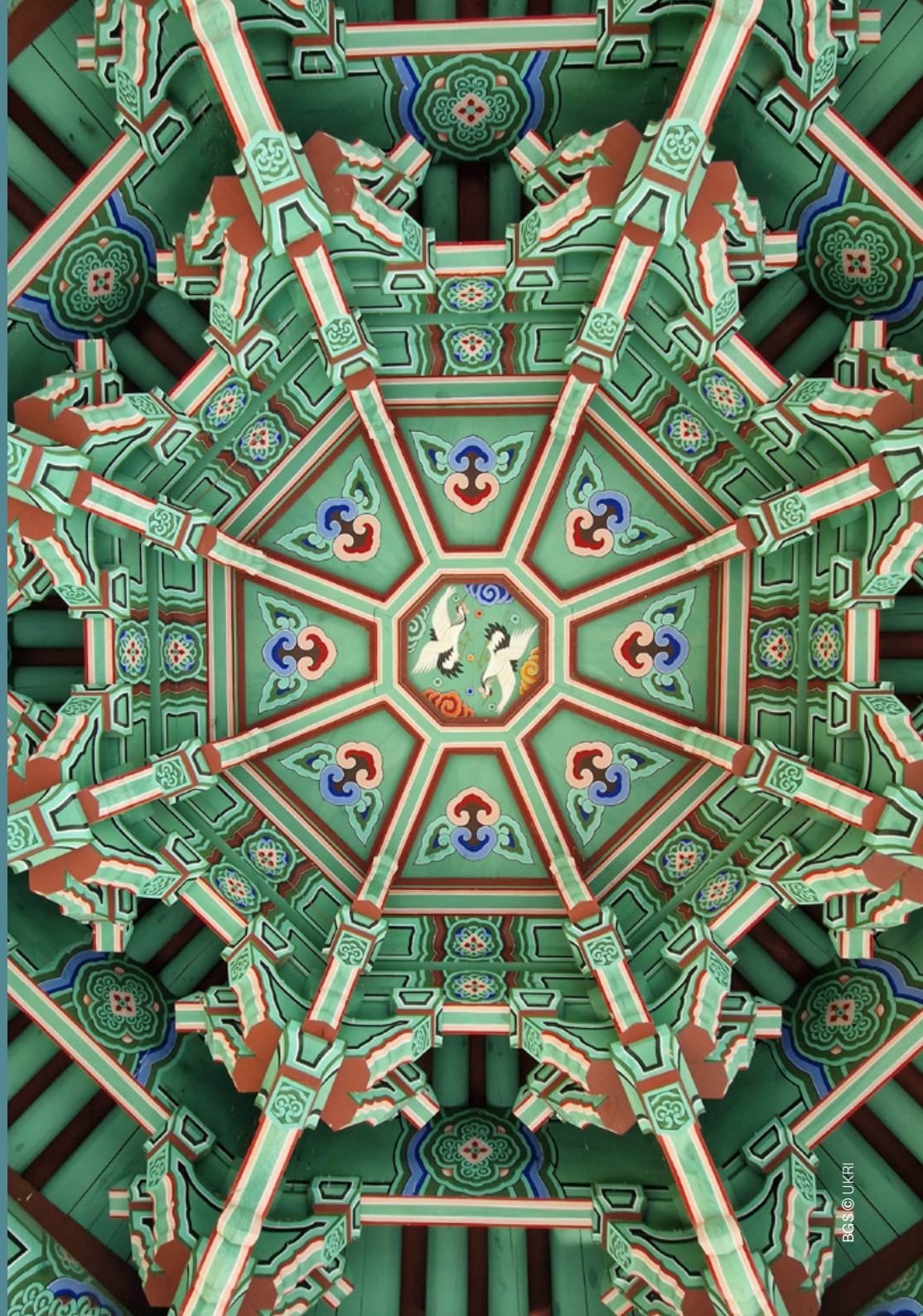
British Geological Survey

BGS INTERNATIONAL

Our partnerships in Asia



Acknowledgements

Our international work would not be possible without the collaboration of our partners on the Asian continent and beyond.

BGS INTERNATIONAL

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BGS INTERNATIONAL

Global partnerships for a connected future

The British Geological Survey (BGS) is renowned for delivering scientific knowledge, innovative approaches and a commitment to shared success with its partners worldwide.

We are the oldest geological survey in the world and we have been trusted to provide geological data, insight and expertise for almost 200 years. Our longevity is built on strong collaborations with governments, research institutions and decision makers, helping them to understand the vital role the subsurface plays in shaping resilient economies, sustainable environments and thriving societies.

We are proud of our international reputation. Through sustained partnerships and mutual trust, we are addressing some of the world's most pressing challenges, from climate resilience to resource security.

Foreword

It is my pleasure to welcome you to BGS's latest international brochure. As director of BGS International Geoscience, I'm delighted to share how our team continues to deliver innovative solutions, build lasting partnerships and make a meaningful, positive change.

Our work in Asia

BGS is proud of its rich history of collaboration throughout the continent. Our approach is founded on mutual respect, shared goals and a deep understanding of the importance of geology from local to national levels. Over the years, we have worked with a wealth of stakeholders, including geological surveys, research institutes, industry, policymakers and local partners and communities.

Strength in partnerships

Together we've exchanged knowledge, built capacity and developed research that addresses some of the most pressing challenges facing society today. Enhancing urban resilience; supporting the clean energy transition; tackling groundwater depletion; exploring carbon dioxide storage feasibility; advancing 3D geological modelling; seismic hazard mapping — our collaborative work puts geoscience at the heart of sustainable solutions.

Ways of working

We maintain a standing scientific capability to meet the needs of multiple stakeholders and will keep developing our research and sharing our knowledge to enable effective partnerships and informed decision making.

Beyond our scientific expertise, we work with in-country partners to strengthen their capacity, providing a holistic approach that combines integrity and scientific excellence, placing them and their needs front and centre.

Our work is truly global, as is our organisation. BGS is committed to working to empower partners to identify actionable strategies and best practices to promote equality. Ultimately, through shared learning and mutual respect, our aspiration is to support a more diverse and equitable workforce in the geosciences.

Thank you for taking the time to learn more about our work. We look forward to continuing these conversations and building new opportunities together.

Dr Maggy Heintz
Director of BGS International Geoscience

THEME ONE

Energy transition

The subsurface has a major role in helping to deliver the transition to net zero. Securing this transition will rely on geoscience-based expertise, from responsible use of the subsurface for technologies such as carbon capture and storage, to sourcing critical raw materials essential to the modern world.

The urgent need to mitigate climate change is driving the demand to decarbonise energy, transport and industry across the globe and South-east Asia will play a growing role in green energy growth over the next decade.

We are supporting our partners across Asia to realise their clean energy potential through research into new, sustainable and energy-efficient technologies. Intrinsic to this are an appropriate transition framework and a commitment to inform societal debate and policy through impartial geological evidence.

THEME ONE

Case studies

Geological cooperation in Mongolia

Mongolia is a country with significant opportunities for development. It has the geological potential for rare earth element resources, particularly in the Gobi Desert region. To boost its economy, the country is investing in efforts to better understand and develop its resources.

BGS and the Mongolian National Geological Survey (MNGS) signed a Memorandum of Understanding that establishes a partnership based on several areas of cooperation, including geological mapping, hydrogeology and mineral resources. A roadmap was signed between the British Embassy and the Ministry of Industry and Minerals Resources of Mongolia, which highlighted the need for collaboration on geology and resources in the country. BGS is a named partner in this roadmap.

Exploration for critical minerals in Mongolia is ongoing and MNGS plays a key role in developing baseline geological data for this purpose. BGS undertook a geological scoping visit in February 2025, delivering a report on mineral deposits and hydrogeology in the region of the South Gobi. Mongolia has the potential to be a major producer of critical minerals in the future due to the prospective, yet underexplored, geology and BGS is supporting MNGS to deliver that potential.

PARTNERS

- Mongolian National Geological Survey, Mongolia

Carbon dioxide storage in India

With the government of India committing to reaching net zero by 2070, the pivotal role of carbon capture, utilisation and storage (CCUS) in enabling clean growth has been recognised. India's independent policy advisory body, NITI Aayog, emphasised the potential of CCUS in reducing emissions from key sectors such as steel, cement, petrochemicals and fertilisers.

BGS is working with partners in India to assess the feasibility of the geological storage of carbon dioxide (CO_2) captured from these energy-intensive industries. Our research has focused on two key areas: CO_2 storage in a mature oil and gas basin setting, and CO_2 storage in Deccan Trap basalts.

Preliminary estimates of the theoretical storage capacity have been undertaken, which highlighted that more analysis is needed to fully estimate how much storage is available. An improved knowledge base is necessary to develop appropriate policies, including details on if, where and how much CO_2 can be securely stored in the rocks beneath the country.

BGS is leading on a new UK/India centre of innovation in CCUS, which will create a bilateral platform to accelerate collaborative research to address barriers to CO_2 storage deployment, as identified by policy and industry stakeholders. It will integrate emerging research groups in India, linking them with expert groups in the UK to share knowledge and expertise.

PARTNERS

- Indian Institute of Technology Bombay, India
- National Geophysical Research Institute, India

Radioactive waste disposal in Japan

Over a 25-year history of cooperation, the Japan Atomic Energy Agency (JAEA) and BGS have worked together on geological aspects of radioactive waste disposal, including mineralogical characterisation, geomicrobiology and geochemistry. Currently, BGS is working alongside international partners on the 'Horonobe International Project' (HIP), which brings together scientists and engineers to study the challenges of long-term implementation of radioactive waste disposal.

BGS is working with HIP partners to develop transport models that can be applied to repository safety assessments for fractured, porous, sedimentary rocks. We will also gain a greater understanding of the evolution of near-field thermal-hydrological-mechanical-chemical (T-H-M-C) conditions following the emplacement of radioactive waste in deep subsurface environments. Additionally, we will undertake a systematic integration of repository technology options to find the correct location for radioactive waste and study safe and correct backfilling and dismantling of sites once the materials have been stored.

A further focus will be training the next generation of engineers and researchers, both in Japan and worldwide, on safe radioactive waste disposal.

Working together with partners, BGS is creating a safer environment for nuclear production in Japan, now and into the future.

PARTNERS

- Japan Atomic Energy Agency, Japan
- Nuclear Energy Agency, Japan

THEME TWO

Disaster risk and climate resilience

The World Bank's South Asia Climate Change Roadmap identifies South Asia as one of the most vulnerable regions to climate 'shocks', such as sea level rise, drought and landslides, some of which are becoming more prevalent due to global warming.

Other natural geological hazards, such as earthquakes and volcanic eruptions and their associated impacts and risks, are of key concern to lives and livelihoods, including long-term economic growth.

BGS supports risk mitigation and adaptation efforts by understanding geological hazards and their risks to a specific country. Using monitoring, characterisation and forecasting of hazardous processes and their impacts, we can better inform risk management practices, empowering those most at risk.

THEME TWO

Case studies

Identifying the underlying causes of tsunamis

Using a combination of field observations, satellite data and numerical modelling, project partners researched the cause of the catastrophic tsunamis that were generated during the 1883 Krakatau volcanic eruption in Indonesia. The importance of the project increased when the flank of Anak Krakatau (a volcanic cone that had grown within the Krakatau volcanic complex) collapsed in December 2018, generating a tsunami that killed more than 400 people along the coasts of Java and Sumatra.

The project has resulted in an improved understanding of the 1883 eruption and its associated tsunami. This research underlines the hazard of tsunamis triggered by volcanic eruptions and the importance of studying them alongside tsunamis generated by earthquakes to improve safety measures for both event types. The results of modelling tsunami impacts on the coast can help local authorities educate coastal populations living on or close to volcanic hazards and appropriate organised responses.

The work was underpinned by longstanding relationships with colleagues across research and government institutes in Indonesia, including the

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National Research and Innovation Agency (BRIN) and the Institute of Technology Bandung. These relationships have aided further projects, including assessing geological hazards at new locations across Indonesia, which will continue to help to build resilience across the country.

PARTNERS

- Institute of Technology Bandung, Indonesia
- National Research and Innovation Agency, Indonesia

Multi-hazards in the Philippines

Alongside well-documented natural events over the last few decades, the inherently multi-hazardous environment of the Philippines provides an opportunity to characterise these events in the country over temporal and spatial scales beyond those previously considered.

Co-developing our understanding of multi-hazard events in the Philippines, BGS and in-country partners used the eruption of Pinatubo (1991) and the Mindanao earthquake (2019) as case studies. Using GeoVisionary software, our partners were able to create an illustrative 3D simulation of the potential effects of a large earthquake striking the Philippine capital, Manila. This simulation is now helping to guide conversations with policymakers about appropriate actions in the event of a large-scale seismic event.

BGS was also able to incorporate building vulnerability into risk assessments for the country, using a multi-hazard risk-modelling toolbox. BGS trained partners in the use of this software through a capacity-building visit.

By working with our colleagues in-country, we have increased understanding of the effect of multi-hazards on populations in the highest-risk country in the world. This increased knowledge will inform science advice given to the Philippine and UK governments and help to identify appropriate risk-reduction strategies.

PARTNERS

- Mines and Geosciences Bureau, Philippines
- Philippine Institute of Volcanology and Seismology

Earthquake hazard from the Jakarta Fault

The Jakarta Fault is a relatively newly recognised, major tectonic fault on the island of Java in Indonesia. The fault runs beneath the southern part of Jakarta, the capital city, which is one of the largest cities in the world: the population of the metropolitan area exceeds 30 million. A major earthquake on this fault would expose a large number of people and significant economic infrastructure to strong ground shaking.

Project staff collaborated to develop an improved understanding of the seismic hazard from the Jakarta Fault. This involved careful analysis of ground-based global navigation satellite system (GNSS) measurements alongside computational modelling to understand how much energy is being stored on the fault each year. The stored energy will eventually be released as an earthquake and this analysis gives us a sense of the potential size of such an event.

In July 2024, the official new earthquake source faults data for Indonesia was released. This dataset will be the fundamental input to a new update to Indonesia's national seismic hazard map, due for release in 2026. The new map will be used to set engineering design standards to ensure the safety of people and infrastructure in future earthquakes in Indonesia. This work is part of strategic UK/Indonesia partnerships on geohazard solutions, as detailed in a 2025 White Paper.

PARTNERS

- Geospatial Information Agency of Indonesia (Badan Informasi Geospasial)
- Institut Teknologi Bandung, Indonesia
- Research Center for Geological Disaster, National Research and Innovation Agency, Indonesia
- Resilience Development Initiative, Indonesia

Courtesy of Edo Marshal

THEME THREE

Resource and security

Global concerns are growing over the long-term availability of secure and adequate supplies of the minerals and metals essential for an equitable society.

Of particular concern are ‘critical’ raw materials, so called because of their growing economic importance and high supply risk. However, as raw material consumption rates grow, we will continue to need to extract minerals and metals from the Earth.

Geology helps to secure sustainable supply chains through monitoring and modelling access to geological materials and associated processes essential to modern life. BGS studies critical raw materials and vulnerability to supply disruption by monitoring global mineral production and trade, mapping supply chains and analysing markets. We are also working to establish countries’ raw material resources and their sustainable extraction, meeting society’s requirements for geological materials and championing a ‘circular systems’ approach.

THEME THREE

Case studies

Sand and sustainability in South-east Asia

Sand is one of the most heavily extracted raw materials on Earth, with global consumption estimated at 40 to 50 billion tonnes annually. This figure is set to rise with a growing population and associated factors. However, without appropriate resource governance, demand could lead to significant environmental, social and economic impacts. BGS is working to address this with geoscience-led solutions.

In Vietnam, BGS and partners developed a novel methodology to quantify construction material use by analysing land-cover change and urban expansion at city scale for Hanoi. This enables accurate estimation of material stocks embedded in buildings, essential for material flow analysis and circular economy policy design.

Building on this, we worked in Malaysia to extend the methodology spatially and temporally, producing scalable assessments of sand consumption across the country. This work integrates Earth observation data, building footprint analysis and material intensity to generate high-resolution insights into construction material demand.

We are only beginning to grasp the true extent of our reliance on sand. In many regions, the ease of access, lack of regulation and assumption of abundance have led to widespread overexploitation. Tools developed by BGS can help increase transparency around sand supply, reduce consumption through alternatives and recycling, and support informed decision making for resource governance, environmental protection and urban resilience.

PARTNERS

- General Department of Geology and Minerals of Vietnam
- Jabatan Mineral dan Geosains, Malaysia

Monitoring mine waste in the Philippines

Mining is a cornerstone of the economy of the Philippines, totalling US$3.69 billion in exports and representing 6.5 per cent of the country's gross domestic product (GDP) growth, according to a 2015 World Bank report.

Mineral waste in the form of mine tailings presents major contamination and pollution issues, and the potential

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for catastrophic dam collapses. Natural hazards, which are common in the Philippines, increase the risk factor for these mine waste deposits. Additionally, tailings often contain considerable quantities of unrecovered metals that could help meet global demand for resources. BGS is investigating issues around this waste, which could provide a significant economic benefit to the economy of the Philippines.

Geophysical monitoring is being used to hydrologically model mine-waste facilities, improving our understanding of risk in order to help prevent catastrophic failure. By developing hydrological models of moisture movement within in situ mine tailings deposits, we have enhanced our understanding of potential failure triggers at site scale. We aim to integrate these results with satellite observations, which will improve risk identification at a regional scale.

BGS monitoring has also been instrumental in advancing methods for extracting metal resources from historic mine-waste facilities using environmentally benign solvents. The technology is now ready to scale up towards economically viable extraction, with the potential to increase the availability of globally important metals and deliver further economic benefits to the Philippine economy.

PARTNERS

- Mines and Geosciences Bureau, Philippines
- Philex Mining Corporation, Philippines
- Philippine Nuclear Research Institute, Philippines
- University of Exeter, UK
- University of Leicester, UK
- University of Reading, UK
- University of the Philippines, Philippines

Groundwater in northern India and Pakistan

Groundwater in north-west India has been overexploited since the large-scale development of groundwater-based irrigation, leading to serious depletion. BGS has collaborated closely with the Indian National Institute of Hydrology (NIH) for the past fifteen years to better understand the risks to groundwater in the region. We have co-developed regional hydrogeology and groundwater-quality maps and investigated the sources of groundwater recharge using isotopes and statistical techniques.

Following large-scale flooding during the monsoon of 2023, we examined the roles of flooding in the plains, and the Himalayas as a source of groundwater recharge. We found that flooding led to short-term increases in groundwater levels in Punjab, but that long-term trends in groundwater levels did not change as a result. We also examined the hydrological and hydrometeorological characteristics of the floods and found that an accumulation of soil moisture led to severe flooding. Dams played a crucial role in preventing these floods, but also reduced the potential for groundwater recharge.

We are currently examining the effectiveness of artificial recharge of deep and shallow aquifers in Punjab as a management strategy for increasing groundwater levels in the state.

BGS's long-term collaboration with NIH has improved the understanding of groundwater resources and recharge, underpinning management strategies and policy efforts to reduce groundwater depletion in the state.

PARTNERS

- Indian National Institute of Hydrology Roorkee, India

THEME FOUR

Urban resilience

Geoscience has an important but often underappreciated part to play in developing and securing sustainable, resilient global cities that will keep communities safe.

Although urban areas only account for around 3 per cent of the Earth's land surface, they:

- are home to 55 per cent of the world's population
- generate about 80 per cent of global gross GDP
- produce over 70 per cent of global carbon emissions

BGS works to improve city resilience by integrating geology into urban subsurface planning and urban catchment science. This includes understanding the subsurface through interpretation of data using state-of-the-art geological models. We also address city-specific issues such as the roles of groundwater, subsidence, building material life cycles and engineering hazards. Anthropogenic pressures and climate change-related stressors are also considered.

THEME FOUR

Case studies

Subsidence in urban areas

Worldwide, coastal lowland cities are experiencing rapid population growth, which has been driven by economic opportunities, migration and urbanisation. This growth intensifies climate-related and environmental risks such as sea level rise, creating a critical and complex challenge for urban development, particularly in Asia and Africa. A growing city adds pressure to its environment, which can lead to subsidence.

BGS is working at the cutting edge of the application of artificial intelligence and machine learning to Earth observation data. We are developing tools that automatically characterise and interpret measurements of ground motion from subsidence detected by satellites. Our research is enabling the identification and understanding of signals hidden within vast quantities of Earth observation data.

Using these new tools, we have identified ground loading as a major contributor to subsidence in Hanoi, Vietnam. In Kuala Lumpur, Malaysia, we recognised that subsidence is occurring as the city expands into rural areas.

We have also produced the first harmonised and calibrated interferometric synthetic aperture radar (InSAR) map for the entire island of Java in Indonesia. The map has been used to identify that one in ten residents of Java's coastal cities could be living below sea level within a century, due to the combined effects of land subsidence and climate change.

Ultimately, we now have a better understanding of the combined effects and potential impacts of ground motion hazards and climate change, enabling better decisions to be made when managing urban growth.

PARTNERS

- Center for Information, Archives and Museum of Geology, Vietnam
- Geospatial Information Agency of Indonesia (Badan Informasi Geospasial)
- Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Indonesia
- Jabatan Mineral dan Geosains, Malaysia

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- Research Center for Geological Disaster, National Research and Innovation Agency, Indonesia
- Resilience Development Initiative, Indonesia
- Vietnam Geological Department

Studying water pollution in southern India

Protecting water resources by identifying pollutants is essential to safeguarding both human health and the natural environment. In Bengaluru, India, we studied local water quality including that of rivers, lakes, groundwater and tap water, which is imported from the Cauvery Basin. Our research demonstrated the urgent need for collaborative thinking to improve water quality in the southern Indian state capital.

A study on the presence of contaminants in water in India provided the first combined assessment of emerging organic contaminants and antimicrobial resistance indicators from multiple water sources in Bengaluru. The study found 125 organic chemical pollutants in the city's water, including medicines, pesticides and industrial compounds. Some surface waters had very high contamination levels and three substances were found at concentrations that could promote antibiotic resistance. The study helped identify key contamination sources and showed how simple protection measures, like preventing sewage inflow to lakes, can significantly improve overall water quality. It lays the groundwork for better water protection in cities like Bengaluru.

By showing how pollution links to antibiotic resistance and how simple restoration efforts can make a big difference to the whole water system, our work helps guide future monitoring and policy. The scoping methods we used can be applied in other urban areas to identify relevant contaminants and safeguard water quality and public health.

PARTNERS

- Ashoka Trust for Research in Ecology and the Environment, India
- Indian Institute of Sciences, India
- UK Centre for Ecology and Hydrology, UK

Philippine Hydrological Model

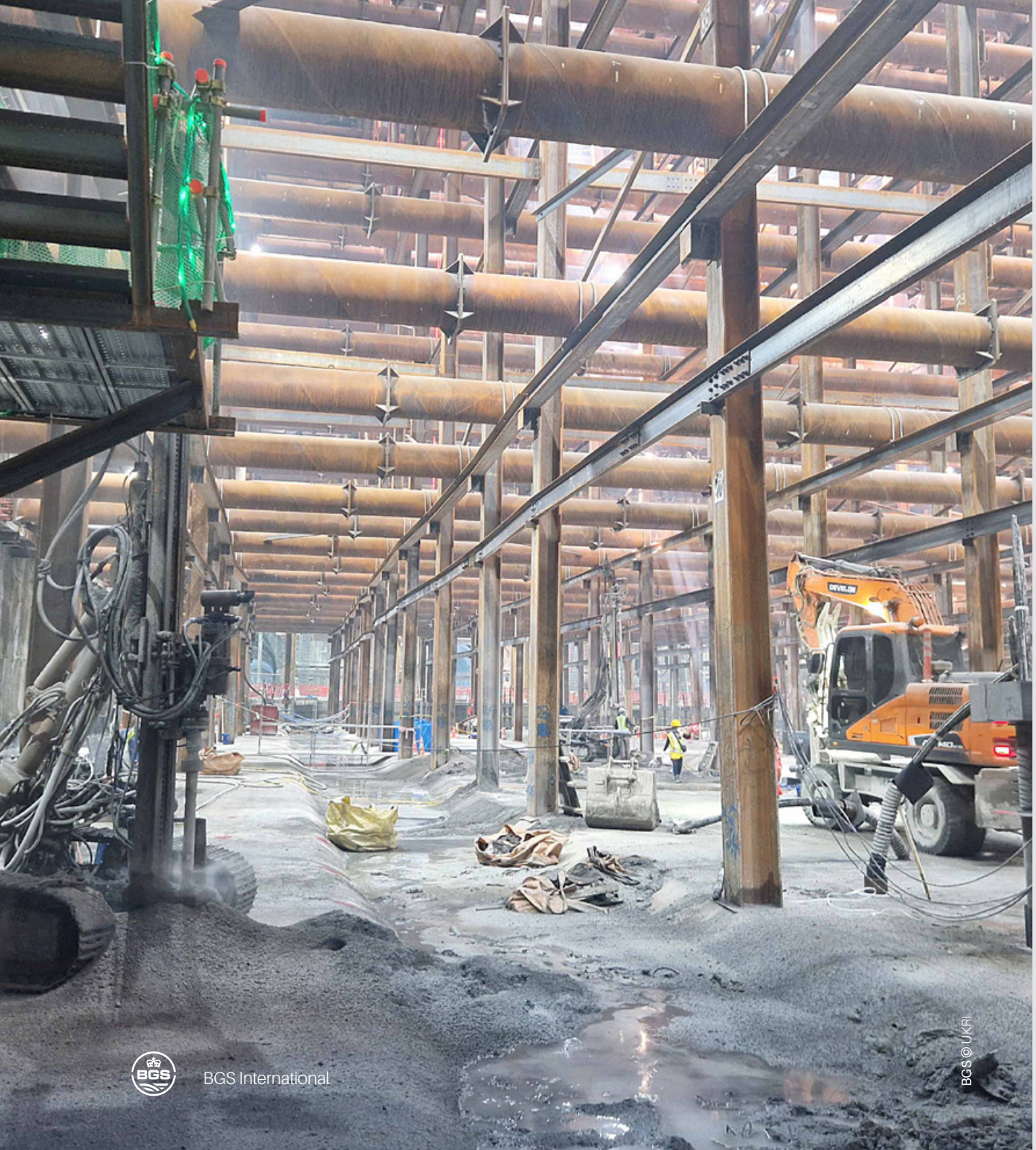
The Philippines is highly exposed to hydrological hazards such as floods, droughts, storm surges and landslides due to its tropical climate and frequent typhoons. Climate change and rapid urban population growth are also intensifying these hazards and increasing the country's overall vulnerability. Researchers, practitioners and decision makers need to collaborate using the best available data, tools and models to discover how best to adapt to these changes.

Working with colleagues in the Philippines, we have developed the Philippine Hydrological Model (PHM), which is the first national-scale hydrological model of the country. It simulates how rainfall drives flows in rivers, the storage of groundwater in the subsurface and changes in soil moisture and evaporation, and provides a tool to quantify the country's water resources and characterise its hydrological extremes. It has also been used to assess the effect climate change will have on water resources. All of the outputs of the historical and climate change modelling are publicly available through an online GIS application.

We have also developed the Philippine Hydro Hub through continued collaboration with partners in the country. This aims to make the PHM and other tools, data and information available through the web. Its vision is of a vibrant network of people, supported by shared resources, working together to protect, conserve and sustain the water resources of the Philippines for future generations, and to safeguard communities and the environment from water-related hazards.

PARTNERS

- Ateneo de Manila University, Philippines
- Mines and Geosciences Bureau, Philippines
- University of Philippines Diliman



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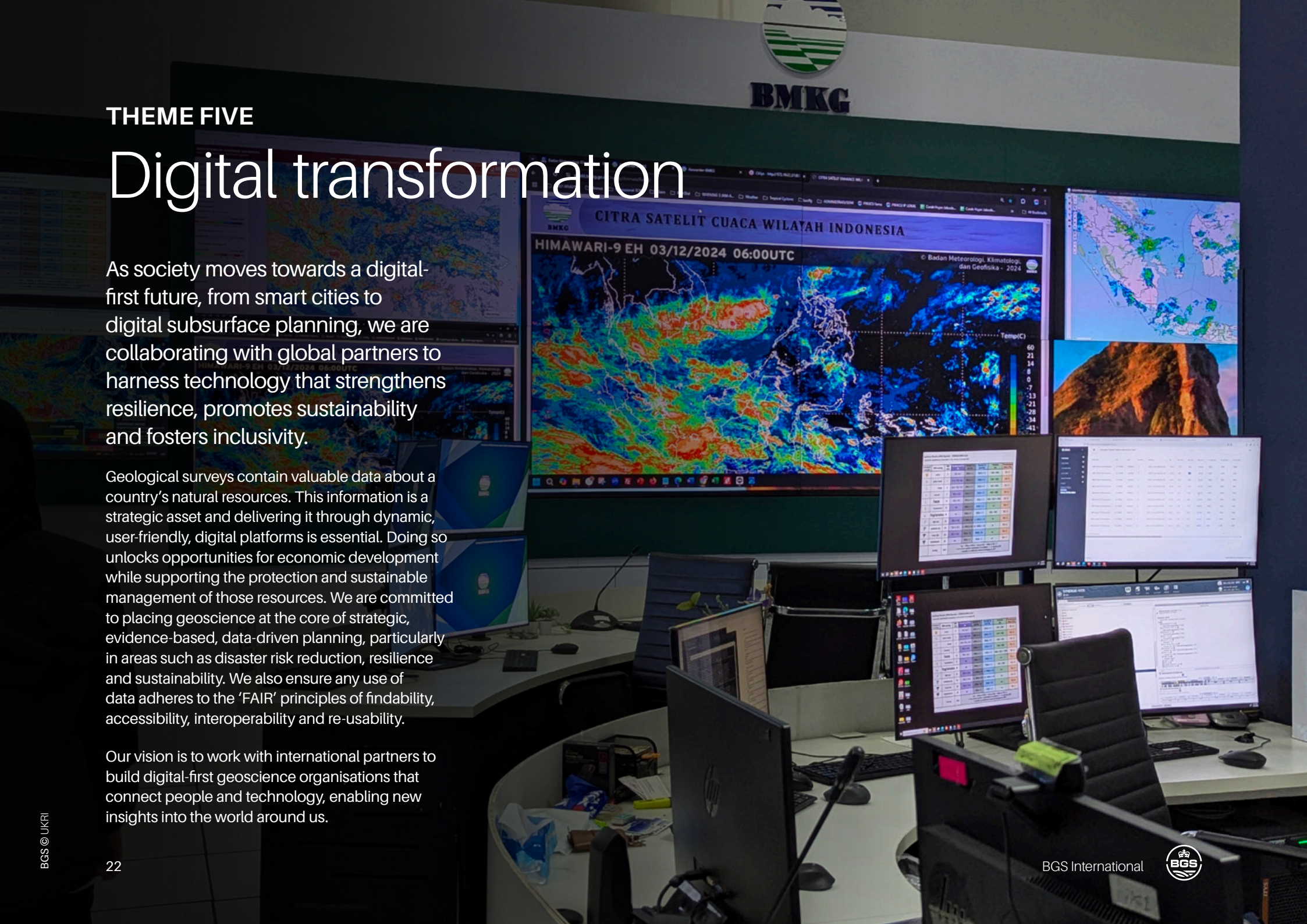
THEME FIVE

Digital transformation



As society moves towards a digital-first future, from smart cities to digital subsurface planning, we are collaborating with global partners to harness technology that strengthens resilience, promotes sustainability and fosters inclusivity.

Geological surveys contain valuable data about a country's natural resources. This information is a strategic asset and delivering it through dynamic, user-friendly, digital platforms is essential. Doing so unlocks opportunities for economic development while supporting the protection and sustainable management of those resources. We are committed to placing geoscience at the core of strategic, evidence-based, data-driven planning, particularly in areas such as disaster risk reduction, resilience and sustainability. We also ensure any use of data adheres to the 'FAIR' principles of findability, accessibility, interoperability and re-usability.

Our vision is to work with international partners to build digital-first geoscience organisations that connect people and technology, enabling new insights into the world around us.

THEME FIVE

Case studies

UKROK: urban modelling in Korea

Geoscience is fundamental to building sustainable, resilient cities by improving our understanding of surface and subsurface conditions and the natural processes that influence them. For effective urban planning, it is vital to raise awareness of subsurface risks and opportunities among broad decision-making circles, including legislators and local authorities.

Three-dimensional geological models are powerful tools for communicating the complexities of the hidden subsurface to stakeholders in government and industry. These state-of-the-art models enhance understanding and provide a framework for integrating geological data into building information models (BIM) and city information models (CIM), supporting better infrastructure development and utility asset management.

BGS and the Korea Institute of Geoscience and Mineral Resources (KIGAM) are applying complementary modelling approaches to improve productivity, accuracy and uncertainty estimation in 3D geological models. Through the UKROK–GeoModX project, both organisations are testing these methods in varied geological settings to identify optimal strategies and workflows that maximise the impact of 3D modelling in urban geoscience.

Ongoing research exchange visits between the UK and the Republic of Korea support this collaboration. The first BGS visit included fieldwork in Seoul to review geology and geomorphology, informing later discussions and analysis for a 3D geological model of the city.

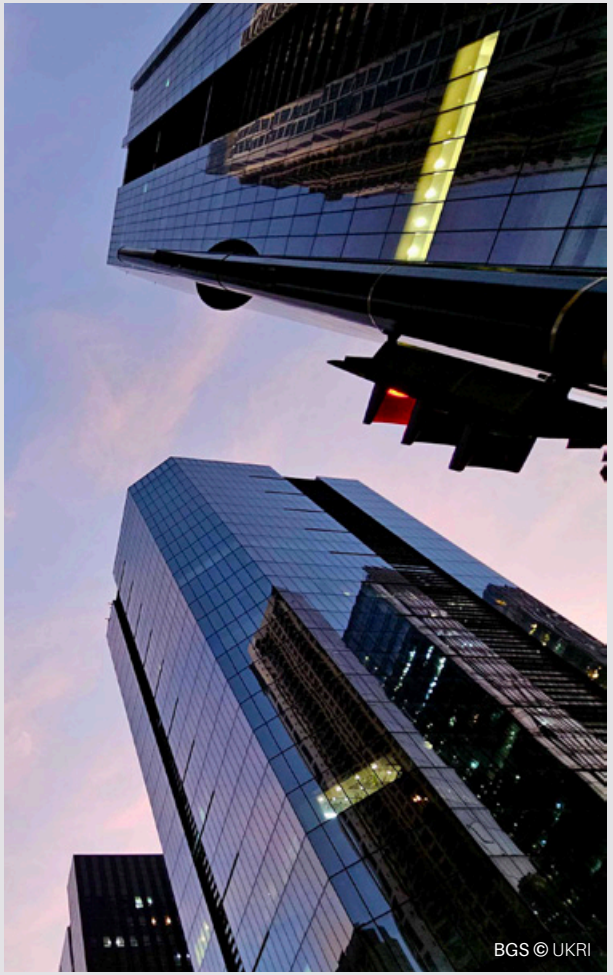
Key collaboration priorities identified include:

- urban subsidence modelling using 3D geological and geomechanical models integrated with InSAR data
- quantifying uncertainty, multi-scale modelling and exploring artificial intelligence applications in 3D modelling
- applied 3D modelling for the energy transition, including CCUS, geothermal energy and energy storage

Together, we are building a shared understanding of the most effective methods of subsurface planning for different geological contexts, with the aim of sharing insights across the wider geological and geotechnical communities.

PARTNERS

- Korea Institute of Geoscience and Mineral Resources



3DKL: the first 3D geological model of Kuala Lumpur

The geology of Kuala Lumpur, Malaysia, is highly intricate. It is also structurally complex and deeply weathered, presenting numerous shallow geohazards such as landslides, buried karst and compressible soils. These conditions make construction highly challenging, often leading to failures and significant time and cost overruns. A comprehensive understanding of the geology of Kuala Lumpur, especially at depth, is therefore critical for its future development.

BGS collaborated with local partners in academia, government and industry to develop a low-cost workflow to deliver the first 3D geological model of the city.

By combining deterministic cross-section interpretation with implicit modelling, the team overcame significant data gaps using expert geological knowledge. This approach offers a cost-effective solution for constructing informative 3D models where subsurface data is limited, particularly benefiting cities in the Global South.

The workflow not only demonstrated proof-of-concept but also highlighted areas where geological knowledge needs improvement. These areas are now being addressed through the Greater KL Subsurface Mapping Project, which is aiming to develop a 3D geological model for the Greater Kuala Lumpur area.

We continue to collaborate with in-country partners on our shared goals of improving the understanding of the geology of Kuala Lumpur, creating a more sustainable and resilient city.

PARTNERS

- Jabatan Mineral dan Geosains, Malaysia
- Kuala Lumpur City Hall, Malaysia
- Mass Rapid Transit Corporation, Malaysia
- Public Works Department, Malaysia
- Universiti Kebangsaan Malaysia
- Universiti Malaya
- Universiti Tenaga Nasional, Malaysia

Digital transformation in Central Asia

Central Asian countries have legacy Soviet extractive sectors and their geological surveys hold huge amounts of data crucial to unlocking, as well as de-risking, geological opportunities. Many of these data sources are still in analogue format or have been digitised in a fragmented manner, resulting in a lack of data interoperability. A lack of online delivery platforms also means the data is inaccessible to stakeholders.

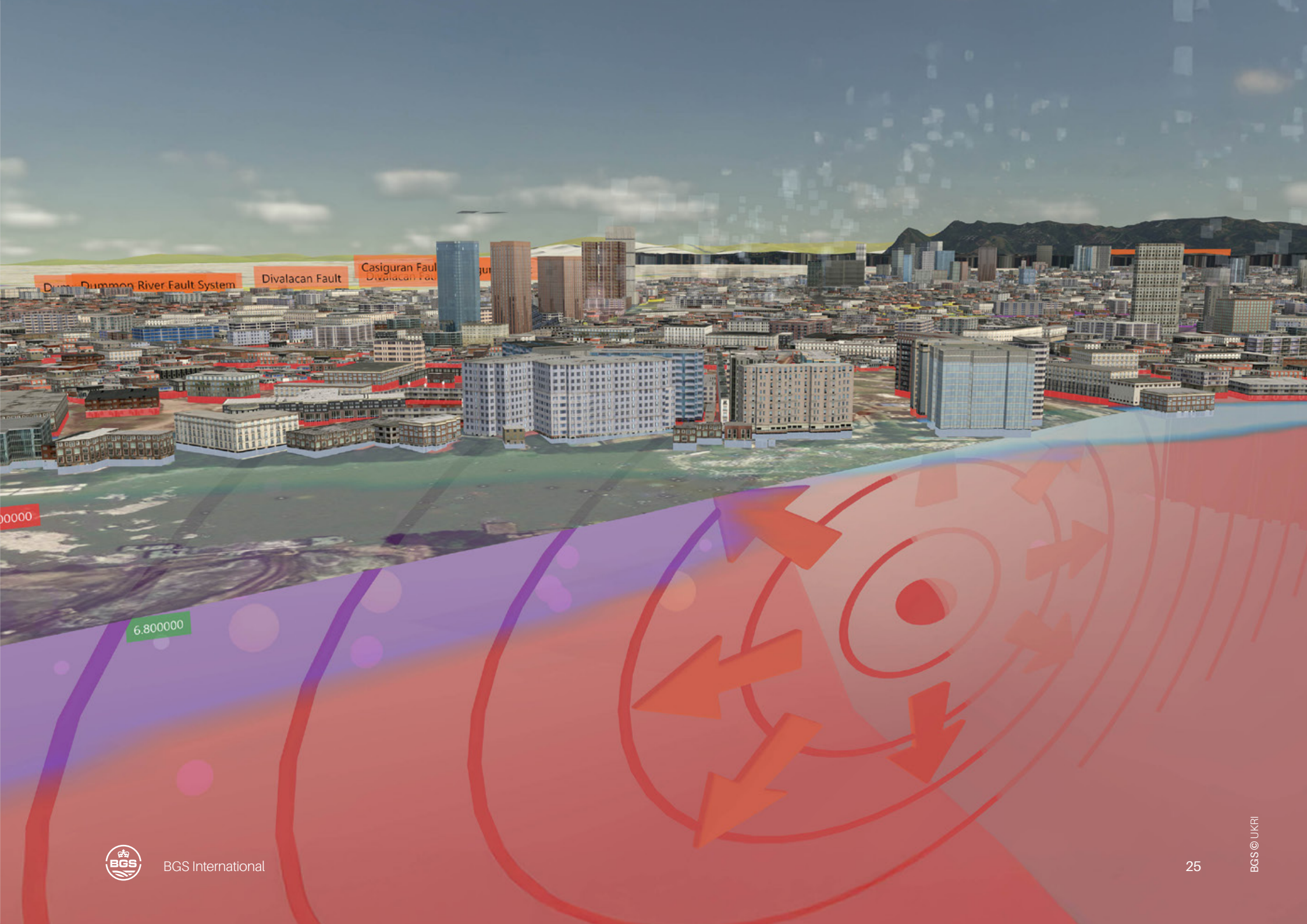
Since 2017, BGS has worked with the geological survey organisations of Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan to strengthen their ability to support the clean energy transition, through provision of their own digital geological data. Our work has assisted these institutions in acquiring, managing, analysing and disseminating digital geological data, as well as strengthened the geological skills essential for improved management of critical minerals.

Sustainability of our work in Central Asia is a core aim. By co-designing digital systems with our partners and facilitating knowledge exchange, advice and support, we have empowered them to drive their own digital transformation agendas. This ensures that the knowledge is held within the geological surveys' digital solutions to access and disseminate, and are sustainable in the long term.

A key topic throughout our collaborations has been empowering geological organisations to best utilise their data. Through our work, we aim to enable them to deliver their own data to their own stakeholders.

PARTNERS

- Kyrgyz Geological Service and Kyrgyz Geologica, Kyrgyzstan
- National Geological Survey of Kazakhstan
- The Main Department of Geology of the government of Tajikistan
- The Ministry of Mining, Industry and Geology of the government of Uzbekistan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Enhancing urban sustainability and resilience: a synoptic view of BGS work in Hanoi

By combining digital geological tools, Earth observation and interdisciplinary research, BGS is helping cities like Hanoi in Vietnam build resilience to environmental hazards, resource scarcity and infrastructure stress.

This model of smart, science-driven planning is vital for sustainable urban futures across Asia.

Our work in Hanoi demonstrates the pivotal role geology can play in supporting sustainable urban development. These efforts span urban geology, resource management, groundwater protection and hazard mitigation, demonstrating how integrated geological knowledge can inform resilient city planning.

One of the foundational elements of this work has been the development and application of digital geological tools, including 3D urban geological models and sensor technologies. These tools enable planners to visualise subsurface conditions, assess geological risks and optimise infrastructure design.

The concept of 'smart geology' has been central to this approach. We have shown how Earth observation and geospatial analysis can quantify the consumption of raw materials by mapping building stock and its evolution over time. This has revealed the spatial and temporal distribution of construction materials, highlighting the urgent need for strategic planning to secure sustainable access to resources. With Hanoi's urban population projected to rise significantly by 2030, demand for sand, gravel, crushed rock, cement, steel and bricks is expected to surge, posing risks of shortages and price volatility.

To address these challenges, BGS developed an innovative methodology to quantify stocks of material for the built infrastructure of Hanoi, providing insights into the city's resource demands and supply chains. This work underscores the importance of integrating geological data into urban planning to ensure long-term resource security and reduce environmental impacts.

Groundwater protection has been another critical focus. Rapid urbanisation in Hanoi has led to increased groundwater abstraction and heightened contamination risks. BGS studies have analysed aquifer characteristics, recharge mechanisms and pollution sources, revealing that leakage from water supplies and sanitation infrastructure contributes significantly to urban infiltration.

In parallel, BGS has applied InSAR techniques to monitor land subsidence across Hanoi. Between 2015 and 2021, subsidence rates of up to 15 cm/year were recorded, particularly in newly developed areas. These findings linked subsidence patterns to both groundwater pumping and construction activity. While buildings on deep pile foundations remain stable,

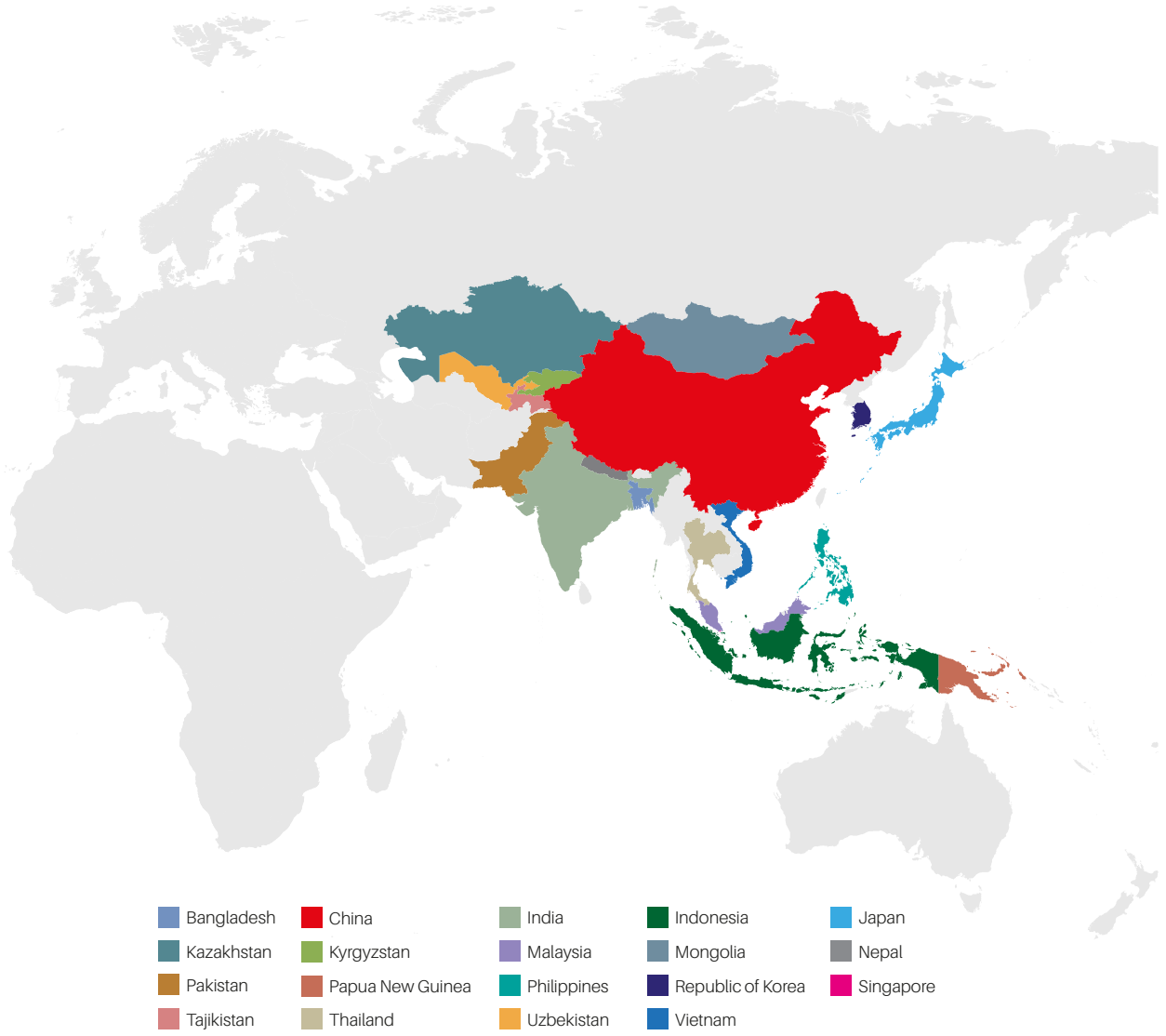
surrounding ground movement poses risks to buried utilities and surface infrastructure. This data is vital for hazard mitigation and informs development strategies tailored to Hanoi's deltaic geology.

The success of BGS's work in Hanoi is rooted in its interdisciplinary approach and longstanding partnerships with Vietnamese institutions. Training courses, collaborative research and knowledge exchange have fostered capacity building and ensured that scientific insights translate into practical urban planning solutions.

Together, these initiatives illustrate how BGS envisions its role in enhancing urban sustainability and resilience, not only in Hanoi but across other rapidly urbanising regions in Asia. By integrating geological science with digital innovation, resource management and policy development, BGS provides a model for how geoscience can support cities in navigating the complex challenges of growth, infrastructure and environmental stewardship.

PARTNERS

- Center for Information, Archives and Museum of Geology, Vietnam Geological Department, Vietnam
- General Department of Geology and Minerals of Vietnam
- Ministry of Natural Resources and Environment, Vietnam
- Territoire, Environnement, Télédétection et Information Spatiale, France
- Vietnam Space Agency



British Geological Survey

Contact us

E enquiries@bgs.ac.uk
T +44 (0)115 936 3100

bgs.ac.uk