



British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

BGS Global Geoscience 2014–15



Including:

- Environmental chemistry in Africa
- Volcanology in the East African Rift
- Studies on the Oman-UAE ophiolite
- Underground in Singapore
- Liberia – before Ebola
- Quaternary mapping in South Korea
- European projects
- India – the Gangetic basin

International work by the British Geological Survey

BGS Global Geoscience



Martin Smith,
Science Director,
BGS Global Geoscience

2014 has witnessed growth and investment in BGS applied and integrated research overseas, with continuation of ongoing programmes and exciting new starts in a number of countries. To aid in this development I am delighted to announce that BGS Global has been joined by Kathryn Goodenough as my deputy and by Jenny Forster who will co-ordinate overseas projects through business development.



Kathryn Goodenough,
Deputy, BGS Global
Geoscience

The global drivers of energy and resource assessment, environmental concerns and urbanisation continue to inform and direct our activities. In particular, a growing realisation of the importance of responsible management of geoscience data to underpin governance and the use of underground space has led to an upsurge in enquiries about BGS information and data storage systems, including core storage facilities, digital delivery of web services and smartphone applications. Whilst it is easy to purchase the necessary hardware and software, understanding how it can be made to work in an effective digital data workflow is a major challenge for many national geological surveys. The 'BGS way', built around decades of effort and investment, demonstrates what is possible and is a model for others to explore.



Jenny Forster,
BGS Global Business
Development

In Africa, one focus has been on environmental issues, in part supported by a Royal

Society grant linking human health to agriculture, water resources and contamination from past mining activities. A new and exciting prospect in helping to rebuild the Geological Survey of Liberia was unfortunately curtailed mid-year by the ongoing Ebola crisis, although similar DFID-funded opportunities are beginning to open up in Africa. In East Africa, success with a new NERC consortium grant will ensure continued effort into volcanic research and risk mitigation in Ethiopia.

In SE Asia, work on urban geology and development of database systems led to delivery of 3D models of Singapore's geology. Through training programmes and discussion with partners, new projects are developing in Indonesia and Brunei Darussalam.

BGS has had a long and fruitful partnership with KIGAM in South Korea. After signing an MOU, technical collaboration and joint training are now ongoing across a number of disciplines including CCS, marine hazards, Quaternary research and digital mapping systems.

India is a new and exciting area with ongoing DFID-funded projects on water balance, and developing projects on resilience of ancient cities in the Gangetic Basin, the world's largest foreland basin.

In the Middle East, the closure of the UAE project was marked with the publication

of a major volume on the Geological History of the region. As a result of 10 years of collaboration the UAE now joins the league of countries with a fully digital national geological dataset and is exploring delivery via web services and apps. In Oman, fieldwork and research into the world's largest ophiolite complex has started to reveal new insights into subduction related processes.

As a number of EU-funded projects came to a close in 2014 included herein is a brief summary of three projects that highlight the breadth of BGS work and the importance of integration and collaboration with our European partners.

Finally, on 1st February 2015 the BGS spin-out company International Geoscience Services Ltd. ceased trading as BGS International (BGSi) and is now known as IGS. The company continues to perform well, focused primarily on collection, compilation, value adding, interpretation and serving of geodata to support mineral exploration.

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Urban groundwater quality in sub-Saharan Africa

Dan Lapworth led a team from the University of Zambia, Surrey University and CEH working on a project to understand the processes that lead to groundwater contamination in growing urban towns in Africa, and the implications for health and livelihoods for the communities that rely on these resources for drinking water. The project is part of the UPGro Programme (see <http://www.nerc.ac.uk/research/funded/programmes/upgro/>), funded by NERC, ESRC and DfID. BGS has been involved in six UPGro projects carrying out groundwater studies across Africa.



Groundwater sampling in Kabwe.

In urban slums, the lack of water provision forces many to use shallow groundwater sources; this is likely to increase with human migration and changing climate regimes. Combined with deteriorating shallow groundwater quality, for example by bacterial contamination from pit latrines, this has serious implications for public health and livelihoods.

In Zambia, Kabwe (population 200 000), is a major transport hub on the highway between Lusaka, the capital, and Ndola the second largest city. The population are heavily dependent on groundwater for their water supply and in slum areas the use of shallow wells is common; on average only 1 in 10 people have adequate sanitation. With the collapse of the mining industry in Kabwe in the late 1970s, there has been a decline in the proportion of houses supplied with clean piped water. The current infrastructure can't

support the rising demand and so residents have turned to shallow, unprotected hand-dug wells to supplement household water use. This potentially increases exposure to the legacy contamination of soils and wind-blown dust from mine waste, including heavy metals. At present the long term risk of groundwater contamination is poorly understood. This worrying trend is commonly seen across Africa.

BGS coordinated a groundwater quality survey in Kabwe during 2013–14 to evaluate the spatial and temporal trends in chemical and bacterial groundwater quality. This revealed that shallow household supplies (no deeper than 10m below ground) were highly contaminated throughout the year with faecal bacteria and nitrate and had elevated concentrations of DEET, a commonly used insect repellent. The level of contamination was

significantly higher in the wet season compared to the dry season, and also higher in low income areas compared to some higher income areas. Deeper groundwater sources (>50m below ground) were generally free from faecal bacteria, however there were some deeper sources in low income areas that showed elevated nitrate. Dissolved and particulate concentrations of heavy metals in groundwater were generally low, although some sources very close to mine waste dumps showed elevated dissolved lead concentrations (> 8 µg/L). Shallow wells therefore pose an ongoing risk to users and deep sources need to be

protected in the long-term. The low cost of shallow well water is attractive, despite the potential risks, and improving well protection is simply not affordable.

As part of the work a field sensor designed to measure a protein called 'tryptophan', which is an indicator of wastewater contamination, was tested to see if it was able to predict the presence, absence and level of faecal bacteria in groundwater. Exciting new findings from this study indicate that the sensor will be a useful tool with wide application for mapping groundwater contamination by faecal bacteria.

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Soil geochemistry, agriculture and public health in southern Africa

A network grant from the Royal Society and DFID is helping to develop a regional soil science consortium in south-east Africa.

This network aims to improve soil science capacity and strengthen the excellent regional academic capability through access to current technologies in lab analyses, data representation and geostatistics. Led by Michael Watts with partners at the University of Nottingham (UoN) through the joint Centre for Environmental Geochemistry (CEG), this is being facilitated via research links with consortium partners in Malawi, Zambia and Zimbabwe, including the national Ministries of Agriculture, the Ministry of Health in Malawi, Lilongwe University of Agriculture Natural Resources, the University of Zimbabwe, the University of Zambia and Copperbelt University.

Building on our previous work on the biofortification of staple crops with essential

micronutrients to target key health issues, the research is expanding into best practice for agricultural techniques to improve the fertility and micronutrient content of soil for food production/quality. Whilst the consortium is developing opportunities for African PhD students or staff in African institutions, there are opportunities for UK students to learn environmental science in tropical environments and to develop their wider understanding of environmental geochemistry. Two-way exchange of students, technicians and research staff will build future collaborative partnerships to the benefit of UK and African science capacity.

Deficiencies of minerals including calcium, iodine, iron, selenium and zinc are a major



Soil and crop sampling for mineral composition analyses in Malawi.

global public health issue. In many African countries the prevalence of dietary mineral supply deficiencies at national and regional scales is not well understood. A UoN-BGS CEG sponsored PhD student is now focused on generating improved estimates of dietary mineral supplies and deficiencies at scales useful to policy makers, and investigating agricultural methods to address the deficiencies. This research is expected to have an impact on development of public health policies.

Agricultural soil amendment approaches such as liming or organic reincorporation improve the mobility or soil retention of minerals such as selenium or iodine. Ongoing efforts in Zambia will explore the potential inadvertent impact of such soil amendments on the mobility of metals present in agricultural soils in close proximity to mine tailings and the subsequent factors influencing soil-to-

plant transfer. Mine spoil sites have been selected by the Copperbelt University, with one local PhD studying the soil-plant transfer of a range of metals and one BGS staff member undertaking a part-time PhD to study the specific mechanisms of chromium equilibria in soils over a range of properties and conditions, and establish whether these mechanisms increase the likelihood of exposure to hexavalent chromium (CrVI). Copperbelt mining in Zambia has been shown to increase total elemental concentrations in both the environment and occupationally-exposed workers, although the specific pathways of exposure have yet to be determined; a more thorough understanding of chromium's soil chemistry could begin the process of addressing this problem.

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East African Rift Volcanism

Volcanism along the East African Rift (EAR) varies a great deal in terms of eruptive types and eruptive products as well as the magnitudes of different eruptions and their frequency of occurrence. Unfortunately, there are limited geological and geochronological data available on which to characterise and define the potential volcanic hazards at any given location based on past events. The Volcanology Team are working with partners throughout the EAR to improve understanding of volcanic hazards at different locations and the processes that drive them. This understanding is essential in order to effectively mitigate the future consequences of such hazards.

Volcanic hazards and risk

Whilst analysis of past eruptions, monitoring of current volcanic unrest and eruptions, and characterisation of volcanic hazards and risk is being conducted in high-resolution in some countries, there are many areas which have little available data or resources to conduct such activities and assessments. These are some of the challenges faced in the EAR.

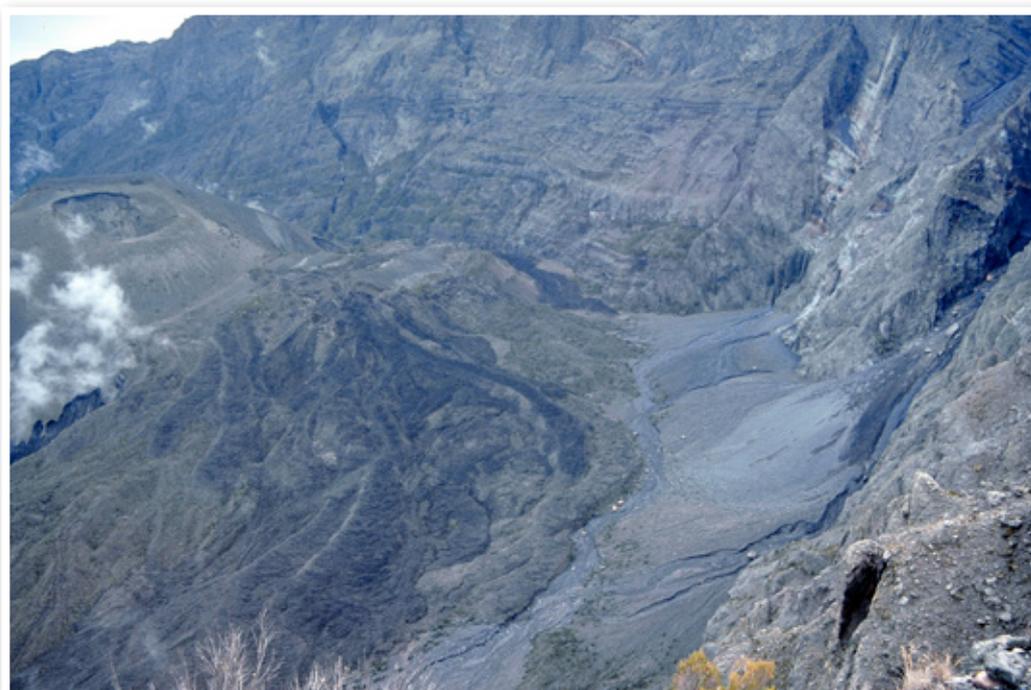
The Volcanology Team has recently finished coordinating an international collaborative effort to assess global volcanic hazard and risk for the next Global Assessment Report to be published by the United Nations International Strategy for Disaster Reduction (UNISDR) in March 2015 (GAR15). This involved more than 50 institutions worldwide and was a major activity of the Global Volcano Model network led by BGS and Bristol University.

The individual African country profiles for GAR15 demonstrate that volcanic hazards are not currently a high priority for authorities in this region. This is the result of the high fatalities and adverse impacts caused by conflict, famine and flood which have resulted in major humanitarian disasters.

The perception of volcanic risks as low priority is due in part to the fact that there have been no medium to large-scale volcanic eruptions in Africa in recent history and documented losses to eruptions have been relatively small. Global records show that most historical fatalities

have been caused by a few eruptions that took communities by surprise. Even small eruptions have had devastating consequences in terms of loss of life. Importantly, volcano monitoring and early warning systems, combined with improved knowledge of hazards and risk, have been shown to be effective means of mitigating losses during many eruptions over recent years. We will work with partners and the UN to encourage and monitor disaster risk reduction activities in the EAR and elsewhere.

Volcanic unrest and eruptions may pose several different hazards, from earthquakes and landslides to falling ash and lava flows.



Volcanic caldera, Mt Meru, Tanzania.

Eruptions are dynamic, with multiple potential hazards which may or may not have a negative impact depending upon exposure and vulnerabilities of people and critical systems. Hazards and risks can to some extent be anticipated, and planning can be developed to mitigate impacts (e.g. enteric disease as a result of displaced populations lacking suitable water supplies; famine as a result of persistent ash fall on crops). Volcanic eruptions may directly and indirectly affect different sectors including: human health, critical infrastructure, water and food security, environment and governance. Thus, a multi-disciplinary and multi-institutional approach to hazard and risk is

appropriate for the EAR as elsewhere.

New NERC large grant – rift volcanism: past, present, future

Some of the least studied and unmonitored volcanoes of the world are in the densely populated Main Ethiopian Rift. These are to be explored as part of the newly funded NERC research project, 'RiftVolc', to understand their past eruptions, current activity and the future threat they pose to the lives and livelihoods of people.

A multi-disciplinary team, including volcanologists from BGS, UK universities and partners at Addis Ababa University and the Geological Survey of Ethiopia, will work in

Ethiopia over the next five years collecting samples for analysis, characterising and mapping the extent of previous eruptions and deploying geophysical instruments. These data will be analysed to establish volcano eruption histories and current states of unrest, and to investigate likely future eruption scenarios. The team will work closely with partners in Ethiopia so results can be used by partners to communicate threats and to support planning for mitigation of the impact of future eruptions.

BGS investigator Charlotte Vye-Brown leads the work package investigating the potential threats from future volcanic activity, with a team of seven BGS researchers and colleagues from the

University of Edinburgh. This work package will:

1. develop probabilistic volcanic hazard assessments for key volcanic centres, and
2. develop a methodology for regional analysis of volcanic hazards.

The whole project consortium includes scientists from BGS and the universities of Edinburgh, Bristol, Cambridge, Leeds, Oxford and Southampton. It also involves Addis Ababa University, the Geological Survey of Ethiopia and Reykjavik Geothermal. The £3.7 million five year project is funded by the Natural Environment Research Council and began in September 2014.

Contact Charlotte Vye-Brown
Julia Crummy
Sue Loughlin



Cliff sections in ancient lava flows, Ethiopia.

The Oman–UAE ophiolite: developing big-picture science from commercial contracts

From 2002–2012, BGS was contracted by the government of the United Arab Emirates (UAE) to produce a country-wide geological map. This included detailed mapping of the northern end of the Oman–UAE ophiolite, the world's largest and best-exposed ophiolite (a slab of oceanic crust and upper mantle that has been thrust onto a continental margin). For many years, ophiolites had been considered to represent typical oceanic crust formed at mid-ocean ridges, but evidence has gradually been building to demonstrate that many ophiolites actually formed above subduction zones.

Our detailed mapping led the BGS team to recognise that the northern (UAE) end of the Oman–UAE ophiolite preserved a transition from crust formed at a spreading ridge, into later magmas with clear supra-subduction zone (SSZ) characteristics. When the mapping was combined with detailed geochemistry, carried out in collaboration with colleagues at Cardiff

University, we were able to show that the whole ophiolite sequence in the UAE formed in the hanging wall of a subduction zone as it formed and developed, possibly with greater amounts of subduction-related magmatism in the north rather than the south (Goodenough et al. 2014).

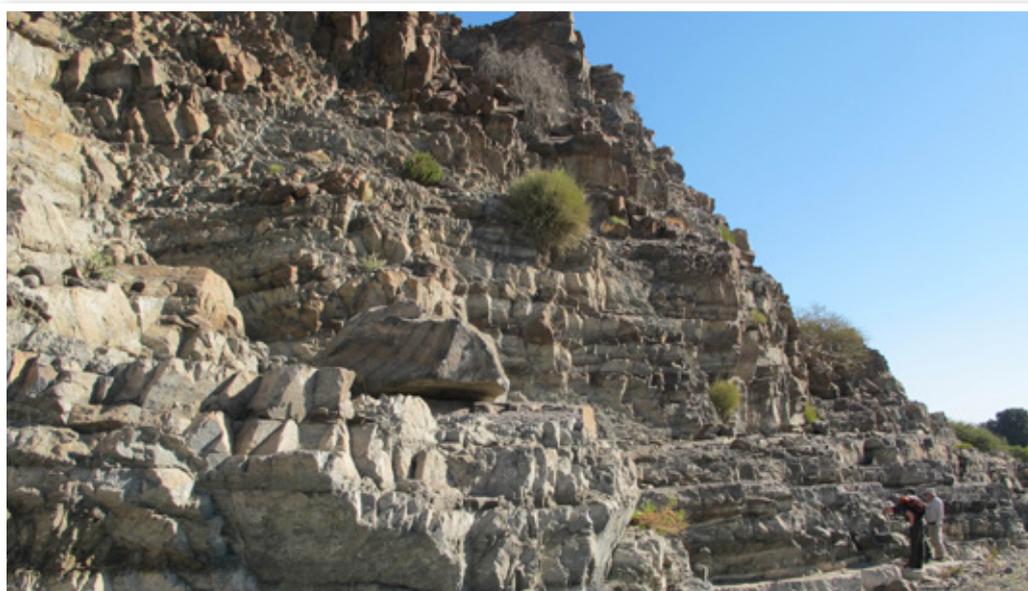
This new model for the ophiolite tallies with the ideas of a number of high-

profile researchers in the field, who have proposed that most of the world's ophiolites formed in fore-arcs above developing subduction zones. This means that ophiolites represent an ideal natural laboratory to study the processes operating above an infant subduction zone – and there is no better example than the mountains of Oman and the UAE.

The fore-arcs of modern subduction zones such as the Izu-Bonin-Mariana arc can largely only be studied by drilling and dredging the sea-bed, but this ophiolite provides a 500 km long, >10 km thick superbly exposed section through the oceanic crust and mantle, with cross-cutting igneous relationships providing an opportunity to investigate temporal as well as spatial changes.

BGS team Kathryn Goodenough, David Schofield and Mike Styles are collaborating with colleagues at the Universities of Cardiff and Plymouth to develop this new research theme in the Oman–UAE ophiolite. A BGS Global-funded visit to Oman in January 2014 showed that complex structural and igneous relationships, similar to those mapped in the UAE, can be investigated in Oman, and we are awaiting analytical data for samples from that trip. This ongoing research will have fundamental implications for our understanding of the processes operating above initiating subduction zones. Our work will also link to a newly-funded International Continental Drilling Programme (ICDP) initiative to drill and collect core from the ophiolite in Oman.

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Layered gabbro in the Oman ophiolite.

Cities of tomorrow – exploring the ground beneath Singapore

Singapore's population is expected to rise to around 7 million by 2030. Its land area is about 715 km² and its coastline has expanded rapidly in recent years as land has been reclaimed from the sea for industrial and civil development. Supporting sustainable urban development and population growth in land-scarce cities like Singapore requires a new way of thinking about planning – if surface space is in short supply, can the ground beneath a city be used just as well or even better? In what ways could it be used and what information would be needed to use it? Exploring the opportunities for using subterranean space in Singapore is now a priority.

The Singapore Ministry of National Development (MND), through the Geological Office of the Building and Construction Agency (BCA) is tasked with exploring how best to use land, above and below the surface. Singapore's ministries and agencies have suggested that land beneath the city could be used for multiple purposes including waste water processing, hydrocarbon storage, retail, research laboratories, groundwater abstraction, expressways and mass rapid transport systems. Singapore already has an urban master plan for land above ground, but how can its subterranean asset be considered in light of these proposed future uses of underground space? Choosing where and how to optimise the use of subterranean space will require careful examination of the properties of the ground, their suitability

and potential for conflict in underground space use.

BGS has been working in partnership with the Geological Office of BCA to start the process by considering the geology of Singapore in 3D. Building

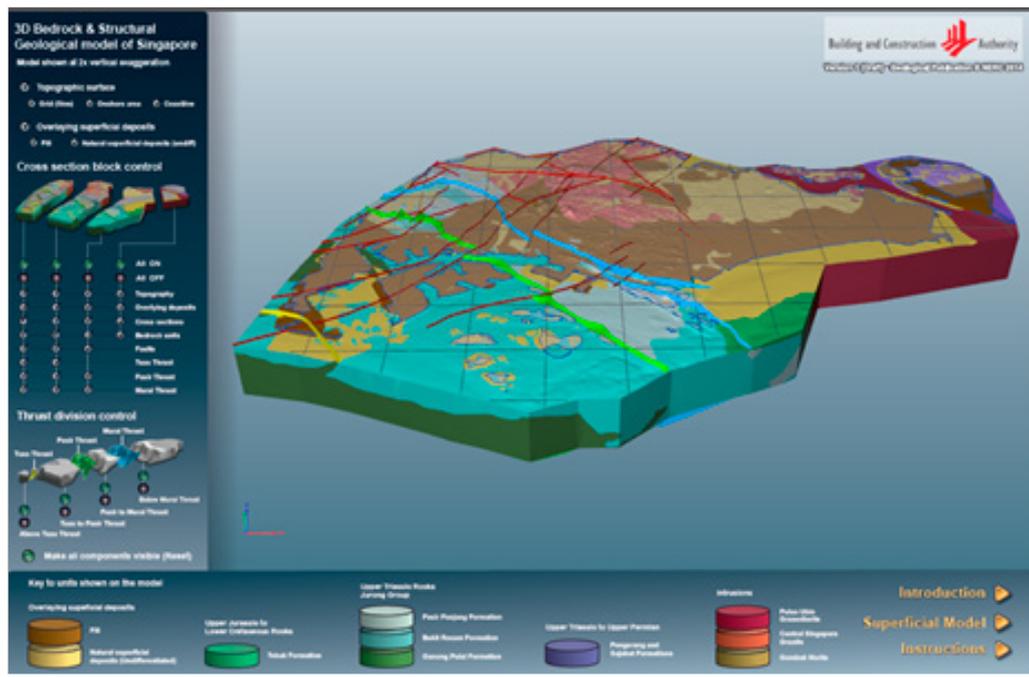
up a 3D picture of the geology of Singapore, from existing information, provides a baseline framework from which to assess the type of ground variability that's important for civil engineering and

management of water resources. A lack of surface exposure means a focus on boreholes and geophysical investigations and so compiling existing and current site investigation data has allowed BGS to produce the first 3D geological framework model of the island state.

Our work has taken account of the geological history of Singapore and surrounding regions, and the volcanic, tectonic, sedimentary and climatic processes that have shaped and sculpted the island over 250 million years of earth history to provide a preliminary, city-wide assessment of the distribution of bedrock and superficial deposits.

BGS has also provided knowledge exchange seminars and training courses in Singapore and





in support of focused ground investigation. This, combined with extensive new data and information from an ongoing programme of drilling and seismic surveys will enhance and refine the understanding of Singapore's geology. Ultimately, this will be applied to underpin subsurface planning, civil engineering and water resource management, providing the basis to support Singapore's long-term development and growth.

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A 3D visualisation of the geology of Singapore presented in a 3D PDF. Different colours represent different units of geological bedrock often separated by geological faults.

UK on topics including core-logging, seismic interpretation, principles of stratigraphy, information systems, radiometric rock dating and 3D geological

modelling. Integrating this knowledge with the preliminary 3D geological framework provides a basis from which to characterise geotechnical and

hydrogeological variability in the ground and its influence on subterranean space use. In 2015 BGS will continue its work in Singapore, by providing geological advice



Members of the BGS and BCA teams in Singapore.

Minerals assistance to the Liberian Geological Survey

Background

Prior to the 1989–2003 civil war that almost destroyed Liberia, mining accounted for 65% of this West African country's export earnings and 25% of its GDP. The mining industry's growth was brought to a stop by the war and was followed by the imposition of international sanctions on the trade of Liberia's diamonds, which remained effective until 2007. Today, Liberia is at a crossroads, moving from the post-conflict stabilisation phase into one of development.

Liberia has substantial mineral resources, which principally include iron ore, gold and diamonds. Other deposits which need further appraisal to determine their economic viability are: manganese, barite, bauxite, kyanite, uranium, phosphate, silica sand and heavy mineral beach sands among others. In addition there are known occurrences of tin, lead, copper,

molybdenum, silver, nickel, cobalt, niobium, tantalum, zinc and several more.

In terms of both modern geological interpretation and mineral resource appraisal, the country is virtually unexplored. A number of Government initiatives for economic transformation have been implemented. These include goals to promote

a sustainable, transparent, and well-managed exploitation of Liberia's mineral resources and an equitable distribution of the benefits among citizens. Liberia has already signed agreements that are poised to contribute more than \$10 billion of investment into the mining sector over the next few years. Well-managed investments in these areas have the potential to propel Liberia's growth and fund diversification and development in other areas of the economy.

The BGS contribution

Like many institutions in Liberia the Geological Survey (LGS), a department within the Ministry of Lands, Mines and Energy, was decimated by the recent civil war. It operates out of premises which were heavily looted and are semi-derelict. As

a result it does not have the capacity to undertake even the most basic of field survey work. Despite this, the LGS has the responsibility for compliance monitoring of companies conducting mineral exploration in Liberia; to conduct research to determine Liberia's mineral potential; to promote the exploration and development of the mineral resources of Liberia; and be the principal curator of national geoscientific data.

With funding provided by the UK Department for International Development (DFID), a team from the British Geological Survey (BGS) has, since December 2013, been establishing a technical capability at the LGS in order to allow it to better fulfil its national responsibilities. Work being undertaken includes:

1. Establishment of a Liberian Minerals Information



LGS office (December 2013).



LGS office (July 2014).



Martin Nice explaining the project during a visit by members of UK Parliament's International Development Committee (June 2014).

- System (LMIS) – comprising a GIS with related mineral occurrence database, the LMIS integrates all available datasets in order to provide a foundation for future mineral resources exploration and evaluation.
2. Establishment of a Liberian Geological Documentation Centre (LGDC) – to provide the LGS and mineral exploration companies easy access to the limited LGS reports which remain.
 3. Establishment of a basic minerals-focussed laboratory capacity at the LGS – to provide the LGS with the capability to both investigate the possibility of new mineral deposits and ensure compliance of current commercial mineral exploration and exploitation.
 4. Development of a strategy to promote mineral investment – undertaking a review of previous and current activity in the minerals sector in Liberia to provide information for implementing a series of activities for the promotion of investment in the minerals sector.
 5. Installation of necessary IT hardware and software – to provide a secure and reliable computer network which will host LMIS and LGDC and support the functioning of the laboratory and future work of the LGS.
 6. Provision of formal training courses – delivering a series of training courses specifically related to

the above tasks being undertaken to provide staff of the LGS with the foundation skills necessary to enable on-going utilisation.

In association with the above we have also been working with the LGS and Ministry to bring their offices back into use. This has required upgrading the buildings and associated infrastructure.

Ebola

Liberia along with Sierra Leone and Guinea has now been hit hard by the outbreak of Ebola. The BGS project team have been unable to travel and work in Liberia since August of

last year. In Liberia schools have been closed and people have not been allowed to attend work. Whilst unable to undertake our work in Liberia the BGS project team have been working on tasks we are able to progress from the UK.

December and January 2015 have seen a marked improvement in the Ebola situation in Liberia. This has resulted in Government restrictions on attendance at work being lifted early in the New Year and schools scheduled to re-open during February. Should this improvement continue it is hoped that the crisis is sufficiently curtailed over the coming months to enable us to return to Liberia and complete our work at the LGS.

Liberia is a new country for BGS to work in and we have begun to make some firm friends. When completed, our project will have provided an essential foundation upon which the LGS can continue to develop its expertise.

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South Korea BGS–KIGAM collaboration

BGS has a long-standing relationship with the Korea Institute of Geoscience and Mineral Resources (KIGAM), and on 31st March 2014 we signed a new memorandum of understanding to develop technical collaboration in a number of areas including carbon capture and storage (CCS), Quaternary research and digital field mapping. As part of this ongoing collaboration, since 2011 BGS staff have been involved in presenting a range of training courses at the KIGAM International GeoSchool on marine geohazards, CCS and Quaternary mapping programmes.



Jon Ford leading field training in South Korea.

Through these training courses, usually lasting 3–5 days, BGS skills and know-how reach out to a truly International audience from across SE Asia, Latin America, Europe and Africa whilst giving BGS staff the opportunity to find out more about the geological challenges faced in their countries and cities. We are apparently highly rated!

After several visits, it is also pleasing to note that

KIGAM has now adopted the design of the BGS core store for its own facilities

Quaternary and 'Anthropocene' collaboration in South Korea

BGS has begun a programme of joint research and training with KIGAM who have established a team of Quaternary scientists with particular expertise

in optical and radiocarbon dating. The team focusses on climatic change and the impacts of agriculture on the sedimentary record. Following on from a visit by KIGAM geologists to BGS field teams in March 2014, Jon Lee and Jon Ford from BGS were invited to join the KIGAM geologists in South Korea. This exchange aims to explore how BGS survey systems can enhance KIGAM's Quaternary mapping and research, and also to identify areas where KIGAM expertise can add value to BGS work in the UK.

The visit involved a brief field campaign to the Yeongsan River Basin, a region of scientifically and economically significant Quaternary geology in the southwest of the country. We were 'parachuted' into the area and, together with the KIGAM team, began producing a Quaternary map using 'virtual field

reconnaissance', feature mapping and SIGMA. Although the terrain is extensively remodelled by paddy fields we were able to build up a clear picture of the geology. Vast spreads of river terrace deposits and artificial ground dominate the modern landscape. Tantalising evidence exists of former Quaternary landscapes that hint at an interesting story of long-term landscape change. This offers a good opportunity to develop joint research in periglacial landscapes and make a link with ongoing BGS surveys in southwest England.

The next training course, scheduled for June 2015, will focus on urban geology and data systems

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Martin Smith and Jon Lee from BGS with Dr Kim from KIGAM.

European partnerships

BGS has a history of fruitful collaboration with numerous European partners to deliver a wide variety of programmes. The following articles describe and highlight three major projects that completed in 2014.

The EO-MINERS project

Minerals, and the industries associated with them, are among the basic building blocks of modern society. However, while the exploitation of mineral resources in many countries is a vital part of economic growth, employment and infrastructure development, it comes at a cost to the environment. The

EO-MINERS project was initiated to utilise Earth Observation (EO) methods to facilitate and improve interaction between the mineral extractive industry and society. The concept, funded by the European Commission, was to provide authoritative methods to underpin an informed debate on the potential impacts of the exploration, exploitation and remediation phases of mining.

The project had three field sites where the capabilities of novel integrated EO systems were demonstrated:

- i. Sokolov lignite open cast mine, Czech Republic
- ii. Witbank coalfields, Mpumalanga Province, South Africa
- iii. Makmal gold mine, Kyrgyzstan.

Interviews with stakeholders, along with project knowledge, were used to determine the environmental conditions in the form of

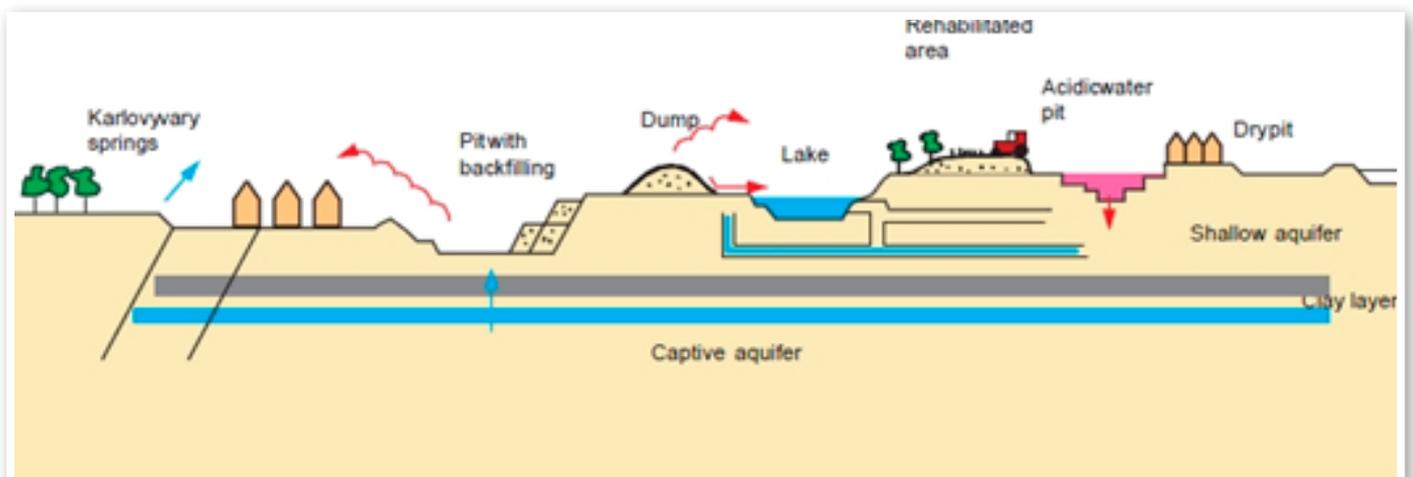
conceptual site models at each site.

BGS used cutting edge EO data that were collected in situ, from the hyperspectral and LiDAR airborne sensors and also from the latest satellites, to develop and deliver novel products to the stakeholders at workshops at each site and also at events in Europe. The results fused these data to deliver a range of products providing authoritative information on impacts such as changes in land use, air quality, water quality, transport, and geohazards. The users of results varied greatly in every way; from local farmers who had no access to computers, to technical mining experts with access to the latest software. For this reason the outputs were delivered in a variety of languages and formats including paper maps, digital maps, 3D maps and even visualisations and animations in GoogleEarth

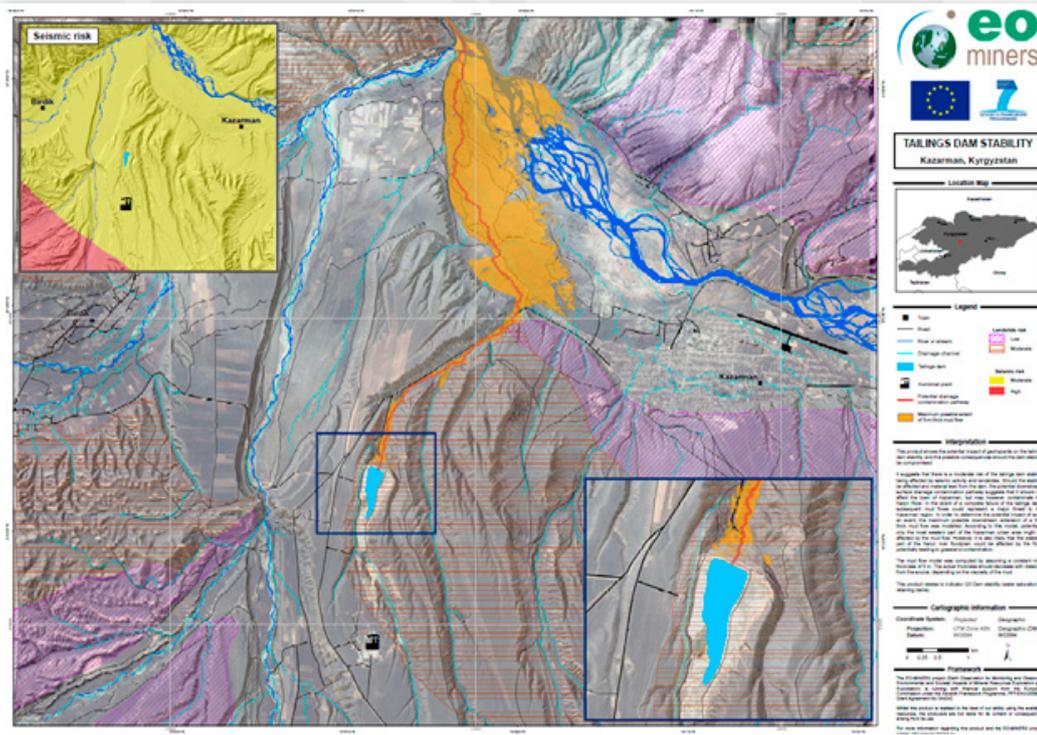
or proprietary software such as Geovisionary™.

One example is from Makmal where a gold mine lies upstream from the town of Kazarman. Some residents expressed concerns that a leak from the tailings dam could contaminate the town. Our work used a Digital Elevation Model (DEM) from high resolution satellite data to model the flow characteristics of water and other contaminants following a potential dam burst. The output map (including processing by partners in BRGM) allowed us to allay the fears that the town would be within the path of a dam burst. The results were presented to the local and regional stakeholders at several meetings in Kyrgyzstan in order to encourage open and constructive discussion of the issues using objective data

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Conceptual site model of potential mining impacts in Sokolov.



Output map from the Kazarman case study in EO-Miners



Geological Data Infrastructure – Scope

The EGDI-Scope study is a starting point in the development of a European Geological Data Infrastructure to provide a Europe-wide geological service. The recently completed first stage scoping study assessed relevant use cases, datasets, functional and technical requirements, legal topics and governance framework.

The EGDI-scope team (BGS, TNO, BRGM, GEUS, EGS and University of Leuven in collaboration with the Geological Surveys

of Europe) held their final project event in Brussels on 20th May 2014 where the results and proposals for future developments were presented. A panel discussion session (including decision-makers and envisaged users) supported the proposals and encouraged continuation.

This Infrastructure will enable European geological surveys to serve and maintain INSPIRE-compliant, interoperable geological data and information reflecting our understanding of the subsurface. It is envisaged that the data will provide information to a broad range

of users, both geological and non-experts, in an accessible, user-friendly environment. Through working closely with a range of stakeholders, the project team have identified areas where interpreted geological information would be highly valuable, and priority data themes (e.g. hydrogeology, ground subsidence, geochemical) have been inventoried.

The next phase will cover the implementation of a first operational, technical and organisational structure, securing the maintenance and further development of datasets, tools and

functionalities from prioritised European projects including OneGeology-Europe, Minerals4EU/ EuroGeoSource, EMODnet-Geology, PANGEO and GEMAS.

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RISCS project – a successful conclusion

The RISCS (Research into Impacts and Safety in CO₂ Storage) project funded by the EU Seventh Framework Programme came to a successful conclusion at the end of 2013. RISCS provided fundamental research on environmental impacts to underpin frameworks for the safe management of onshore and offshore CO₂ storage sites. Field and laboratory experiments have simulated, under well-constrained conditions, the potential impacts from elevated CO₂ concentrations in the near-surface and surface, in both terrestrial and marine environments. Experiments were made onshore in the UK and Norway and for offshore ecosystems in the Netherlands, UK, Italy and Norway. Investigations of natural CO₂ leakage have addressed key gaps. Observations were made at onshore sites in Greece, Italy and France, to study groundwater and near-surface impacts. Offshore observations have also been made off Panarea, Italy.

The project has developed a set of credible impact scenarios from which to assess potential leakage

in a range of terrestrial and marine reference environments. The baseline (most likely) scenario in each case was that of the evolution of the system with no leakage of CO₂. Alternative, low likelihood, impact scenarios considered leakage from point sources, such as escape through wells or faults, or more diffuse leakage.

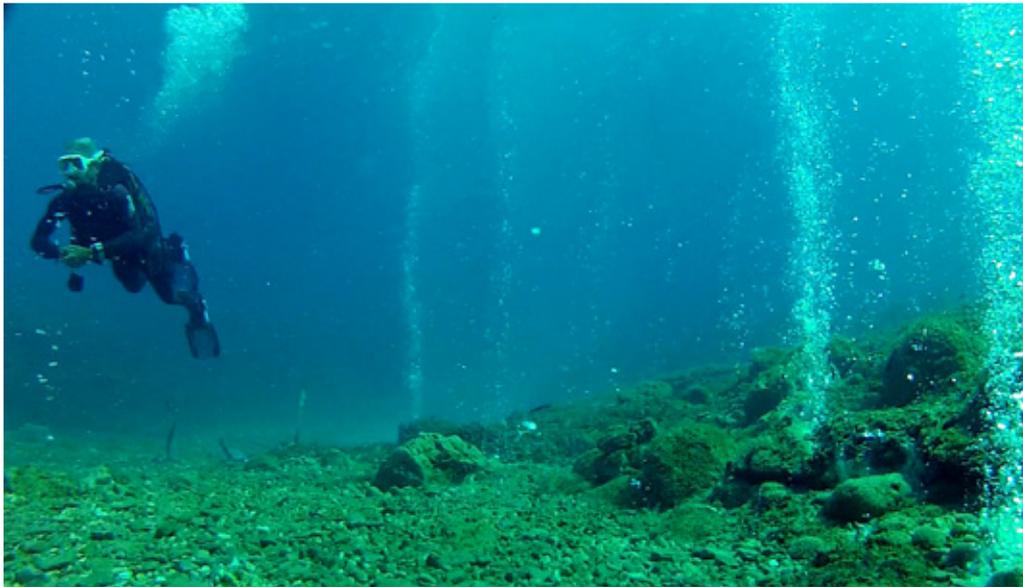
The results indicate that leakage occurs most commonly over small areas (metres to tens of metres across) and that dispersion can be rapid in both the atmosphere and in sea water or groundwater. However, dispersal can be limited in unusually still air conditions or when ocean water is stratified, such as in areas where dense colder water

underlies warmer less dense water under calm summer conditions.

Terrestrial studies have shown that impacts are spatially restricted to areas that experience high CO₂ concentrations in the soil. These tend to be of limited size in natural leakage occurrences. Plant and microbial responses are species or group specific,



Impact of a natural CO₂ seep on vegetation, northern Greece, with bare soil and no plant growth in the area of highest CO₂ concentrations.



A diver investigates natural CO₂ emissions off the island of Panarea, southern Italy.

with some species/groups able to tolerate higher CO₂ levels. They also depend on how developed the plant is when exposed to CO₂. At moderate levels of CO₂, plant and microbial responses can be masked by seasonal or year on year variability in other factors such as rainfall or soil moisture levels.

Marine impacts are also limited in spatial scale. Responses are species specific and impacts can be compounded by variations in other environmental factors such as temperature or the presence of other stressors. The effects of natural baseline variability are not well understood in the marine environment. Pelagic organisms are less sensitive to CO₂ impacts. The stage of development of the organism is also important.

Enhancement of a range of modelling tools aided experimental design and allowed the data obtained

from experiments and observations to be applied more widely in assessing the potential environmental impacts of any leakage from CO₂ storage sites.

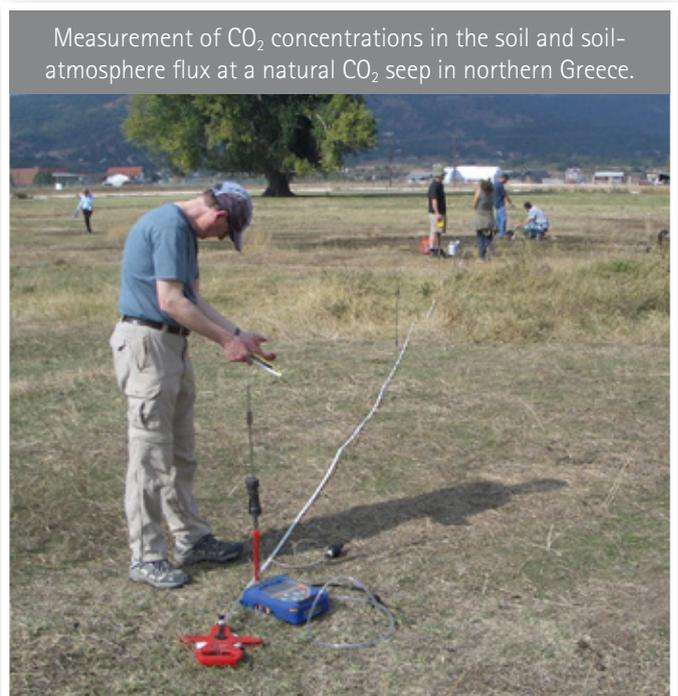
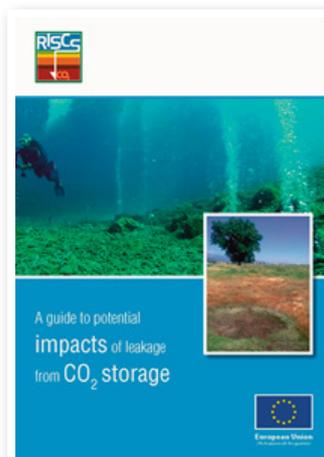
RISCS has developed a knowledge base for both storage site operators and regulators to assess the potential impacts of leakage. As Europe and the world moves from proof-of-concept small-scale demonstrations to full-scale, full-chain demonstrations of the technology, operators

and regulators require both the underpinning information and robust frameworks necessary to make appropriate decisions about the potential environmental impacts of CO₂ storage projects. Such information will also support policy makers, politicians

and the general public in their assessments of the feasibility and long-term benefits and consequences of large-scale CO₂ capture and storage (CCS) deployment.

RISCS will also help to meet the requirements of legislation, including the EC Directive on Geological Storage of CO₂, the OSPAR Convention and the London Protocol, both in ensuring environmental protection and the planning of near surface monitoring programmes. For more information please visit the project website at www.riscs-co2.eu or contact the project coordinator.

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Measurement of CO₂ concentrations in the soil and soil-atmosphere flux at a natural CO₂ seep in northern Greece.

India: Impact of over-pumping on deep groundwater resources

BGS is working on a DfID-funded groundwater study in Punjab, NW India, led by Dan Lapworth and in collaboration with colleagues from India's National Institute of Hydrology. This is part of a larger project across the Indo-Gangetic Basin, which aims to improve our understanding of the resilience of groundwater resources to pressures from changes in climate and long-term over-pumping.

Long-term groundwater monitoring undertaken since the 1970s shows declining shallow pre-monsoon groundwater levels (up to 0.8 m/y in places) across a large part (20–5%) of the Bist-Doab catchment, a highly agriculturally productive and populous region nestled between the River Satluj and River Beas. Using a range of environmental tracers, the project has investigated the connectivity of shallow and deep aquifers that make up

the alluvial plains aquifer system, a major source of irrigation water and drinking water across large parts of North West India. As part of this work groundwater sampling campaigns were carried out in paired shallow and deep boreholes under pre and post-monsoon conditions.

Results obtained from chlorofluorocarbons (CFC-12), a groundwater age tracer, show that median residence times (MRTs) are 25–30 years for shallow

groundwater (<60 meters below ground), while deeper groundwater (>100 mbgl) had MRTs of 45 years. The deep groundwater is much younger than might be expected under natural groundwater flow regimes, where groundwater residence times of the order of ca. 100–1000 years or more might be likely, which suggest that pumping is having a major influence on groundwater flow. Stable isotope results suggest that the dominant source

of recharge in both the shallow and deep aquifers is meteoric water, rather than canal irrigation. The region with fastest long-term declining groundwater levels shows evidence of enhanced modern recharge in both shallow and deep groundwater, suggesting that there is a significant component of vertical leakage to deeper aquifers induced by long-term intensive pumping. There is also evidence of nitrate breakthrough from the shallow groundwater to depth and this is likely to continue in the future if the current increases in pumping from the deep aquifers are sustained.

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Dr Gopal and Dr Rao from the National Institute of Hydrology in Roorkee sampling water from tube wells in Punjab.



International Continental scientific Drilling program (ICDP)

The BGS invest in membership of the ICDP on behalf of the Earth science sector to build national capability for the UK geoscience community. Geoscientists need access to key geological sections that are well constrained in terms of time and formation; this allows us to determine the processes of global change that affect the Earth and to understand the controls on resource development. We can also monitor and model natural hazards and fluid-related biological processes in the subsurface through instrumentation in ICDP drill holes. Through the unique capacities of scientific drilling ICDP supported projects provide fundamental and globally significant knowledge of the composition, structure and processes of the Earth's crust. BGS are involved in many ICDP projects, and two are described here.



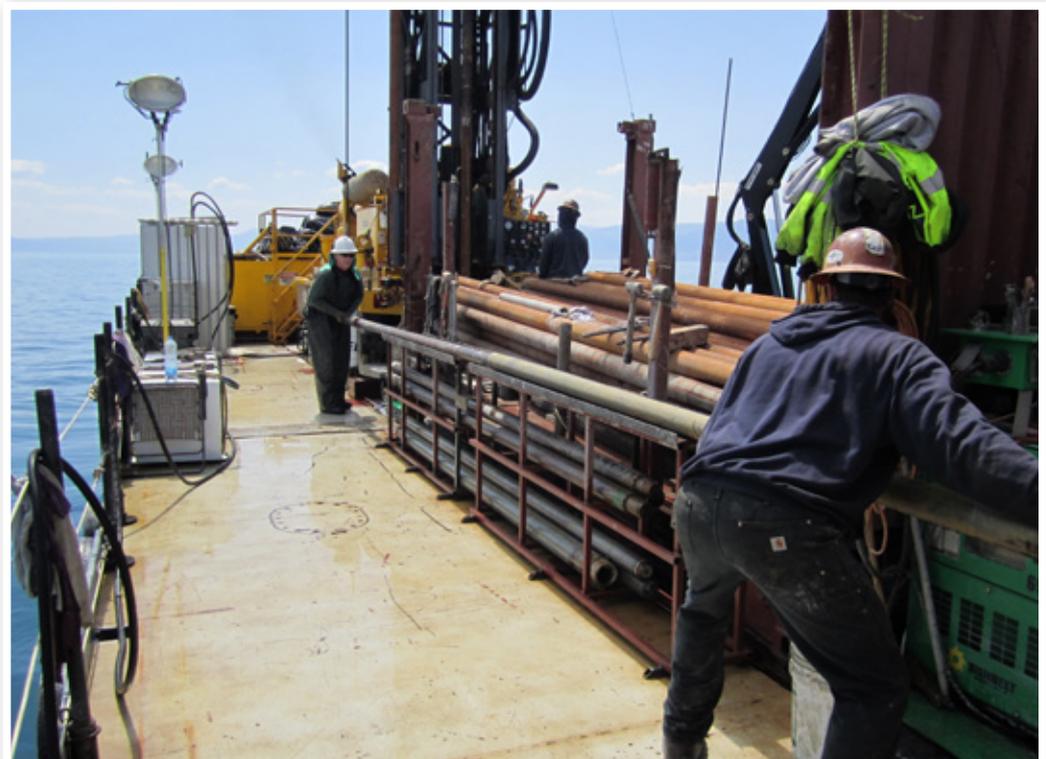
the sediment succession covers >1.2 million years (Ma) in a quasi-continuous sequence. These early findings suggest that the record from Lake Ohrid will substantially improve the knowledge of long-term environmental change and short-term geological events in the northeastern Mediterranean region, which forms the basis for improving understanding of the influence of major geological and

SCOPSCO

The SCOPSCO (Scientific Collaboration on Past Speciation Conditions in Lake Ohrid) project is an international research initiative to study the influence of major geological and environmental events on the biological evolution of lake taxa. SCOPSCO drilling campaigns in Lake Ohrid, on the Albania-Macedonia border, were carried out in 2011 and 2013. In 2011 we used gravity and piston coring at one of the five proposed drill sites, and in 2013 we undertook deep drilling with the Deep Lake Drilling System (DLDS) of Drilling, Observation and Sampling of the Earth's Continental Crust (DOSECC). In April and May 2013, a total of 2100 m sediments were recovered from four drill sites with water depths ranging from 125 to 260 m. The

maximum drill depth was 569 m below the lake floor in the centre of the lake. By retrieving overlapping sediment sequences, 95%

of the sediment succession was recovered. Initial data from borehole logging, core logging and geochemical measurements indicate that



Drilling on Lake Ohrid.

environmental events on the biological evolution of endemic species.

Hominin Sites and Paleolakes Drilling Project

In November 2014, a team of researchers from the UK (working with partners from Germany, the US, and Ethiopia) drilled a deep sediment core from Chew Bahir, an ancient lake basin in south Ethiopia, close to some of the world's most famous human fossil sites. Over the next three years, the cores will yield a high-resolution record of changes in rainfall, temperature and vegetation potentially spanning the last 500 000 years, a period that covers the evolution of our species, *Homo sapiens*, and dispersal of our distant ancestors from Africa into Asia and Europe. Until now, there have been no such long environmental records from the African centre of human origins, so ideas about how climatic change may have influenced the emergence and dispersal of modern humans have remained largely speculative. By placing the fossil and archaeological data against a detailed record of regional climatic variation, and by modelling the likely effects of changing local environments on ancient human populations, the project will develop the first rigorous tests of hypotheses about how climate drove the genetic and cultural evolution of our species, and our eventual spread to every

part of the globe. The Chew Bahir project is part of the Hominin Sites and Paleolakes Drilling Project (hspdp.asu.edu), a multi-national research effort to obtain core records of climatic change from five key palaeoanthropological sites in east Africa, covering the last 4 million years of human evolution. The UK part of the project involves researchers from BGS and Aberystwyth, Bangor, Liverpool, Newcastle,

Oxford, and St Andrews Universities. The research is also supported by grants from the National Science Foundation (USA), the German Research Foundation (DFG), and the International Continental Drilling Programme (<http://tinyurl.com/HSPDP-ICDP>). The Natural Environment Research Council (NERC) has provided £1.2 M of funding for the UK part of the research. The cores are now at the US National Lake Core

laboratories (LacCore) at the University of Minnesota, Minneapolis. Samples for dating, microfossil, and geochemical/isotope analysis will be studied at the team's specialist laboratories (including the BGS stable isotope laboratory) in the UK and Cologne, Germany. ICDP-UK <http://www.bgs.ac.uk/icdp/>

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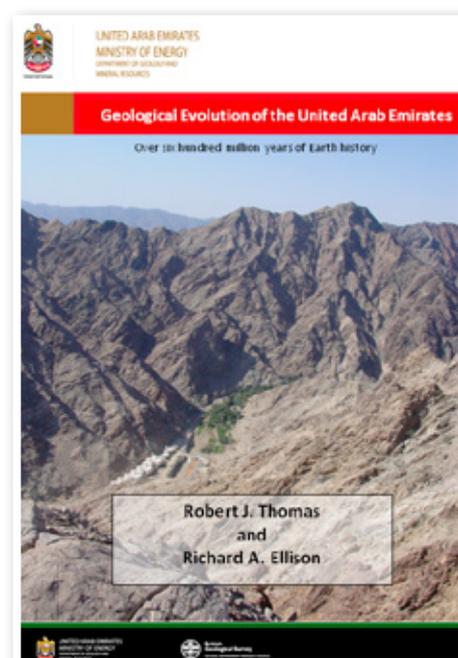


Drilling at Chew Bahir.

OTHER NEWS in 2014–15

- BGS and the Companhia de Pesquisa de Recursos Minerais (CPRM) of the Ministry of Mines and Energy, Brazil signed a memorandum of understanding for technical collaboration in natural hazard assessment
- Following a visit by Dr Surono (Director of The Geological Agency of the Ministry of Energy and Mineral Resources of the Republic of Indonesia) and his team in July, discussions on technical collaboration and BGS input to information systems are ongoing.
- In June BGS joined the DFID funded Investment Facility for Utilising UK Specialist Expertise (IFUSE, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/328288/IFUSE-flyer-july2014.pdf). The first deployment to Kenya was undertaken by Martin Smith in January 2015 and was followed by deployment of BGS staff (Jo Mankelow, Tim McCormick, Martin Nice) to investigate information systems and capacity building in the Ministry of Mines during February 2015. Further IFUSE deployments to Ethiopia, South Africa and Morocco are in the planning stages.
- Oliver Wakefield and Martin Smith visited India to attend workshops on urban development and on a multi-disciplinary (SANDHI) project on the heritage city of Varanasi with IIT Kharagpur.
- Kathryn Goodenough and Paul Lusty visited Morocco to further develop contacts with the Geological Department at the Ministry of Mines, Energy, Water and the Environment, and collaboration with Cadi Ayyad University and the Managem mining group.
- Andrew Newell and Jon Ford visited Brunei to undertake training in digital field data capture (SIGMA) and provide advice on urban geology.
- The Department of Geology and Mineral Resources in the UAE Ministry of Energy, and BGS, published a book on the Geological Evolution of the United Arab Emirates <https://www.moenr.gov.ae/>

en/our-services/geological-reports/geological-reports.aspx. This marks the final deliverable in 12 years of successful collaboration in survey and research that has provided the UAE with a national digital geological database.



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