is dominated by influential

Agricultural land in Jordan. According to 2017 estimates, irrigation farming in Jordan uses around 470m m^3 of water annually.

Alongside inadequate sanitation, illegal waste dumping is a key problem affecting groundwater conservation in Lusaka.

entrepreneurs who are well-connected with political decision-makers. This political representation has far more influence than the water sector's political lobby ", explains Eichholz. Development cooperation as another political actor has also failed so far to bridge the gap between these diverging interests.

Based on the study by Hussein and Eichholz, this is due to change, at least in German development cooperation with Jordan. On behalf of BMZ, BGR is planning another groundwater project for 2024, with the first-time participation of the Ministry of Agriculture. At the same time, BGR is already supporting the Ministry of Water and Irrigation with information campaigns on groundwater conservation as part of the ongoing projects work.

"The study shows that a sustainable solution to Jordan's water problems also requires a transformation in economic pathways that will involve all stakeholders working towards a common goal", says Eichholz. Even water-saving technologies will have only little effect if the agricultural sector continues to maximise exports and plants unsuitable crops.

This approach of governance studies preceding the implementation of geoscientific and technical projects has proved to be successful not only in Jordan. An earlier governance study in Zambia that provided fruitful insights concerned groundwater protection in the country's capital Lusaka. According to Professor Dr. Thomas Himmelsbach, who heads the *Groundwater and Soil* Science department at BGR: "Lusaka is bursting at the seams and has in fact already overused its water resources. Without proper sanitation, wastewater infiltrates into the ground untreated – the start of a fatal cycle. Cholera is by now endemic in Lusaka."

BGR expert Eichholz interviewed actors from the government and city administration, and from the water and sanitation sectors in Lusaka, to get an idea of the structures of administration and collaboration in the capital's water sector. He identified shortcomings there, too. "The water authority has hardly any institutional communication channels with the city planning office", says Eichholz. However, the study also identified ongoing initiatives for translating integrated concepts into coordinated action. Establishing and institutionalising such approaches has since been a key recommendation by BGR experts in the implementation of technical cooperation projects. Sometimes, however, coordination is difficult between the international project partners. "Organisations from different countries organise their projects primarily based on their own cooperation strategies and this does not necessarily lead to a coherent approach to the challenges", explains BGR expert Eichholz. Governance studies, such as those carried out by BGR in Jordan and Zambia, can therefore improve the overall efficiency and sustainability of technical cooperation. ■

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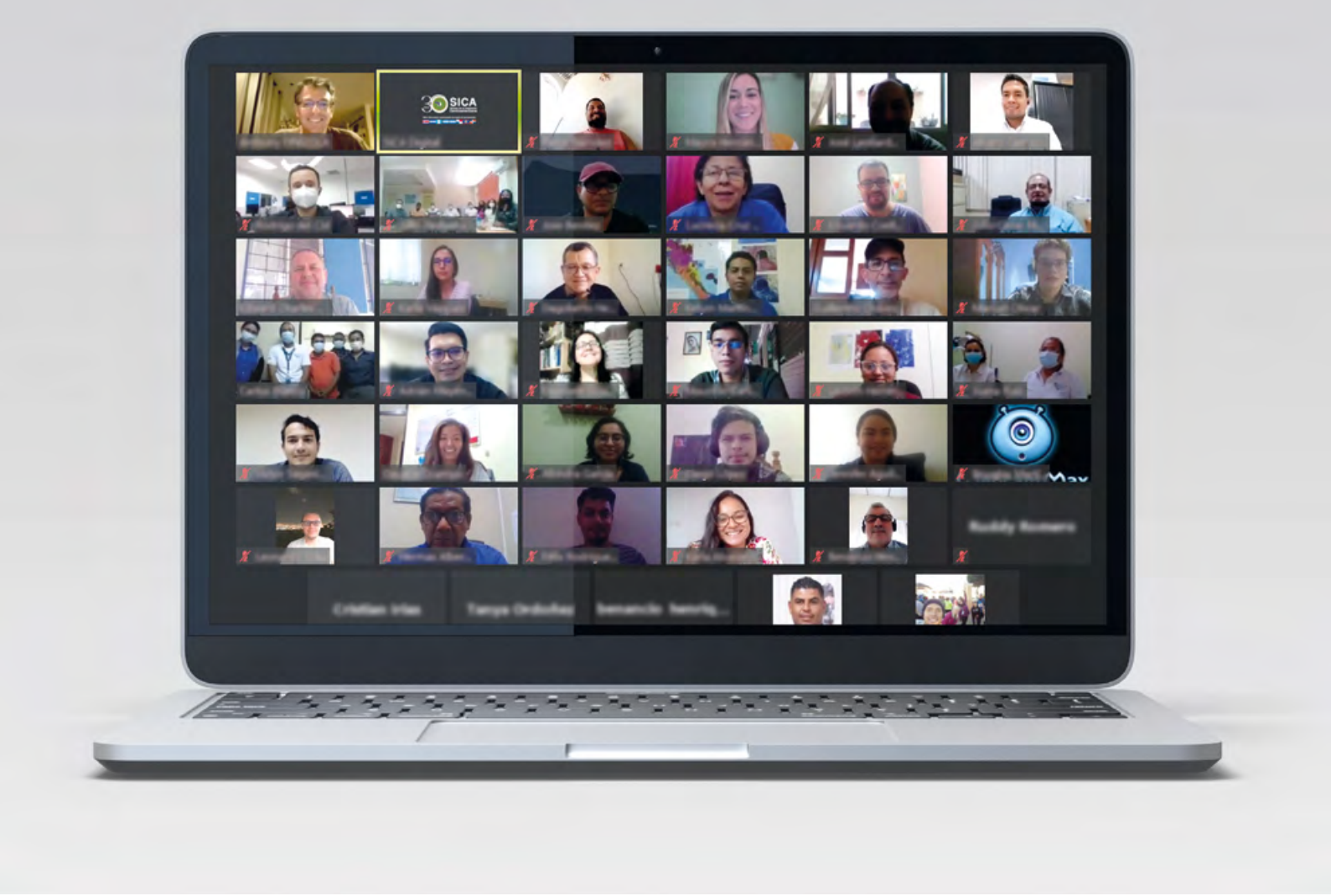
Landscape in eastern Jordan



Online workshop for a regional project on geothermal energy in Central America during the 2020 pandemic.

PANDEMIC ACCELERATES DIGITALISATION

In the pandemic year 2020, video conferencing boomed like never before. BGR staff, too, had to rely on online communication. Particularly in development cooperation, digital channels were the only way of interaction for project teams who had been recalled to Germany to communicate with partner institutions in partner countries.

The Covid-19 pandemic also put an abrupt stop to BGR's technical cooperation activities. "When the pandemic started, at the end of March, almost all project staff were recalled from their workplaces abroad and everything was switched to remote", remembers Annette Lisy. The experts were not working at the project location, but from the central office in Hanover or home, trying to keep in touch with BGR partner organisations.

In next to no time, BGR's IT unit managed to provide the staff with privacy-compliant applications that met the strict data protection rules for government authorities, to enable virtual collaboration. "BGR is currently moving further ahead in this area, it's really impressive", says Sulamith Kastl, who manages a regional project for BGR, promoting the use of geothermal energy in Central America.

Particularly in partner countries with a good telecommunications infrastructure, the switch-over to online tools proved very useful. "Internet coverage in this region is generally very good", reports Achim Constantin from South America, for one. He manages a regional project

Tablet-based survey of farmers in northern Cameroon on the soil improvement techniques used.

on sustainable mining and, unlike most of his BGR colleagues, stayed in Santiago de Chile, where his office is located. Restrictions in Chile were far more severe than in Germany, he says, but video conferencing meant he could reach even project partners in a mining village at almost 4,000 m altitude. "It works perfectly, although they are in an area where there are hardly any paved roads", says Constantin.

In fact, the project manager reflects on many positive aspects to compulsory video conferences. "That was the only way to, say, get together 80 people from five countries for a one day seminar. It would not have been feasible as a face-to-face meeting, logistically, financially or in terms of the time needed", says Constantin. The same goes for the attendance of high-profile speakers, like international experts or ministers. "It's rarely possible to get them to come to another country to give a talk – but joining a virtual meeting for just half an hour often is no problem", explains Constantin.

The pandemic has accelerated and boosted a trend towards digitalisation that had already started. "As a geoscientific and technical authority, we use digital tools in our everyday work, and we teach their use in our projects", explains Annette Lisy. That includes, for instance, the regular use of digital databases and geographic information systems, the computer-assisted analysis of remote sensing data, or automated data logging and transfer in monitoring networks.

Field work in the German-Cameroonian ProSEP project, for instance, is currently being recorded on tablets. The project concerns capacity building in sustainable land management in two regions in Cameroon. Local staff have been provided with tablets, enabling them, for instance, to carry out surveys. "Most people here use a smartphone anyway", reports project manager Daniel Leibitz from Cameroon's capital Yaoundé. "They can even use these devices to access the questionnaires." In the long term, mobile computers will be used to collect other data as well, such as the water levels recorded by data loggers in wells, or meteorological information.

The pandemic has also shown that there are clear limits to virtual collaboration, and that it is not suitable for every purpose. "A digital format is perfect for planning meetings, monitoring or short workshops – but it can't replace face-to-face communication in intensive learning situations such as field work, training or conflict resolution." That is Sulamith Kastl's conclusion after over a year of very intense online experience. Even once the pandemic is over, video conferences will continue to feature more in our everyday lives than before. But they will not replace face-to-face contact. There will probably be a mixture of the two. "Video conferences are of undeniable value for quick discussions", says Annette Lisy, "but they can't take the place of direct collaboration with our local partners and the trust it builds." ■

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Preparations for borehole drilling to explore the kaolin deposit near Hassi Abyad in Mauritania.

CAPACITY BUILDING IN MAURITANIA AND NAMIBIA

Many resource-rich African countries see few benefits from their wealth, as raw materials are generally processed elsewhere. In development cooperation projects, BGR is working with institutions in Mauritania and Namibia to implement strategies that will create more added value in these raw material-producing countries.

Mauritania's economic welfare is determined by metal. Iron ore from Zouérate in the far north of the desert state and mined gold and copper-gold concentrate from the northwest account for 54% of the West African country's income from exports. The mining of mineral resources thus yields the largest share of the national budget – hence Mauritania's dependence on commodity prices on the global market. Following promising developments in the early 2000s, the 2008 financial crisis hit the country hard. Its slow recovery was halted again by the Covid-19 pandemic.

"The Mauritanian economy's dependence on global market prices is such that we have been asked how the commodity industry could be diversified", says Annika Lüttig of the sub-department International Cooperation. That was at the start of the German-Mauritanian cooperation project. It involved experts from BGR and the Mauritanian Geological Survey ANARPAM searching for commodities that would let local companies develop the domestic value chain, strengthening the economy and creating jobs.

In the south of the country, an opportunity could now open up. In the region around M'Bout, local residents searching for groundwater had not found a spring but a white rock. Following extensive sampling by the experts, the find turned out to be a significant kaolin deposit of excellent quality. Now the kaolin from Hassi Abyad – which translates to "white well" – is to be used by the Mauritanian construction industry for tiles or even sanitary ware. "A Mauritanian company has already acquired a mining licence", says Annika Lüttig, adding: "The start of kaolin mining would be a huge success for our project." While there are currently no industrial customers in Mauritania who could produce tiles or other ceramic products from the kaolin, "there are potential customers in nearby Gambia", says the BGR project coordinator.

Another of BGR's technical cooperation partnerships with developing and emerging economies is with Namibia. Like Mauritania, Namibia is another partner country where strategies for a better value chain are being implemented,

Large feldspar crystals in a pegmatite in central Namibia.

"We want to explore the options these countries have for keeping more added-value processes in-country rather than just exporting their natural resources."

Antje Hagemann

enabling it to grow beyond the status of a mere supplier of natural resources. "We want to explore the options these countries have for keeping more added-value processes in-country rather than just exporting their natural resources", explains Annika Lüttig's colleague Antje Hagemann. She coordinates the Namibia project in BGR's sub-department International Cooperation. Namibia is determined to diversify its mining industry and BGR is supporting the Namibian Geological Survey GSN in analysing the profitability of domestic resources and identifying opportunities for a local value chain.

Extensive mineral potential studies have been prepared on feldspar and lithium in Namibia. They are intended as an information base for the Namibian authorities and stakeholders in mining and industry. The aim is to encourage exploration and investment, thus creating new markets and jobs. "One possible use for the resources currently under investigation in Namibia is glass production", says Antje Hagemann. Glass manufacture is not the most significant application for either feldspar, which is used primarily in the ceramic industry, or lithium, which plays a key role in lithium-ion battery technology. But both resources have great potential for the local value chain, given the size of the deposits. Namibia has a flourishing brewery industry, so investing in an expansion of domestic glass production could be an attractive proposition. Currently most beer from Namibian breweries still comes in bottles produced in neighbouring South Africa.

Mauritania and Namibia are promising examples of the Capacity Building approach pursued in BGR's cooperation projects on behalf of the Federal Ministry for Economic Cooperation and Development, BMZ. The aim is to enable local partner organisations – in this case, the geological surveys and the competent ministries of mining – to explore their national mineral resources themselves to increase their benefit for the population and the country. "We provide assistance to our partner organisations, in state-of-the-art sampling, how to prepare, analyse and ultimately evaluate samples", says Antje Hagemann giving details of the Capacity Building modules of the projects in Mauritania and Namibia. ■

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BGR'S EXPERTISE IS OF KEY IMPORTANCE FOR EUROPE

Interview with Dr. Milan Grohol, EU Policy Officer Raw Materials

What is the importance of Europe's geoscientific research institutes for the EU Commission and other European institutions?

The growing demand for natural resources – energy, raw materials and groundwater – is a key challenge for the EU, requiring a more integrated, efficient and sustainable use of these resources. An example: the EU is increasingly dependent on global supply of mineral resources, particularly those needed for power generation, energy storage and transport, for the transition to climate neutrality. Unfortunately no complete and harmonised data exist to date at European level on mineral resources potential and quality. There is also a need for standardised reporting and a uniform appraisal of subsurface capacities for CO_2 sequestration and the temporary storage of sustainable energy carriers such as hydrogen, to support a secure, affordable and low-carbon energy supply. Groundwater resources, too, are under increasing pressure as a result of climate change and competing subsurface uses, such as for energy and mineral resources. This is why we have called for integrated geological services for Europe. The aim is to provide high-quality, policy-relevant geoscientific information and expertise to European civil society and businesses and the EU institutions. Geoscientists can also help the EU to use the full potential of Earth observation technologies, for instance, in the management of geohazards, the exploration of mineral resources, and the monitoring of mining activities. The EU is actively collaborating with other countries on a wide range of topics. Work includes the strategic partnerships on raw materials with Canada, Ukraine, Serbia, Latin America and Africa, for which support by the Geological Surveys is critical.

"Unfortunately no complete and harmonised data exist to date at European level on mineral resources potential and quality."

How do you rate BGR's work in this context?

BGR as one of the leading National Geological Surveys is a major actor in shaping the geological services for Europe. BGR's international activities, including those in the Arctic region, are important for the EU. With the German Mineral Resources Agency, DERA, BGR provides a unique institution regarding raw materials. DERA delivers very valuable global information on a range of mineral resources, particularly the assessment of their potential and key data on price and supply risks.

What are the EU Commission's expectations regarding the work by EuroGeoSurveys (EGS)?

EuroGeoSurveys has been a driving force in the coordination and long-term alignment of research and knowledge activities among the National Geological Surveys in Europe. That has never been an easy task. But the EU needs a service provider who is able to respond to EU-wide challenges. For this reason, for more than a decade, we have been supporting efforts to integrate the existing geological services in Europe, particularly regarding raw materials, with funding and policies.

BGR is a partner in GeoERA, a programme that receives funding from the European Commission. What is the strategic importance of this programme?

After the EU research project Minerals4EU, GeoERA represents another major step towards the long-term aim of establishing a common knowledge and research base of the National Geological Surveys. The focus in GeoERA is on mineral resources, energy and groundwater resources. For the mineral resources, we see the main added value of the project in harmonising of national data and information at EU level according to the United Nations' UNFC system.

What is your assessment of the further development of the Geological Surveys in terms of participation in so-called "coordination and support actions" (CSA)?

EuroGeoSurveys' long-term vision is that of a community of geological service providers for Europe – as a permanent cooperation network of the National Geological Surveys. That matches the requirements of a common European policy precisely. We need a strong partner who is able to provide geological knowledge and services at a Pan-European level. This could be supported by joint projects funded under national research programmes.

DR. MILAN GROHOL
works for the Directorate-General Internal market, Industry, Entrepreneurship and SMEs (small and medium-sized enterprises) of the European Commission, where he is responsible for raw materials. He joined the BGR Board of Trustees in 2021.

"Horizon Europe does indeed offer great opportunities to secure funding for excellent ideas with high impacts."

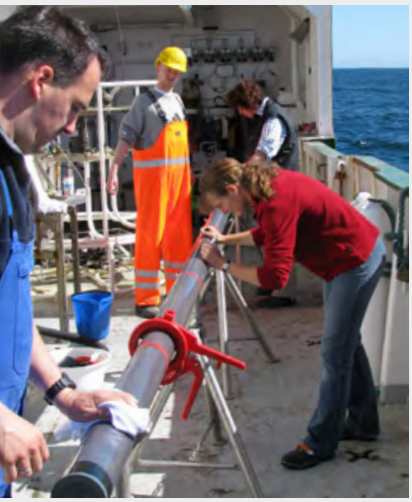
Horizon Europe is the most important funding programme for research and innovation in the EU. What prospects does it offer the National Geological Surveys in Europe and particularly BGR?

Horizon Europe does indeed offer great opportunities to secure funding for excellent ideas with high impacts. It is also the funding instrument for CSA to support the activities of the National Geological Surveys and calls for tender relating to projects that concern the sustainable use of geothermal energy and storage options in the geological subsurface. Regarding raw materials, we have launched a number of relevant calls, for instance on geological characterisation, modelling and mapping of mineral deposits; Earth observation technologies for the mining life cycle; identifying the future availability of secondary raw materials; monitoring and supervising systems for exploration and future exploitation activities in the deep sea; but also building EU-Africa partnerships on sustainable raw materials value chains. ■

ANNEMIEK VINK: SUCCESS IN SCIENCE REQUIRES OPENNESS AND FLEXIBILITY

Dr. Annemiek Vink is a biologist. She has been a member of the marine geology team at BGR for 17 years. Two years ago, Annemiek Vink took over coordination of the *Marine Resource Exploration* sub-department's project for the exploration of polymetallic nodules in the German contract area in the East Pacific. In spring 2021, she also led a European research expedition to monitor the environmental impacts of the first ever tests of a polymetallic nodule collector at great water depths of over 4000 m.

The Dutch scientist's career started in 1996. Following a degree in biology – with a focus on geobiology/palaeoecology – at the University of Utrecht, she moved to Germany. Driven by her interest in climate issues from the more recent geological past, Annemiek Vink pursued a PhD at the University of Bremen on the reconstruction of late Quaternary surface water masses of the subtropical Atlantic Ocean based on fossil phytoplankton.



A sediment core from the German North Sea sector is labelled and cut into segments, then opened and analysed.

Annemiek Vink standing on a pile of 1.1 tons of polymetallic nodules dredged in the German contract area (East Pacific).

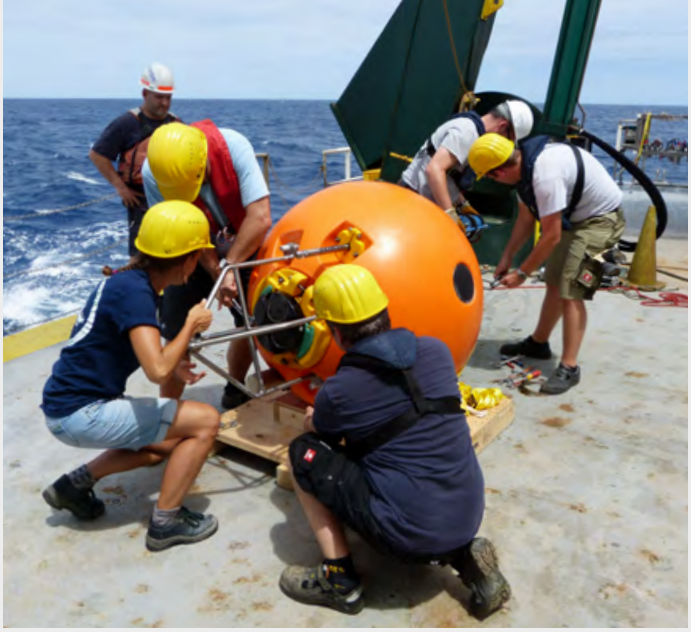
When she started her job in the marine geology group of BGR in 2004, it was, in her own words, "like winning the jackpot". Annemiek Vink had almost given up on a job in research, having spent most of the previous 18 months travelling in South America. "Taking time out from science for more than a year was considered a bad career move even then", she remembers. The job at BGR was precisely what Annemiek Vink had been looking for: "Following my PhD and a post-doc position at the University of Bremen, I had decided that I wanted to do more applied work, preferably based on societal and political demand. Which was precisely what BGR was offering me, with a mixture of scientific and advisory work." Her fields of expertise have changed several times since.

Annemiek Vink started out at BGR with sedimentological, palaeoclimatological and stratigraphic work on sediment cores from all oceans and the North Sea. When, following a consolidation of tasks in 2008, palaeoclimatology no longer fell within BGR's range of responsibilities, she focussed her attention on a German cooperative project for the investigation of the geopotential of the German North Sea. One outcome of the project was a publication on basal peats found in sediment cores during seagoing expeditions – a well-cited contribution to the reconstruction of the sea level of the North Sea area during the past 12,000 years.

In 2011, yet another new task awaited the biologist. She took over coordination of the environmental management programme for exploration of polymetallic nodules in the East Pacific. Her new task involved collecting baseline data on the marine environment and biodiversity of the German contract area. Another major aspect of her work has been to analyse the environmental impacts of potential future mining activities. "Deep-sea mining is controversial. As a biologist, I have the advantage that I have a somewhat different view of the ecosystem of the deep sea and the potential impacts of deep-sea mining on the marine environment", says the scientist.

This perspective is a strong benefit in her current BGR job as overall coordinator of the nodule exploration project. For this task, Annemiek Vink puts her own scientific research on hold. She is now responsible for the organisation of exploration campaigns and the preparation of annual reports to the International Seabed Authority, research proposals and government contracting projects. Within her network of research partners and memberships of international panels, the biologist is nevertheless an established member of the research community.

Annemiek Vink, who spent her childhood and adolescence in English-speaking Botswana in southern Africa, values international exchanges. "My command of the German language may not be perfect, but I can communicate all the better in an international setting", says the Dutch scientist, smiling. Another personal strength for her work, she says, are her "openness and flexibility". She considers these characteristics as two major factors that have contributed to her professional success: "It would otherwise have become difficult to tackle new tasks recurrently."



Preparation of a current meter (ADCP) as part of a long-term mooring deployment to monitor hourly variations of the current speed and direction on the seafloor over a period of one year at a depth of 4,100 m.

Leading her first research expedition as Chief Scientist in April and May 2021 aboard the Norwegian vessel ISLAND PRIDE was a new career challenge. As part of the European JPI Oceans research project MiningImpact, in which many German and European research partners participated, the environmental impacts of the first ever tests of a polymetallic nodule collector developed by the Belgian company Global Sea Mineral Resources (GSR) were monitored in the East Pacific at great water depths of around four kilometres.

"The findings of our analyses and investigations will make a significant contribution to the development of high environmental standards, to be included in the International Seabed Authority's future mining regulations", explains Annemiek Vink. That is also her goal as a BGR coordinator. "Research on mineral resources, and particularly on the potential environmental impacts of deep-sea mining, must be objective and transparent for everyone. This is not always an easy task, because public opinion on the topic is often hypercritical", says Annemiek Vink.

The single mother of two daughters faces rather different challenges when it comes to achieving a good work-life balance. "I'm very lucky in that respect. BGR is an extremely family-friendly employer, I think, with its many part-time and remote working options", says Annemiek Vink. "Also, people at the institute are very appreciative of my family situation and the related work restrictions I sometimes have."

Annemiek Vink is quite composed about her future career. On the topic of resource exploration, she would like to work more closely with developing countries, preferably in her former home Africa. But for the moment, her focus for the next few years will be on demonstrating the technical and financial feasibility of environmentally sound deep-sea mining. And that work is far from accomplished. ■

EXPLORATION OF POLYMETALLIC NODULES IN THE GERMAN CONTRACT AREA

On behalf of the Federal Government, BGR has been carrying out exploration work in the German polymetallic nodule areas of the Pacific since 2006. The legal basis for these activities is a contract between the International Seabed Authority and BGR, which gives Germany the exclusive right to explore the metal-rich polymetallic nodule resources and their accompanying environmental conditions in an area of 75,000 km² for a period of 15 years. This contract is now due to be extended for another five years.

During its exploration work, BGR has discovered a number of promising polymetallic nodule fields on the seafloor, with high nodule abundances and a great resource potential. In addition to the industrial metals nickel, copper and cobalt – important metals for renewable energy technologies that account for approx. 3% of the nodule mass – the economic use of manganese as the main constituent of the nodules (around 31%) is also conceivable.

In parallel, comprehensive investigations of the environmental baseline in the contract area have been carried out. Amongst others, these have involved the development of an inventory of marine benthic organisms, which include microscopically small organisms in the sediment such as nematodes and copepods as well as larger animals such as sea cucumbers, brittle stars and sponges.

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B1.4 Marine Resource Exploration

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Patrick Hupe on Open Day at BGR's GERES station (Bavarian Forest).

At the CTBTO Science and Technology 2019 Conference in Vienna.

Field trip to the seismic station at Petra (in Jordan).

SKILLS OF TOMORROW – YOUNG SCIENTISTS AT BGR

They are at the start of their academic careers. At BGR, young scientists find an environment that fosters growth and development. As well as providing various types of support for their everyday work, BGR offers young researchers at the Geozentrum Hannover's Early Career Scientists Club an opportunity for exchange and networking with colleagues from other research institutes and disciplines. One such young scientist is Dr. Patrick Hupe, who works in the sub-department *Federal Seismological Survey, Nuclear Test Ban* at BGR.

Having completed his degree in meteorology at Leibniz Universität Hannover (2009-2015), he started at BGR in October 2015 in an EU-funded project position, focusing on infrasound and atmospheric dynamics. During the 3-year project, Patrick Hupe also completed his PhD at Ludwig-Maximilians-Universität München. "Despite the physical distance from my supervisor in Munich, I felt very well looked after. For that, I also have to thank my colleagues here at BGR, who provided scientific support and motivation", reports Patrick Hupe.

Infrasound was a completely new research area for the recent graduate, but the intense exchange with his new colleagues helped him quickly get to grips with it. "I was able to use my meteorological background in an interdisciplinary field", says Hupe. This made him a perfect addition to the expert team on the project ARISE (Atmospheric dynamics Research InfraStructure in Europe).

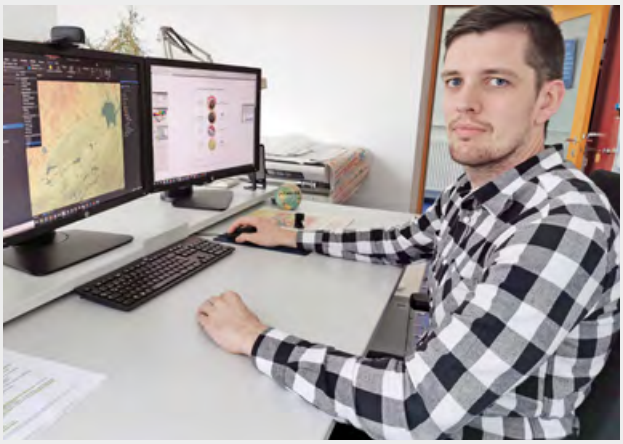
Since 2019, Hupe has held a post-doctoral position at BGR. He works in nuclear test ban research, focusing on seismoacoustic studies, which includes infrasound research and the assessment of earthquakes. "That makes my work very varied", says Patrick Hupe, who also handles applications for third-party funded projects. Regular presentations of research findings at international conferences and the attendance of workshops are opportunities for sharing information and connecting with fellow scientists in his field. Possible benefits are, for instance, ideas for new project proposals or joint publications for scientific journals.

Since the Early Career Scientists Club was set up at Geozentrum Hannover, scientific exchange across the disciplines has become easier for young researchers at BGR and the other two organisations, LBEG and LIAG. "It can be very useful for methodology issues, and regular scientific discussions between PhD students and post-doc researchers are also very valuable", explains Hupe. "Particularly when you're doing your PhD at a university that is a long way from Hanover, as I did, the Early Career Scientists Club is an appreciated addition to similar programmes at your university. Plus, we can talk about later career goals, such as a post-doctoral qualification, or share other colleagues' experiences", says Hupe. ■

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

APPRENTICES – DIFFERENT 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.



Eduard Schilinsky (photo) started training as a geomatician at BGR in August 2019. He had seen the apprenticeship advertised on the job board of the German employment agency Bundesagentur für Arbeit. "I've always been interested in geography. Now I'm learning a lot about geology as well. That makes training very interesting for me", says Eduard Schilinsky. The future geomatician sometimes attends the internal house colloquia. He particularly likes the daily communication in his unit. "Even when I was working from home I was given suitable tasks and the trainers taught content very well", says Eduard Schilinsky. In his first year, he was introduced to GIS and cartography, which put him way ahead at vocational school. "I was able to help my fellow students with their work", he remembers. Once he completes his apprenticeship, Eduard Schilinsky would like to work as a geomatician and continue training to expand his knowledge.

Annika Gölzner (photo) completed her training as a precision mechanic at BGR in early 2021. Her father had also trained in that profession, which gave her the idea. After Annika Gölzner had completed a number of work placements, she found out about the apprenticeship at BGR through the careers advisory service. "I felt very much at home at BGR right from the start", says Annika Gölzner. During her apprenticeship, she learnt not just about milling, turning, drilling and welding, but also how to prepare CAD drawings and use CNC machine tools. "I was taught everything from scratch, so I actually made various components needed for research work at BGR", says Annika Gölzner, who now works as a precision mechanic in BGR's central workshop. She has concrete plans for the future: "I'd like to share the pleasure and enjoyment of this job with others", says Annika Gölzner. For this, alongside her work, the skilled precision mechanic is continuing education to become a master craftswoman, which will enable her to train others.

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)
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ABOUT BGR

BGR offices

BGR employees

775

+ 11 APPRENTICES

Employees	**562**
Civil servants	**213**
Permanent employees	**620**
Fixed-term employees	**155**
Women	**315**
Men	**460**
With a degree	**378**
Without a degree	**397**
PhD students/post-doc researchers	**21**

Data as of: 30/06/2021

2020 budget

Income (incl. third-party funding)

16,209,243.90 €

Expenditure

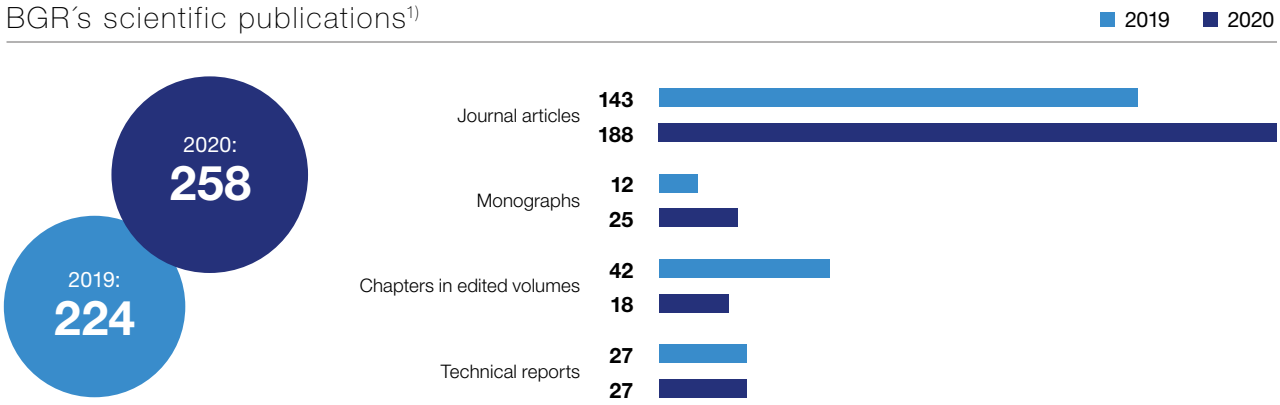
93,896,515.88 €

Expenditure on orders from other federal agencies and third parties (particularly BMZ)

15,352,178.44 €

PUBLICATIONS

BGR´s scientific publications[1)]

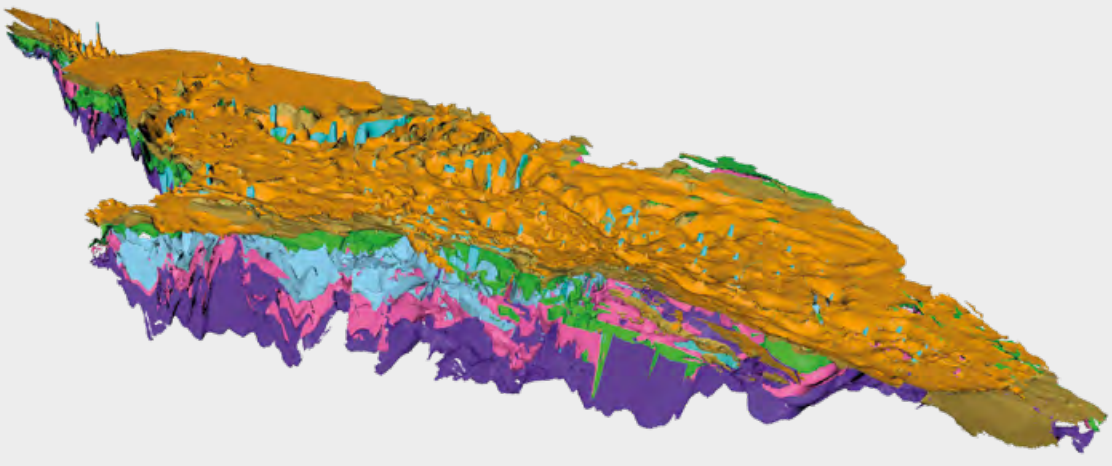


[1)] Either the first author or one or several co-authors are affiliated with BGR.

Data as of: 30/06/2021

PRODUCT CENTRE

Digital scientific information is made available by BGR via the product centre on the BGR website. The product centre currently provides access to around 730 thematic data sets relating to the geosciences and natural resources, in particular single maps (sheets) and map series. Most of the latter are regularly updated. More geological 3D models of the subsurface have recently been added to the product centre range. These include the 3D structural geological model of the North German Basin (TUNB) created by the Geological Surveys of the Northern German states and BGR.



An example of the product range: the 3D model of the North German Basin (see article on pp. 30-31).

↗ Product centre: https://produktcenter.bgr.de (To access the TUNB model, enter the search term “TUNB” in the search box.)
↗ 3D structural geological model in the 3D viewer: https://gst.bgr.de/shortlink/tunb

INTERNATIONAL FIELDS OF APPLICATION AND RESEARCH OF BGR

GERMAN MINERAL RESOURCES AGENCY (DERA)
DERA Projects

NUCLEAR TEST BAN
CTBTO and IAEO

INTERNATIONAL COOPERATION
Regional Projects
Groundwater
ABN – Niger Basin
CBLT – Lake Chad Basin
CUVECOM – Cuvelai Basin
OSS – Maghreb

Mineral Resources
CEPAL – Andean Countries
ICGLR – Great Lakes Region

Geothermal energy
AU – East Africa
SICA – Central America

Bilateral Project
Soil
Geo-Hazard
Geothermal Energy
Groundwater
Mineral Resources

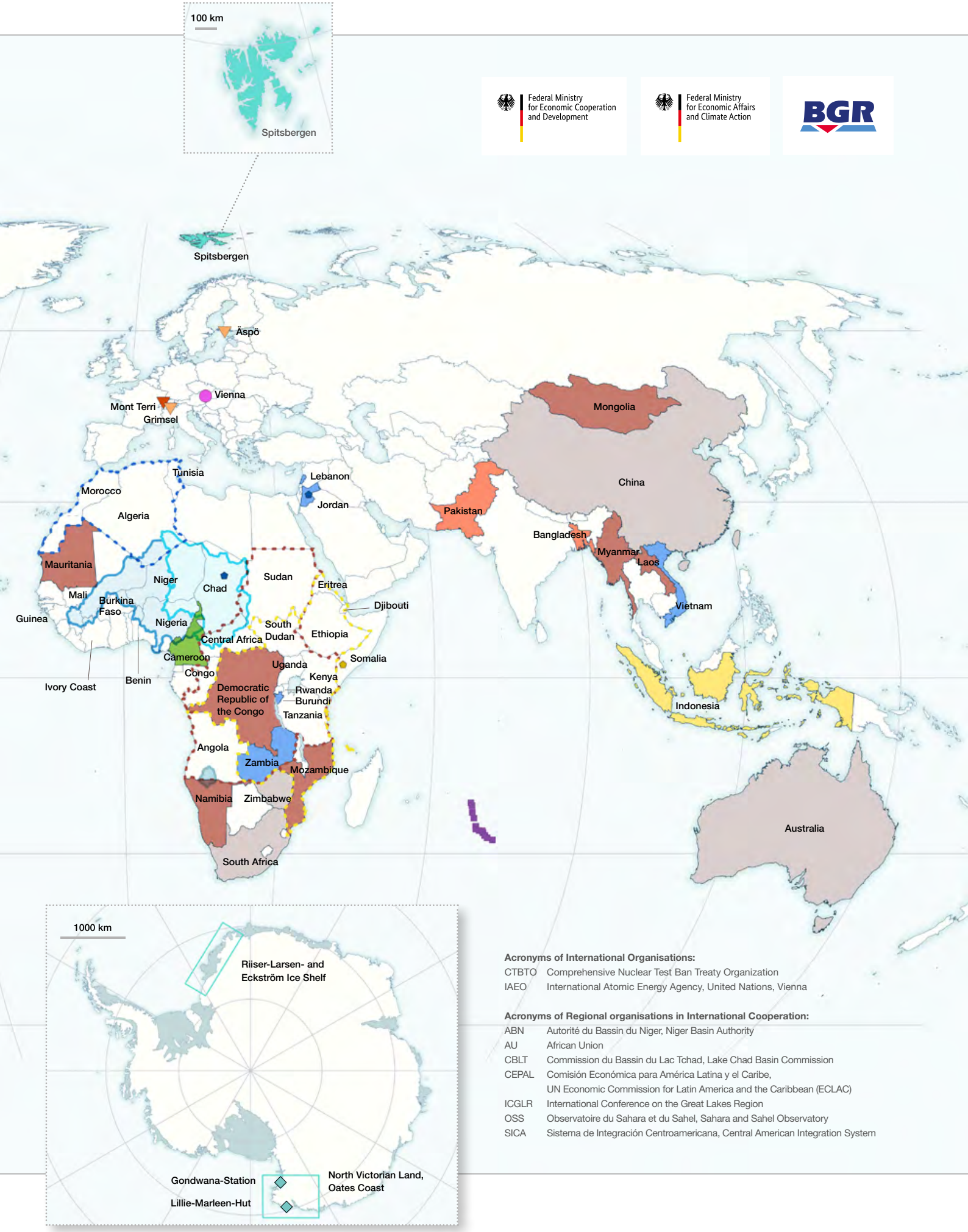
GeoSFF small-scale measures
Geothermal Energy
Groundwater

FINAL DISPOSAL OF RADIOACTIVE WASTE
International Underground Laboratories
Crystalline
Clay

MARINE RESOURCE EXPLORATION
Licence Areas
Manganese nodule
Massive sulphides

POLAR RESEARCH
Antarctic
Destination area of the Antarctic expeditions
BGR Research Station

Arctic
Destination area of the Arctic expeditions



Acronyms of International Organisations:

CTBTO	Comprehensive Nuclear Test Ban Treaty Organization
IAEO	International Atomic Energy Agency, United Nations, Vienna

Acronyms of Regional organisations in International Cooperation:

ABN	Autorité du Bassin du Niger, Niger Basin Authority
AU	African Union
CBLT	Commission du Bassin du Lac Tchad, Lake Chad Basin Commission
CEPAL	Comisión Económica para América Latina y el Caribe, UN Economic Commission for Latin America and the Caribbean (ECLAC)
ICGLR	International Conference on the Great Lakes Region
OSS	Observatoire du Sahara et du Sahel, Sahara and Sahel Observatory
SICA	Sistema de Integración Centroamericana, Central American Integration System

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 German 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 the sustainable management of georesources. 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 BGR's 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 and support institutions such as the United Nations, the EU Commission, the World Bank and the German public development bank (Kreditanstalt für Wiederaufbau).

Examples of BGR advisory responsibilities

SECTOR PROJECT EXTRACTIVES AND DEVELOPMENT

Through the sector project Extractives and Development, BGR advises the Federal Ministry for Economic Cooperation and Development, BMZ, on developmental issues in the extractive sector and supports the ministry in international dialogues, multi-stakeholder initiatives (such as the European Partnership for Responsible Minerals) and other events. Studies and analyses that support the BMZ in its strategic extractives policy are additionally published regularly. The most recent publications were an analysis on the improper disposal of drill cuttings in the course of oil and natural gas drillings as well as an assessment of the situation of mining local procurement in the Democratic Republic of the Congo.

SECTOR PROJECT POLICY ADVICE GROUNDWATER

Population growth, dynamic economic development and climate change are putting increasing pressure on the use of declining water resources, particularly in the world's arid regions. BGR's sector project Policy Advice Groundwater supports BMZ with strategies and concepts for sustainable groundwater management in German development cooperation. BGR operates active agenda setting on international conferences, prepares publications and comments, and develops training material for capacity development. The sector programme is currently supporting the African Ministers' Council on Water AMCOW in setting up the Pan-African Groundwater Programme APAGroP.

GROUND MOTION SERVICE GERMANY

Ground motion caused by natural or anthropogenic processes can damage buildings or infrastructure and presents a safety risk. BGR's Ground Motion Service Germany, BBD, uses up-to-date satellite data from the Copernicus Sentinel-1 mission to detect ground motions across Germany. Deformations of the Earth's surface are measured from space, processed and visualized by using big data applications. This technology can help detect potential hazards in the subsurface. With this service, BGR currently supports the State Geological Surveys, federal authorities, mining and surveying offices, utility companies and research institutes. Information is also made available in conferences and publications.

DEKSOR

The German Competent Authority EU Due Diligence Obligations in Mineral Supply Chains, DEKSOR, which is part of BGR, is responsible for monitoring compliance by German EU importers with the so-called EU Conflict Minerals Regulation and for carrying out ex-post checks from 2022 onwards. DEKSOR works in an advisory role with the relevant departments, and customs and law enforcement authorities. DEKSOR makes important contributions to a harmonised implementation and interpretation of the EU Regulation in events organised by the EU Commission (Member State Expert Group on Responsible Sourcing of 3TG), as well as information sharing meetings with other member states' authorities, associations, businesses and NGOs.

GERMAN MINERAL RESOURCES AGENCY (DERA)

Mineral resources are at the starting point of the industrial value chain. They are the basic building blocks of production for every sector, from primary to high-tech industry. To be competitive as a location for industry and technology, Germany therefore depends on a secure and sustainable supply of the necessary raw materials.

Since Germany has to rely on commodity imports – particularly of metals and intermediate products – to a very large extent, the monitoring and analysis of commodity markets play a crucial role.

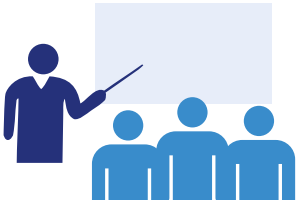
For 10 years already, the German Mineral Resources Agency (DERA) has with its raw materials monitoring service contributed significantly to greater market transparency in the commodity industry. As a federal service and part of BGR, DERA advises German industry and politics on price, supply and demand developments on the commodity markets. It provides consulting for more than 60 mineral raw materials and over 200 intermediate products of the first levels of the value chain. Critical developments on the international commodity markets can therefore be identified early and support provided to businesses in optimising their strategies for a secure and predictable raw materials supply.

Particularly for small and medium-sized enterprises, it is crucial to have an independent partner who monitors the complex trends on international commodity markets promptly and can, where required, make concrete recommendations for a diversification of the raw materials supply. Science-based commodity advice is a quality feature of DERA. Its detailed risk assessments of selected raw materials include, for instance, supply and demand scenarios, analyses on commodity-specific supply risks, and mitigation strategies.

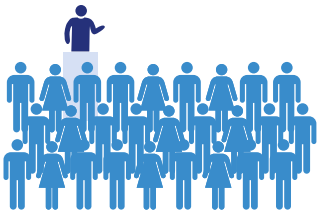
In addition to analysing potential price and supply risks, DERA also assesses resource potentials outside Germany. In the context of its country cooperation projects, DERA studies new supply and investment opportunities in the world's major mining regions. This helps businesses with the diversification of their supply sources, thus leading to long-term raw materials security.

DERA will be expanding the scope of services offered as part of its raw materials monitoring in the next few years, to further improve market transparency and provide consulting to German industry and politics. In addition to market assessments of critical raw materials, products from higher levels of the value chain as well as raw materials from recycling will also be analysed more detailed.

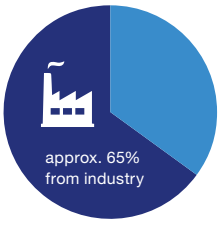
DERA statistics (2011–2020)



385 lectures



5,600 guests
at DERA events



approx. 2,500
consulting enquiries

98
press releases

60 DERA events
Organised or co-organised by DERA

48 external events
Trade fairs and conventions such as PDAC, Hannover Messe, etc.

>100
publications

About BGR

The Federal Institute for Geosciences and Natural Resources, BGR, is a scientific and technical higher federal authority. It is subordinate to the Federal Ministry for Economic Affairs and Climate Action, BMWK. As the German centre of excellence for geoscience, BGR advises and informs the Federal Government and German business on all issues relating to geosciences and natural resources. 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. 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
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Organisational chart of the Federal Institute for

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[1] Joint administration of BGR and LBEG in accordance with the administration agreement of 1 January 2021
[2] Acting / on probation
[3] Entrusted with the conduct of business
[4] Responsible for risk management

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