2011–12

Annual Science Review

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

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The British Geological Survey (BGS) is part of the Natural Environment Research Council and is its principal supplier of national capability in geoscience.

We advance understanding of the structure, properties and processes of the solid Earth system through interdisciplinary surveys, monitoring, modelling and research for the benefit of society.

We are the UK's premier provider of objective and authoritative geoscientific data, information and knowledge for wealth creation, sustainable use of natural resources, reducing risk and living with the impacts of environmental change.

Our vision
To be the world's leading centre for applied geoscience.

Some research reported here may not yet have been peer-reviewed or published.

The Natural Environment Research Council

The Natural Environment Research Council (NERC) delivers independent research, survey, training and knowledge transfer in the environmental sciences, to advance knowledge of planet Earth as a complex, interacting system. The BGS is one of six major environmental research centres operating under the NERC.

The NERC's work covers the full range of atmospheric, earth, biological, terrestrial and aquatic sciences, from the deep oceans to the upper atmosphere, and from the poles to the equator.

Our mission is to gather and apply knowledge, create understanding and predict the behaviour of the natural environment and its resources, and communicate all aspects of our work.

The NERC regularly monitors, evaluates and reports on progress against delivery of our strategy, to inform our decision-making and to demonstrate that we are effectively and efficiently investing public funds to make economic, political and social contributions both in the UK and internationally.

Next generation science for planet Earth

The BGS's programme is closely aligned with the NERC's strategic goals, which are to deliver world-leading environmental research at the frontiers of knowledge:

- Enabling society to respond urgently to global climate change and the increasing pressures on natural resources.
- Contributing to UK leadership in predicting the regional and local impacts of environmental change over timescales from days to decades.
- Creating and supporting vibrant, integrated research communities.

With our researchers and stakeholders, the NERC develops the priorities that provide a focus for the marine, polar, atmospheric, geological, terrestrial and freshwater science communities. This research is often multidisciplinary and carried out in collaboration with national and international partners.

The NERC runs a fleet of research ships and scientific aircraft. We have bases in some of the world's most hostile environments and invest in satellite technology to monitor environmental change on a global scale.

The NERC is committed to developing UK and international capability across the environmental sciences. We fund centres and universities to carry out research and to train and support a world-class community of environmental scientists.

The NERC's six major environmental research centres provide leadership to the environmental science community in the UK, and play significant and influential roles in international scientific collaborations:

British Antarctic Survey	BAS
British Geological Survey	BGS
Centre for Ecology & Hydrology	CEH
National Oceanography Centre	NOC
National Centre for Atmospheric Science	NCAS
National Centre for Earth Observation	NCEO

Visit www.nerc.ac.uk for more details.

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Cover: The Geological Walk at Keyworth, three billion years of Earth's history represented by spectacular paving and feature boulders, is open to the public during office hours. P801504. BGS © NERC.

Bibliographical reference

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Introduction

Executive Director
John N Ludden

This was yet another year when the UK was waiting for the global economy to rebound and one in which the government's cuts in funding started to bite. Although funding from the Natural Environmental Research Council (NERC) was ring-fenced, in common with all the Research councils, inflation in infrastructure costs coupled with earlier planned ramp-downs in national capacity funding resulted in a net decrease in baseline budget. The NERC allocation (£24.2 m) when combined with our competitively won income of £21.6 m gave a total resource income of £45.8 m. This funding covered staff costs of £30.1 m (science staff £21.2 m, science support £8.9 m). Non-pay budgets were £7.8 m for operational science and £7.5 m for support (including estates). At the end of the year BGS had 642 full-time equivalent employees. The outputs from BGS scientists continued to increase and our staff produced 810 publications and 166 items of advice to UK national and local government, government agencies, the EU, and policy-makers in other countries. Web visits averaged over 300 000 a month and we continued to release imaginative digital applications to the public, some of which are featured in this report.

The BGS with the NERC brought a workforce plan into action to ensure that we are ready for the scientific challenges that the UK will face in maintaining high impact in key science areas. Specifically this involves us maintaining our ability to monitor, map and model the environment of the UK and its future resources. At the same time we increased our global reach by expanding our involvement in international resilience, specifically in Africa with respect to water, but also through diversification of our business model by creating a limited company trading as BGS international (www.bgsinternational.co.uk) and by transferring some resources to Panalytical Ltd (www.panalytical.com). Both companies are based on site and mark the first steps in the creation of an enterprise hub at the Keyworth campus.

Although our baseline funding from the NERC decreased, their major capital investment in our facilities continued. The renovation of the Keyworth site as the NERC–BGS Environmental Science Centre in Keyworth, was completed in 2012 and, in all, the NERC will have invested around £25 million over the past 8 years in the BGS estate. The geological walk that runs through the spine of the site and is featured on the cover of this report is truly exceptional, as are the National Geological Repository, the De la Beche media centre and library, housed in the Kingsley Dunham Building and the James Hutton Building. Please feel free to visit, as the site is now open to the public.

The BGS replaced its Board with a new Advisory Committee towards the end of 2011. This decision was supported by the NERC Council and I would like to thank past Board members for their contributions to the Survey. I also thank the members of the new Advisory Committee for their willingness to be involved; the membership of the committee is given at www.bgs.ac.uk/about/programme.html

As part of our workforce planning, we have decided to focus our geological mapping on strategic actions involving UK resources and infrastructure. In this way we will maintain and

The entrance to the new James Hutton Building features a stylised representation of the famous unconformity at Siccar Point, the locality most synonymous with Hutton.

refresh the geological map of the UK where needed, but will not undertake systematic geological mapping. Key energy questions that were followed this year include better mapping and estimation of UK shale gas resources and detailed assessments of the physical properties of Triassic sandstones through detailed mapping and field logging; the latter underpinned models for carbon capture and storage (CCS) and for groundwater sustainability. Another key infrastructure focus has been on urban geology and the subsurface and also for major transport systems. Interestingly, we are applying the same approach to international mapping and this year completed an urban geology synthesis for Abu Dhabi that is featured in this report *(see page 13)*.

" Although these are financially difficult years for the BGS, our scientific outputs continue to move from strength to strength. We are on track to deliver our strategy despite these constraints and our staff remain committed to excellence providing the UK with much needed national capability, and in many areas international leadership in geosciences "

Denis Peach, Chief Scientist

The impact of humans on the natural environment increasingly extends underground, especially in urban areas, as competition for space to deliver a range of services grows.

The UK experienced a drought this year, although one could be forgiven for doubting it now. Through partnerships with the Environment Agency (EA), we have a detailed programme of monitoring and modelling groundwater. This sort of analysis is essential for the UK as it enters a regime of extremes in climate and we hope to be able to predict the behaviour of the subsurface in conditions of extreme drought or rainfall. We are building stronger partnerships with the EA, the Met Office and key universities in order to develop these models. A study that was completed this year on the groundwater resources of Africa is highlighted on page 23. This work has been extensively cited and will be a cornerstone in the development of our future global science research programme.

The Tohoku earthquake of March 2011, as well as having a significant effect on Japan, also tested the limits of our understanding of natural hazards. The BGS was involved in the scientific response and is part of a team looking at tsunami deposits around the world. Although the Icelandic volcanic system has remained relatively calm this year we have stepped up earth science monitoring in Iceland and are participating in a 'supersite' initiative in which we will further develop our analysis of hazards for the region. At the same time we are developing a powerful natural hazards partnership with UK and international reach through collaboration across the NERC and other government agencies.

We have continued to build partnerships in other areas too; these involve academic placements by BGS in geochronology, climate change sensitivity, groundwater contamination modelling, critical metal resources and CCS. We also extended our influence in scientific drilling by joining the International Continental Scientific Drilling Program (ICDP) on behalf of the UK community.

We continue to create imaginative science products that are of use to society and are increasingly releasing our data as free downloads, either from the World Wide Web or smartphone apps. These are proving highly popular so we will expand this service for researchers and the general public and will be working with industry to develop smart commercial applications.

All in all the BGS had a good year which saw a significant shift in our science focus. We continue to work on three fronts: as a geological survey; a geosciences institute; and as a niche supplier to industry; and all of our science areas increasingly inhabit this mixed funding environment.

Geology and landscape

Geology of London

Although the land on which London stands is one of the most intensively studied areas in the world, construction work in the capital continues to reveal the presence of unexpected ground conditions. Many of these instances are recorded in isolation with no further work to explain them. The failure to share information and data about anomalous ground conditions has prevented any refinement of the geological model for the area and, as a result, failed to reduce the risk to major engineering projects from costly project overruns and health and safety risks. A better geological framework for London is required to support scientific, industrial and commercial activities. An important paper by Royse et al[1] has reviewed the geological setting of London as it is understood at present and outlines the issues that current research is attempting to resolve. It highlights the complex nature of London's geology and the possible implications for current and future development.

London: a constantly evolving cityscape. A better geological framework is needed to support scientific, industrial and commercial activities.

Isle of Wight

We recently remapped the Isle of Wight at a scale of 1:10 000, and this has provided a wealth of new geological material. Many of the scientific outputs emerging from this integrated project were showcased in a special issue of the Proceedings of the Geologists' Association comprising 18 papers dedicated to the work of the BGS on the island.

The geology of the Isle of Wight is particularly significant as it offers a window into the geological history and landscape development of Southern England. Consequently, it is an important teaching resource for school children and academic research alike, as it provides a field workshop for studying various aspects of geology, such as stratigraphy, tectonics and climate change. In addition, the survey emphasised the link between geology, the landscape it influences and human interactions with it.

Some of the most significant outcomes from the survey were its use in formulating policies to address a wide range of issues, all of which rely on modern and accurate geological information. These include hydrogeological resources; aggregate resources; the status of parts of the island as Areas of Outstanding Natural Beauty; the blighting of stretches of coast by, and mitigation required to address, landslide hazard; infrastructure development; and geotourism. The paper written by Booth and Brayson[2] for a non-specialist audience gives examples of environmental issues such as the landslides at Ventnor; geotourism at The Needles, Alum Bay and various dinosaur sites; water supply; and the artificial landscapes resulting from quarrying.

A view of Chale Bay, Isle of Wight, looking south-east from Atherfield Point to St Catherine's Point.

[1] http://nora.nerc.ac.uk/16528
[2] http://nora.nerc.ac.uk/16085

Lime and Ice

The North York Moors National Park Authority (NYMNPA) opened an interactive exhibition at its visitor centre at Sutton Bank in May 2012. The exhibition is part of the NYMNPA's Lime and Ice project funded by the Heritage Lottery Fund, and describes the geology, landscape and natural history of the surrounding area. We were commissioned to write a report to inform the design of the exhibition. The report summaries the geology and landscape that characterises this tract of the North York Moors, including the Hambleton Hills and part of the Howardian Hills.

Lime and Ice is an outreach and community project that aims to inform and excite visitors about the landscape and underlying geology of this beautiful area. To understand the development of the landscape and its natural history requires an appreciation of the geological evolution of the Jurassic bedrock geology ('lime') and the impact of the last ice age ('ice') that carved out the escarpment and glacial meltwater channels to leave a thin veneer of glacial deposits overlying part of the area. A geological history covering 200 million years and recording ancient shallow seas, rivers and deltas, major earth movements and the later impact of major glaciations, especially the most recent ice age, is brought to life in the report to illustrate the dynamic earth history and the more recent influence of humans on the landscape.

Modelling and predicting future glacial erosion

Nuclear power stations in Scotland are situated close to the coast in terrain that has been heavily glaciated by ice sheets over the past million years. There is a very high likelihood that these sites will be glaciated again within the next 10 000 years, well within the half-life of some of the radioactive material. For this reason it is important to understand the likelihood of buried material being exhumed in the future.

Numerical modelling work, in collaboration with Aberystwyth University, shows that powerful ice streams within the British Ice Sheet tend to form in large topographical troughs, where ice flow is focused and meltwater lubricates the bed. Our improved knowledge of the former glaciological regime of the British Ice Sheet, combined with site-specific information on the properties of the substrate, has allowed us to estimate erosion rates and sediment movement in various geographical settings. For example, in the larger fjords of western Scotland a vertical thickness of around 50 to 100 metres of rock was removed with each glaciation, and roughly four metres of sediment movement occurs during relatively short-lived events of ice-sheet advance. This research shows that indications of rates of future glacial erosion and sediment movement are vitally important when planning engineering projects with very long lifetimes.

Glacial sediments under the microscope

Collaboration with scientists at the Centre for Micro-morphology[3] at Queen Mary University of London has led to the development of a new approach to analysis using micromorphology. Glaciologists and earth scientists are increasingly using this technique to study the sediments (gravel, sand and mud) left behind after a glacier or ice sheet has melted away. This approach can help us understand what is happening deep beneath the icy wastes of modern polar ice sheets in Antarctica and Greenland. This 'microstructural mapping' method has the potential to greatly increase understanding of the complex processes occurring at the margins and below both glaciers and ice sheets. The study looked at modern glacial sediments from the Turtmann Glacier in Switzerland, as well as ancient deposits from north Wales and north-east Scotland.

[3] http://nora.nerc.ac.uk/15181

The Lower Calcareous Grit and Hambleton Oolite capping the high ground of Hawnby Hill and Easterside, Hambleton Hills, North York Moors.

Following the magnitude 9 Tohoku earthquake of March 2011, BGS scientists have helped an international team to investigate tsunami desposits, map the areas flooded, measure inundation heights and assess damage to coastal defences.

Marine geoscience

Marine mineral resources map

In 2011, The Crown Estate commissioned a mineral resource assessment of the UK's continental shelf over two years, with the results to be depicted in a series of maps. The first area to be assessed encompasses the East Coast Inshore and East Coast Offshore Marine Plan Areas and a map has been published at a scale of 1:500 000 with an accompanying descriptive report. The marine mineral resource maps provide a comprehensive, relevant and accessible information base that allows all stakeholders — planners, industry and members of the public — to visualise the distribution of offshore minerals to a common standard and at a common scale. With increased pressure on marine space, it is important that these natural resources are not needlessly sterilised by other forms of development, leaving insufficient supplies for future generations.

The 2011 Japan tsunami

In March 2011, the magnitude 9 Tohoku earthquake caused a devastating tsunami along much of the eastern shoreline of Honshu Island, Japan. Our scientists visited the affected areas several times during 2011 and 2012 and are working in collaboration with international colleagues to investigate tsunami deposits, map the areas flooded, measure inundation heights and assess the impact of the tsunami on the coast and coastal defences.

In May 2011, BGS scientists joined an international team studying sediments laid down by the tsunami. The research will lead to a better understanding of the magnitude of past tsunamis and the frequency with which they occur. This, in turn, should lead to better mitigation strategies. In June, a BGS team (funded by a NERC Urgency Grant) returned to carry out further research on the sediments and, using high-resolution satellite imagery, extended the mapping of the tsunami sediments to other areas. As the work responded to a major disaster, we were granted access to satellite imagery from the International Charter for Space and Major Disasters. This charter is activated to provide satellite imagery for relief efforts.

Results from the fieldwork are, as yet, preliminary but highly promising and have the potential to improve our ability to identify ancient tsunami sediments in the geological record. They will also help us to discriminate between sediments laid down by tsunami and those deposited by storms — a major challenge at present. In addition the new work shows that older, historical

earthquakes may have been of greater magnitude and thus caused larger tsunamis.

MAREMAP

MAREMAP, the Marine Environmental Mapping Programme, is a new NERC initiative led by the BGS, the National Oceanography Centre and the Scottish Association for Marine Science to improve understanding of the seabed environment around the UK. It brings together expertise and resources from across the NERC to deliver a national research programme. The aim of the initiative is to develop the detailed seabed and geological information necessary to underpin the future development of our marine resources effectively and efficiently. Additional partners include the University of Southampton and the Channel Coastal Observatory. Partnerships such as MAREMAP have taken a lead in promoting effective and economic ways to survey and interpret hydrographic data in response to continuing pressure on publicly funded bodies to find efficiency savings.

As part of the MAREMAP programme, we have been surveying the seabed of the Sea of Hebrides around the islands of Muck, Rhum and Eigg (the Small Isles in Scotland). The Sea of Hebrides is an area of complex seafloor bathymetry to the west of the Small Isles on the UK continental shelf. This area has experienced multiple glaciations and has been overridden by ice sheets on numerous occasions throughout the Quaternary Period. The survey data and core samples collected will enable more accurate geological maps and interpretations to be produced. Papers on the Quaternary and the bedrock of the area around Muck, Eigg and Rhum based on multibeam data acquired during the project have been submitted for publication.

Hazards

Space Weather

During 2011/12 there has been increasing governmental concern over the risks posed by space weather and geomagnetic storms, particularly on the UK power generation infrastructure. We examine solar activity daily and forecast whether this is likely to have significant geomagnetic impact on the Earth. So far during 2012, we have issued three separate geomagnetic storm warnings associated with energetic solar activity and the increased chance of seeing the aurora in the UK on each occasion was widely reported in the media.

We briefed the Government Chief Scientific Advisor on the risks posed by space weather on various occasions throughout the year and provided evidence to the House of Commons Defence Select Committee inquiry into Developing Threats to Electronic Infrastructure in November 2011.

We have also undertaken studies into geomagnetic hazards in the UK for National Grid and Scottish Power and currently provide a space weather monitoring service for National Grid. Our forecasting service is being integrated with the Met Office through the Natural Hazards Partnership *(see below)* and is building links to the US Space Weather Prediction Centre. Within Europe, we are a major contributor to the 'European Risk from Geomagnetically Induced Currents' project, concerned with space weather impact across the continental power system and funded through the Framework Programme.

Geomagnetic storms are a potential hazard to power generation but can also be responsible for spectacular aurora events. © Jim Henderson Photography.

Natural Hazards Partnership

The Natural Hazards Partnership (NHP) is a consortium based around leading UK Government Agencies and aims

to deliver a forum for the exchange of knowledge, ideas, expertise, intelligence and best practice in matters relating to natural hazards. It also provides a consistent source of advice to government and emergency responders for civil contingencies.

We led the initial phase of work of the Hazard Impact Modelling (HIM) subgroup of the NHP, which also included representatives from CEH, the Environment Agency, the Met Office, the Flood Forecasting Centre, ADAS and the Ordnance Survey. This subgroup worked in partnership on a 'proof of concept' for a prototype hazard impact demonstrator. Three hazards were incorporated into the impact demonstrator: surface water flooding (including leaf fall), vehicle overturning by wind throw, and landslides (including debris flow). During the inception of the HIM initiative, the partnership agreed to consider the impact on the road network of these hazards, in this first instance, for two case study areas: Devon and Cornwall, and South Wales.

During the initial six-month period, the partnership succeeded in bringing together a diverse range of capability into one holistic modelling environment to prove the HIM concept. This was achieved largely by regular meetings to review progress and in some instances physically working together for short periods. This way of working has helped facilitate the sharing of information and knowledge within the team and partnership organisations.

The model will help to improve resilience and reduce the risk to life and infrastructure from natural hazards by providing longer lead times and better intelligence for those who have roles and responsibilities for emergency preparation and response at the local level under the Civil Contingencies Act (Category 1 and 2 responders).

Advising government on eruptions

Following the lessons learnt when the Eyjafjallajökull volcano erupted in Iceland in 2010, together with the Met Office we were able to respond within an hour when Grímsvötn in Iceland began to erupt on 21 May 2011. Our experts provided advice to the Scientific Advisory Group for Emergencies (SAGE) on the Grímsvötn eruption and to the UK Ministry of Defence on the eruption of the Puyehue-Cordón Caulle volcanic complex in Chile. Sue Loughlin was invited to join an expert group chaired by Sir John Beddington looking at requirements for future volcanic ash observations.

Infrastructure and development

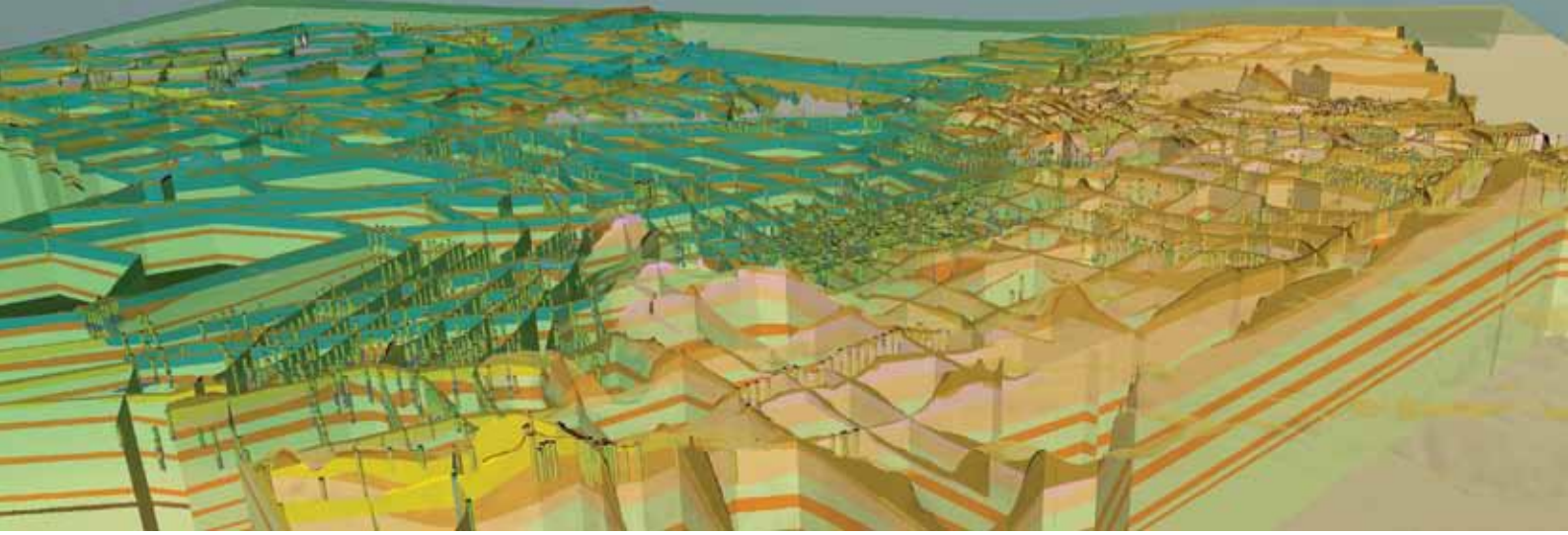
Modelling urban geology in the UAE

A three-dimensional geological model of the Abu Dhabi urban area, part of Abu Dhabi Emirate and the capital of the United Arab Emirates (UEA) has been funded by the UAE Federal Ministry of Energy, Department of Geology and Mineral Resources. We used existing ground investigation data provided by private and public sector organisations and agencies to create the model which shows the distribution, thickness and elevation of rock units beneath the Abu Dhabi urban area. The model provides a geological framework that will be used for planning urban development and sustainable land use, and for assessing hazards.

The urban modelling of Abu Dhabi was informed by the geological framework provided by a wider programme of geological mapping in the UAE, which will result in a series of country-wide geological maps of the UAE at a scale of 1:100 000, to be published in November 2012. The mapping provides a record of Quaternary climate change over the last 200 000 years and will help archaeologists understand the impacts of climate change on human populations through time.

ALERT-ME

Working with partners including Network Rail, London Underground, and British Waterways, we have demonstrated the application of our Automated time-Lapse Electrical Resistivity Tomography (ALERT) technology for the real-time monitoring of strategically important and 'at risk' earthworks within the transport network, such as embankments and cuttings. ALERT allows the real-time measurement of the geoelectric, hydrological and hydrochemical properties of the subsurface, giving early warning of potential threats to vulnerable ecosystems, aquifers, or safety-critical sites.



A 3D view of the cross-sections and boreholes used to construct the geological model of Abu Dhabi in GSI3D.

In 2010, a test site was established at East Leake along a section of railway line operated by the Great Central Railway (Nottingham) Ltd. The test site forms part of the goods link between Loughborough and East Leake. The earthworks along the line were originally constructed in the 1890s. Victorian earthworks generally lack uniformity in composition or character because of the techniques used in their construction. The ALERT technology installed at the site allowed our scientists to monitor the movement of moisture through the trackside embankment.

The overall aim of the ALERT-ME project was to provide early warning of potential failure events, such as the effects of very heavy rainfall on embankment structures. This will aid strategic planning and design of low-cost, targeted, preventive maintenance to ensure the long-term stability of earth structures. The system will also lead to more efficient use of maintenance resources and underpin sustainable construction within the UK transport network.

Landsliding in Scotland

We have successfully undertaken a national assessment of landsliding within land managed by Forestry Commission Scotland, an area of over one million hectares. The study focused on identifying where landsliding could potentially impact upon assets such as roads, houses and infrastructure. We used our extensive national datasets including the National Landslide Database, GeoSure and DiGMap to highlight where landsliding could be a hazard. We used expert judgement to identify where high levels of landslide potential corresponded to assets and developed a scoring system to prioritise these areas. The Forestry Commission Scotland will use the results to help them manage and maintain their assets as well as to focus remediation measures where necessary.

Background concentrations of contaminants in soil

England has a varied geology and a long history of industrial activity and urbanisation; both contribute significantly to the distribution of chemical elements in soil. In support of a recent revision to Part 2A of the Contaminated Land Statutory Guidance, in which reference is made to 'normal'

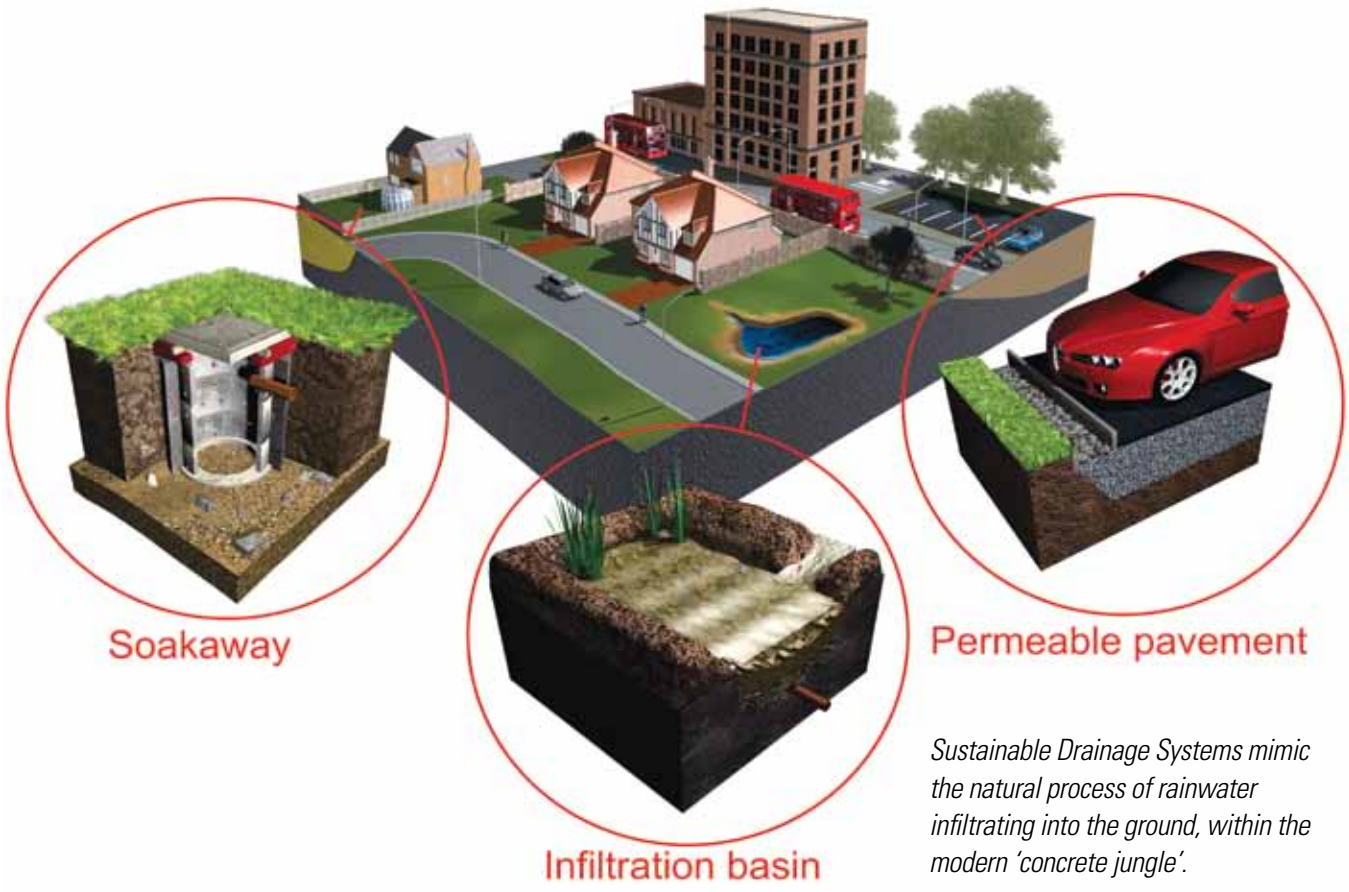
Road networks in the UK are susceptible to natural hazards, such as this landslide on the Rest and Be Thankful Pass (A83) west of Loch Lomond.

levels of contaminants in soils, the BGS was commissioned by the Department for Environment, Food and Rural Affairs (Defra) to determine typical and widespread (background) concentrations of arsenic, benzo[a]pyrene, cadmium, copper, mercury, nickel and lead in English soils. The Statutory Guidance defines background as a combination of natural and diffuse human contributions. The data collected as part of the BGS's Geochemical Baseline Survey of the Environment (G-BASE) programme provided a comprehensive dataset that has been used to determine normal background concentrations (NBCs). BGS scientists assigned NBCs to regions (domains) that were associated with higher levels of contaminants, rather than assigning a single national value. These NBCs will help to simplify the process of identifying the most significant areas of contaminated land. An estimated 20–40% of current remediation work is thought to be unnecessary and clearer Statutory Guidance and supporting tools will help to reduce costs (the benefit in net present-value terms is estimated to be £1.7 bn over ten years) and target remediation efforts more effectively.

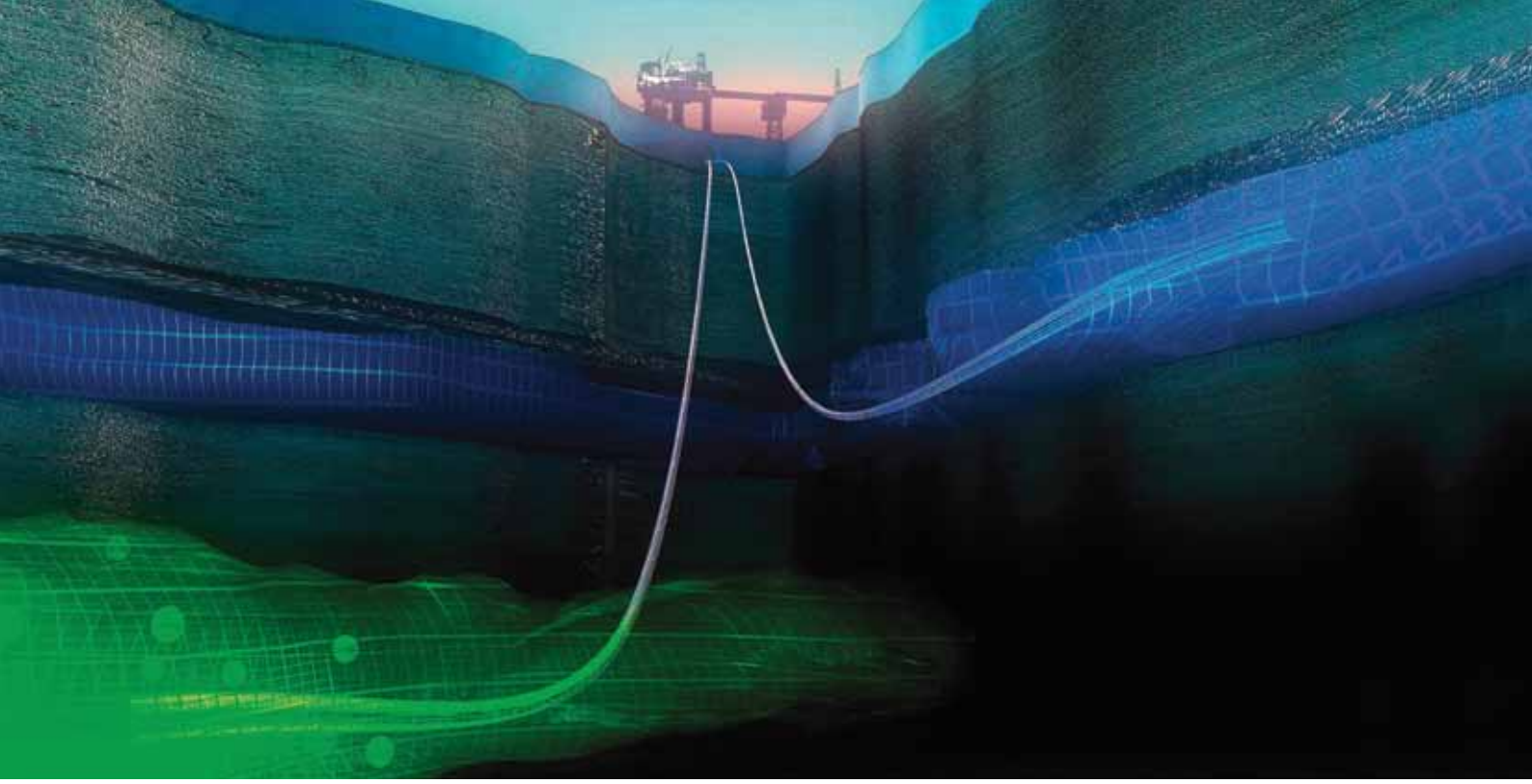
Sustainable Drainage Systems

We released a new digital map of the UK in February 2012, aimed at helping planners, developers and local authorities reduce urban flooding. The map shows areas where rainfall can soak into the ground through Sustainable Drainage Systems (SuDS) such as soakaways, infiltration basins and permeable pavements. These SuDS mimic the natural process of rainwater infiltrating into the ground, a process almost entirely removed from our modern 'concrete jungles'. By adopting SuDS, the pressure on underground drainage networks, including sewer systems, is reduced. This in turn decreases the likelihood of floods and the pollution of watercourses caused by overflows to combined sewers that take both sewage and storm water runoff.

The Flood and Water Management Act 2010 made provision for the implementation of SuDS and national standards for their design and performance to mitigate the impacts of surface water flooding. The standards prioritise the use of infiltration SuDS over other systems that store or reuse surface water. In response, the infiltration SuDS map was developed to provide an assessment of the suitability of the subsurface for infiltration, and so far it is proving to be a valuable resource for stakeholders. Rachel Dearden, a BGS hydrogeologist, has been awarded a three-year NERC Knowledge Exchange Fellowship on the topic of sustainable infiltration. The fellowship aims to enhance the effectiveness of the recent government legislation by improving the knowledge base of decision-makers.



Sustainable Drainage Systems mimic the natural process of rainwater infiltrating into the ground, within the modern 'concrete jungle'.



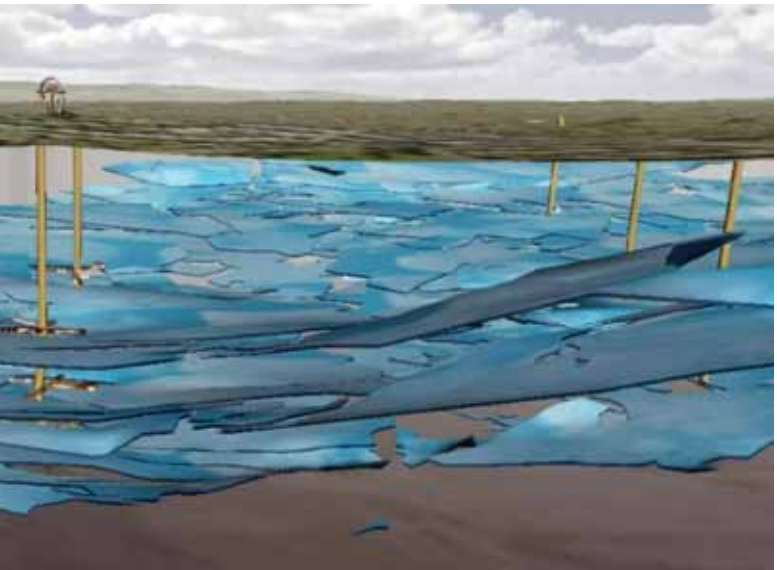
Carbon storage at Sleipner. © Alligator film/BUG/Statoil.

Energy

Heat energy beneath Glasgow

We have been working with Glasgow City Council to explore the use of heat energy from the ground to help to warm homes and communities. Glasgow already has a small scheme using heat from minewaters to keep 17 houses in the Shettleston area warm, and this has worked well for over ten years. Collapsed mineworkings beneath Glasgow provide the conduits for extracting groundwater from the rock, as well as the much lesser amounts of minewater. Heat pumps can be used to 'concentrate' heat energy sufficiently from lower temperature waters in the mines to heat buildings. Our research is helping to identify which parts of Glasgow would offer the best prospects for supplying this kind of energy, looking at the potential heat within minewaters, superficial deposits and bedrock aquifers beneath the city. We estimate that 20 gigawatt-hours per square kilometre each year from ground source heat could contribute at least 40% of Glasgow's heating demand, and provide a low-cost source of energy for at least 100 years.

3D model showing the extent of mine workings under Glasgow.



New data on temperatures at depth

We have published new analyses of the temperatures likely to be found in Britain at borehole depths between 100 and 1000 metres. Accessing heat from the ground is predicted to have an increasingly important role in the renewable energy mix. In a paper published in the Quarterly Journal of Engineering Geology and Hydrogeology,[4] we have used discrete temperature measurements to compile maps of the temperatures expected at depths of 100, 200, 500 and 1000 metres below the ground surface. From these data regional trends and anomalies have been defined. Estimating temperatures in areas where there are no borehole measurements will be important information for

[4] http://nora.nerc.ac.uk/14877

local people wishing to take advantage of the ground's renewable heat.

Shale gas

The extraction of shale gas has been a subject of considerable media interest throughout the year. Our expertise in shale gas has been called upon in different ways, including briefing Sir John Beddington, Chief Scientific Advisor to the UK government, on aspects such as the environmental impacts arising from fracking fluids, methane and formation waters (including radioactivity). We have initiated a study of baseline chemical composition of groundwater in areas where shale gas might be extracted, and are planning a map of rock stress in the United Kingdom to help in planning shale gas development. We have developed new web pages to reflect our extensive capabilities in this area. These include information on what shale gas is, how much shale gas we have in the UK and how safe is the extraction of shale gas.

Directional drilling for oil and gas

The BGS Global Geomagnetic Model (BGGM) is widely used in the oil industry for directional drilling with Measurement-While-Drilling magnetic survey tools. These tools measure the direction of the well-bore relative to the direction of the local geomagnetic field and are used to navigate wells towards precisely known underground targets. The BGGM models the Earth's magnetic field in its undisturbed state, and is revised every year to allow for the inclusion of new data and development of the modelling methodology. With annual revisions it is also possible to minimise the errors that arise from predicting the field at some date after the time span of input data. We make the BGGM and its associated software available under licence. Licence holders for 2011 include major companies such as Shell, Total, Statoil, Schlumberger, Chevron and BP.

Energy storage in Northern Ireland

Northern Ireland is heavily dependent on imports of natural gas to meet its power generation and wider energy needs and could be vulnerable to supply interruptions in the future. The construction of underground storage caverns in salt beds for the storage of gas or compressed air energy can help secure energy supply. The Geological Survey of Northern Ireland (GSNI) is providing advice and geoscientific information to help the Northern Ireland government develop such resources and ensure the smooth functioning of the regulatory system for gas storage projects. Two consortia of British and European companies are currently assessing the suitability of the Permo-Triassic salt beds in the Larne area of County Antrim.

Geologists assessing sandstone formations near Port Elizabeth, South Africa, which may have potential for storing carbon dioxide at depth.

Geological disposal of carbon dioxide

We played a substantial role in the UK CO_2 Storage Appraisal Project (UKSAP) commissioned and funded by the Energy Technologies Institute (ETI) in September 2009. This £4 m project provides a fully auditable and defensible estimate of UK carbon dioxide storage capacity in offshore geological formations, to inform future roll-out of carbon capture and storage (CCS) in the UK. The results of the project are expected to be released in late 2012. The major deliverable from the project is a web-enabled database and geographical information system (GIS) containing the geological data, storage estimates, risk assessments and economics of almost 600 potential storage units identified by the project, covering both depleted oil and gas reservoirs and saline aquifers. Our role was to lead the mapping and characterisation of the potential storage reservoirs and, with the University of Edinburgh, enter the data for all the storage units on which the assessment is based into the project database and GIS. The data represent a major UK asset to develop CCS both for our own carbon emitters and, potentially, those nearby in Europe.

Soil sampling in the gardens of Lambeth Palace.

Soils

London Earth

We completed a survey covering the whole of London to obtain baseline information on the chemical composition of soils for over 50 elements. It will enable local authorities and others with an interest in the urban environment to assess the health of London's soil, in addition to stimulating and supporting research in the environmental sciences. A set of geochemical maps and short interpretations for a selection of environmentally sensitive elements are now available to download from the BGS website. London Earth is the largest urban survey of its kind in Europe and sampled over 6200 individual locations across the entire city including industrial areas, domestic gardens and allotments.

Advanced Soil Geochemical Atlas of England and Wales

This atlas is published as an interactive e-book and is the outcome of collaborative research with Rothamsted Research (a BBSRC institute). The total concentration of different elements in the soil — its geochemistry — has implications for both human and animal health. The original atlas published by the Soil Survey of England and Wales in 1992 was based on 17 elements while the advanced atlas presents chemical analyses for a total of 53 elements, including the original 17. It provides geochemical maps, descriptions of the spatial distribution of each element and summary statistics for each element.

Assessment of carbon stocks in soils

Accurately assessing stocks of carbon in the soil is important because in many areas the soil is expected to emit carbon into the atmosphere as temperatures rise and microbial activity increases. This is reflected in our recent publication on the importance of inorganic carbon in soil carbon databases and stock estimates.[5]

[5] http://nora.nerc.ac.uk/15007

Minerals

Minerals risk list 2011

Our 'Risk list 2011'[6] gives a quick indication of the relative risk (in 2011) to the supply of the chemical elements or element groups that we need to maintain our economy and lifestyle. The position of an element on this list is determined by a number of factors that might impact on supply such as the abundance of elements in the Earth's crust, the location of current production and reserves, and the political stability of those locations. The risk list highlights a group of elements where global production is concentrated in a few countries. The restricted supply base combined with the relatively low political stability ratings for some major producing countries significantly increase the risk to supply. The list highlights economically important metals which are at risk of supply disruption including

[6] http://nora.nerc.ac.uk/17409

rare earth elements, platinum group metals, niobium and tungsten. The list also shows the current importance of China in the production of many metals and minerals.

Mineral safeguarding

Mineral resources are finite and can only be worked where they occur. Increased pressure on land use in the UK can result in mineral resources becoming sterilised (through restricted access) by other forms of development. When included in the planning process, mineral safeguarding can help avoid unnecessary sterilisation by providing a mechanism which allows for the consideration of mineral resources in the decision-making balance.

We published a second edition of 'Mineral safeguarding in England good practice guide'.[7] This edition, which has been updated and its content expanded, outlines the national approach to planning for minerals, taking into account the need to safeguard and conserve mineral resources in accordance with the principles of sustainable development. It addresses, among other things, the issues of the loss of access to mineral resources by development, a concept known as 'mineral sterilisation' and aims to negate future problems caused by the effects of unnecessary sterilisation by providing a stronger national policy for the 'safeguarding' of minerals. This document provides advice and supporting case studies for the implementation of national policy on mineral safeguarding and is available for download.

Critical resources

We have published a new guide to niobium and tantalum and their occurrence on our www.MineralsUK.com website. These little-known metals have some unique properties which make them essential ingredients in a wide range of products, from mobile phones to artificial hips. This publication provides an authoritative guide to the origins, production and trade of these important metals, at a time when access to some of these so-called 'critical metals' is causing particular concern.

In view of the continuing global interest in rare earth elements, we have released an update to our Rare Earth Elements profile (also available as a free download from www.MineralsUK.com). With growing concerns, volatile prices and a multitude of new projects, there continues to be a great deal of media attention on the rare earth

[7] http://nora.nerc.ac.uk/17446

Mobile phones are among a wide range of hi-tech products that rely on critical resources like niobium and tantalum for their manufacture.

elements. The REE update includes a new section on China's rare earth industry, a new map of global REE deposits as well as updated information on the more advanced projects, production, trade and world resources of REE.

Advice to government

The Department of Communities and Local Government (DCLG) published the results of an Aggregate Minerals Survey for England and Wales that we undertook for the Welsh Assembly Government and DCLG. These help monitor the effectiveness of national minerals policies and feed directly into future government guidelines for aggregates provision.

Working with Green Balance and Capita Symonds, and funded by the Department for Environment, Food and

Crystals of allanite, a source of Rare Earth Elements (REE), associated with albite and quartz in an open cavity. Arran, Scotland.

Dredging for aggregates on the Thames near Greenwich.

Rural Affairs (Defra), we produced a major research report which presents an evidence-based analysis of the likely patterns of aggregate supply over the next 30–40 years. This research highlights where and why supply problems can be expected to arise in the future and it suggests ways of easing the transition where continuity of supply could be at risk.

Minerals in Northern Ireland

Northern Ireland has the most varied geology of any area of comparable size in the UK and has a long history of mining base metals, iron ore, coal and salt. The Geological Survey of Northern Ireland (GSNI) provides technical advice to Northern Ireland's Department of Enterprise, Trade and Investment on the issue and management of Mineral Prospecting Licences. Gold mineralisation has been the principal target of prospectors in recent years and currently there is one mine in production and another prospect at an advanced stage of evaluation. Some 49% of Northern Ireland is licensed for exploration, a high level prompted by the results of GSNI's Tellus Project. Some licences fall within or close to environmentally sensitive areas and GSNI works closely with the NI Environment Agency to ensure environmental compliance.

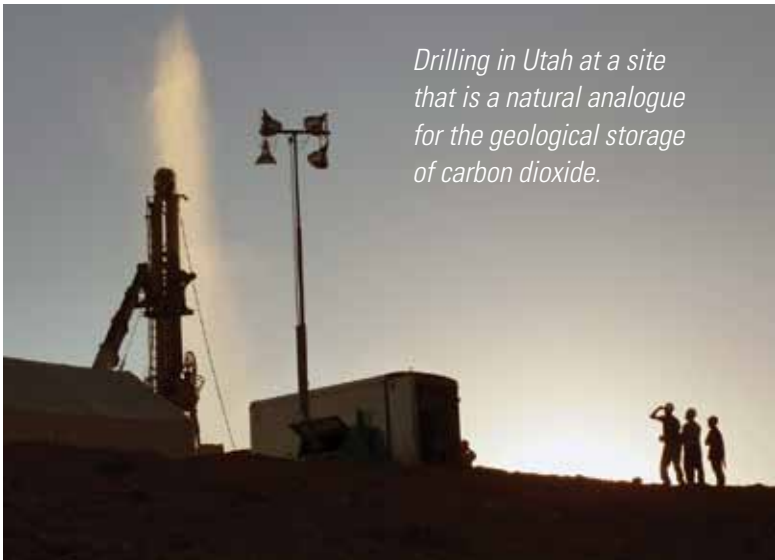
The new Mineral Resources Map of Northern Ireland, commissioned by the Department of the Environment and produced by the BGS and with GSNI, provides planners, industry and the wider community with a powerful new tool to assist in decision-making related to mineral supply and protection of the environment. Effective planning for the sustainable development of mineral resources in Northern Ireland requires knowledge of both their extent and location. The mineral resources map will allow all stakeholders to visualise the distribution of mineral resources and to relate them to other forms of land-use (such as urban areas or nature conservation areas) or to other factors (such as transport infrastructure). The Mineral Resources Map of Northern Ireland comprises six sheets, one for each county (including county boroughs) at a scale of 1:100 000. The mineral resource data depicted on these maps are also available in a digital format for use within a geographical information system. The resource maps for Northern Ireland are now available as downloads from MineralsUK.com and the NERC Open Research Archive.[8]

[8] http://nora.nerc.ac.uk/18973, 18979–81, 18983, 18984

Waste

Managing radioactive waste

About 20 radioactive waste disposal specialists from around the world attended a training workshop organised by the BGS on behalf of the International Atomic Energy Agency on the 'Role of Natural Analogues and Safety Indicators'. The course included lectures and practical experience relating



Drilling in Utah at a site that is a natural analogue for the geological storage of carbon dioxide.

to analogues of geological disposal facilities for radioactive waste that help to demonstrate the safety of such facilities over geological timescales.

The BGS is also a key partner in a number of international projects undertaking research into the safe geological disposal of radioactive waste. As part of the Fate of Repository Gases (FORGE) project funded by the European Commission, our scientists have been working on the development of a new conceptual model of gas flow in clay rich rocks. Radioactive waste held in a geological disposal facility will need to be securely contained for hundreds, perhaps thousands, of years. By studying the movement of gas through the rock, scientists can identify the geological barriers that need to exist to contain the material securely and prevent its escape into the rock surrounding the disposal facility.

Comparing the geological disposal of carbon dioxide and radioactive waste

We have been involved in a number of initiatives and workshops that have compared the deep geological disposal of both radioactive waste and carbon dioxide (carbon capture and storage, or CCS). While the approaches and techniques of these two industries are different, there are many similarities between them and opportunities for lessons learned from one sector to be applied in the other. The deep geological disposal of radioactive waste is a mature industry, having been actively under consideration and development for over 30 years, while CCS is a comparatively young industry. An outcome from one of these workshops was a book 'Geological Disposal of Carbon Dioxide and Radioactive Waste: A Comparative Assessment' that includes a chapter on 'Environmental Issues in the Geological Disposal of Carbon Dioxide and Radioactive Waste'[9] examining some of the environmental factors and the similarities and differences between the two sectors.

Gas migration in shales

Recent findings from experiments in our Transport Properties Research Laboratory (TPRL) have given substantial weight to the concept of gas migration through shales by way of 'dilatant pathway formation'. Traditional

Gas escape from a Callovo-Oxfordian shale while submerged in a glycerol bath. The sample had previously been subjected to a gas injection test at in situ conditions. The localised nature of the gas escape hints at the mechanism of gas flow through the shale.

modelling concepts used for such materials assume the displacement of one fluid by another as the primary mechanism of gas transport in saturated shales. However, recent findings from the TPRL's custom-designed Stress Path Permeameter have clearly demonstrated that this is not the case. Instead, gas flux increases as the flow opens a series of pressure-induced pathways. These are accompanied by an increase in sample volume, detected by the highly sensitive measurement devices incorporated in the apparatus, as the sample expands to accommodate these pathways.

Observations from this and other experiments in the TPRL indicate that these pathways are an important feature of multiphase fluid flow in low permeability materials. Pathways may also exhibit time-dependent self-sealing behaviour, leading to a contraction of the sample as they close. These results demonstrate that the coupling of gas flow to volume change must be considered in the development of numerical models used to describe these systems.

[9] http://nora.nerc.ac.uk/13800

Groundwater flooding in a garden in Oxford, July 2007.

Water

Groundwater Droughts

The UK has experienced several groundwater droughts over recent decades; our hydrogeologists have investigated some of these to understand better how future groundwater droughts may develop. Working with CEH, we produce a monthly review of groundwater levels in the UK, and have now created a web-based tool showing groundwater levels from 1970 which indicates areas with exceptionally high and low groundwater levels. As well as providing water for domestic, industry and agricultural use, groundwater helps to maintain ecologically important flows in many of our rivers during periods of drought. In these ways, groundwater provides the UK with resilience to droughts. We are currently undertaking a systematic analysis of groundwater droughts in the UK for the whole of the twentieth century. By investigating the relationship between the length of droughts and the area they affect we aim to improve the monitoring and prediction of groundwater droughts. This work will be published in 2012.

Advice to government

The BGS coordinated the successful scientific peer review of revised Water Framework Directive technical guidance documents and the supporting evidence base in preparation for the second cycle of river basin management planning (2012–16).

Our Head of Groundwater Science, Rob Ward, chaired an EU Working Group which developed recommendations for amendments to Annex I and II of the EU Groundwater Directive (2006/118/EC). He was also principal author of the final report from the Working Group (December 2011) which presented the outcomes for further consideration as part of the European Commission's formal review of Annex I and II. The Groundwater Directive on the protection of groundwater against pollution and deterioration is one of the daughter directives of the EC Water Framework Directive. Its purpose is to establish specific measures to prevent and control groundwater pollution. Annex I establishes groundwater quality standards that must be applied as part of the assessment of chemical status for groundwater bodies. Annex II establishes the framework for defining and reporting threshold values. Threshold values must be established for all pollutants (and indicators of pollution) which put groundwater bodies at risk of failing to meet the objectives for good chemical status.

Groundwater flooding susceptibility map

Groundwater flooding can cause significant social and economic disruption and is a threat in many areas of north-west Europe, including the UK. For example, it is estimated that 380 000 properties located on the exposed Chalk of southern England are vulnerable to this form of flooding. We have produced a groundwater flooding susceptibility map covering Great Britain and this is being used widely by local authorities and the environmental regulators as the EU Floods Directive requires the risk of groundwater flooding to be assessed.

Future flows and groundwater levels

We have collaborated with CEH and Wallingford HydroSolutions (WHS) on the Future Flows and Groundwater

Levels project to assess the impacts of climate change on the water resources of Great Britain over the twenty-first century. The £0.75 m project was co-funded by the Environment Agency, Defra, UK Water Industry Research, BGS, CEH and WHS. It has undertaken the first consistent, national-scale assessment of the impact of climate on river flows and groundwater levels, using the Met Office's latest probabilistic climate projections (UKCP09) for which we led the simulation of impacts on groundwater. The results of the work were incorporated into the recent UK government's Water White Paper. Two peer-reviewed journal papers about the groundwater modelling will be submitted to a high-impact hydrological journal in 2012. The results of the study have been made available to the public through dedicated pages on the CEH and BGS websites. The results were also disseminated at special workshops to the Environment Agency and water companies.

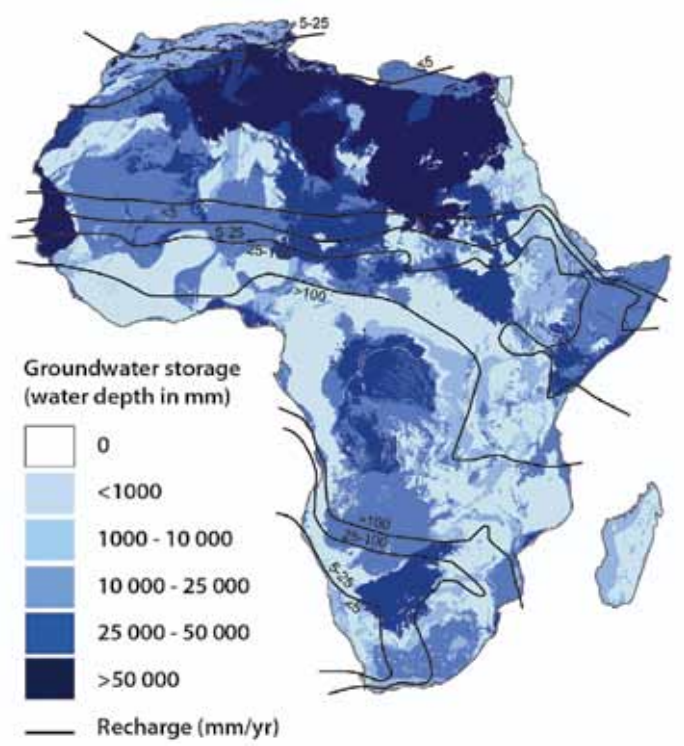
Climate change

Groundwater resilience in Africa

A team led by BGS scientists has shown how groundwater can be used to improve the security of drinking water across Africa. Groundwater provides most of the domestic water supply in rural Africa and supports poverty reduction through irrigation. Climate change along with rapid population growth are likely to impact all water resources, but the response of groundwater will be slower than that of surface water and this could provide a potential buffer to support adaptation strategies.

The aim of the project, funded by the UK Department for International Development (DfID), was to improve the understanding of the resilience of African groundwater to climate change and how groundwater can be used to develop climate adaptation strategies. We have undertaken a series of studies in Nigeria, Mali, Tanzania, Uganda and Ethiopia which show that water supplies based on groundwater are much more resilient to drought and climate change than other sources. We identified a further link between these more reliable, secure water supplies and improved health.

As part of this work, the BGS developed the first quantitative maps of groundwater resources for Africa. These showed that the volume of water stored naturally underground in cracks and pore spaces in rocks was approximately 20 times the water visible in rivers and lakes. Many of the countries thought of as chronically water scarce have large reserves of fossil groundwater. The maps also show that across Africa it is generally possible to successfully drill boreholes for drinking water, but finding high borehole yields for intensive irrigation will be more problematic.

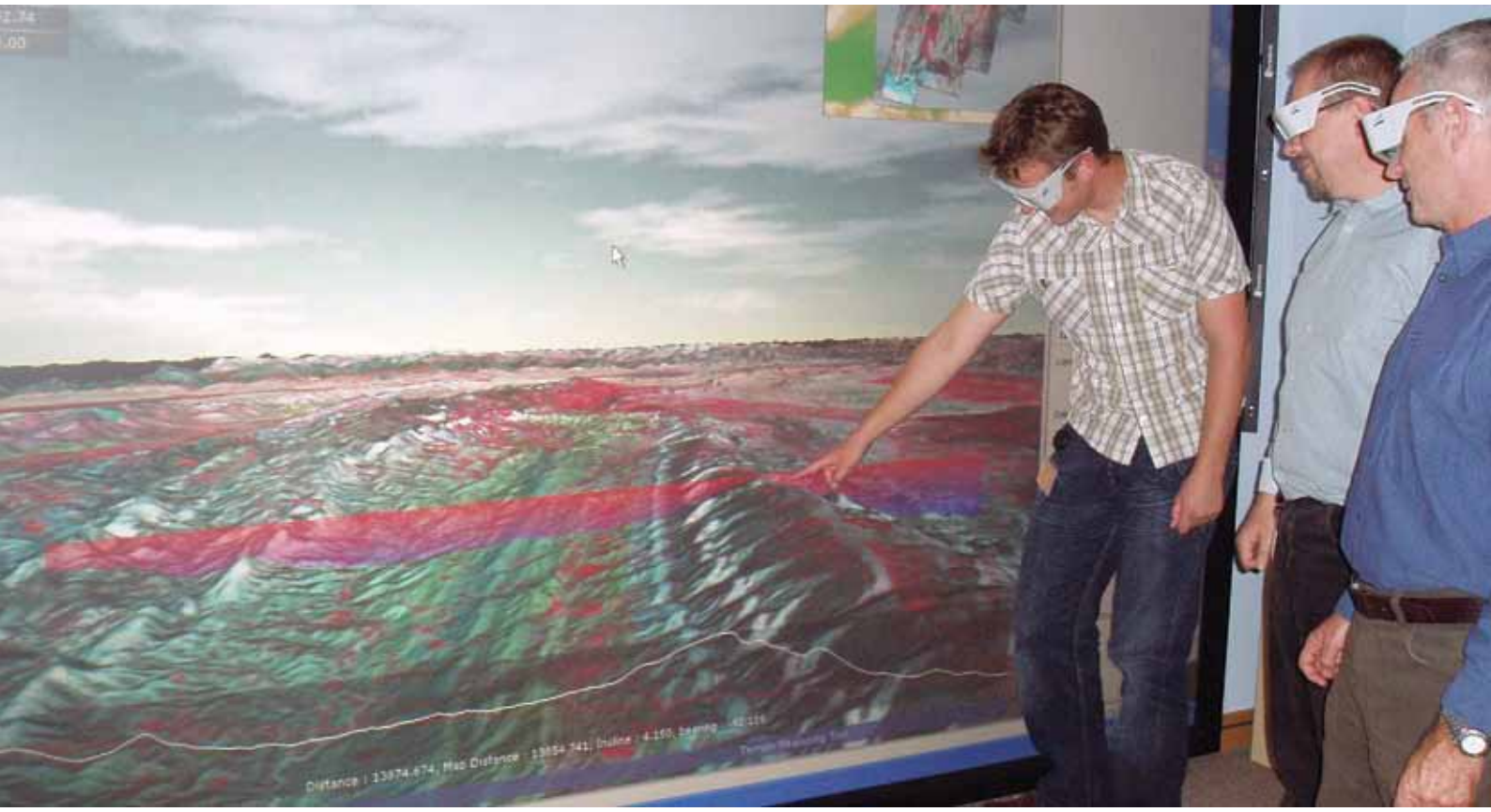


The storage map shows that there is considerable groundwater storage in Africa — 0.66 million cubic kilometres. This is more than 100 times the estimated annual renewable freshwater in the continent, and 20 times the water stored in African lakes.

Mangroves, termites and the carbon cycle

Mangrove forests play a key role in the cycling and storage of organic carbon in tropical coastal ecosystems. The chemical composition of mangrove sediments is known to depend on the proportions of leaf, wood and root matter, their resistance to breakdown by animals, fungi and bacteria, and tidal movement and redeposition. The role of insects like termites in these decay processes is less well known, because little direct evidence of the breakdown of lignin in woody tissues (as opposed to leaves and soil) by termites has been found.

We looked at the chemical transformations caused by the digestion of *Nasutitermes acajutlaea*, a termite known to feed on decaying wood, and the sources of the mangrove litter it used. These studies will help us to understand better the sources and processes affecting organic matter accumulation in the sediments. Using bulk carbon-13, carbon/nitrogen ratios, stable carbon isotopes, alkaline copper oxide oxidation and solid state carbon-13 nuclear magnetic resonance analysis, we have characterised the first stages of decay initiated by wood-decaying termites, a key step in understanding early diagenesis within mangrove systems.



GeoVisionary software allows geological data to be overlaid on to a Digital Elevation Model and visualised in a 3D virtual environment, and is increasingly used in industry and other geological surveys.

Technologies

IMAGER

The Investigation and Monitoring of Aggregate Deposits Using Geo-Electrical Resistivity Imaging (IMAGER) project was funded by the Department for Environment, Food and Rural Affairs (Defra), with support from industry partners, to develop Automated Time-Lapse Electrical Resistivity Tomography (ALERT) technology for mineral industry applications. ALERT employs field sensor networks and instrumentation that are permanently installed and are interrogated remotely via wireless telemetry, to enable the 4D monitoring of subsurface processes at high temporal and spatial resolutions. We have successfully established proof-of-concept for the use of ALERT to image complex groundwater processes associated with quarry dewatering, which can be difficult to monitor using conventional point monitoring.

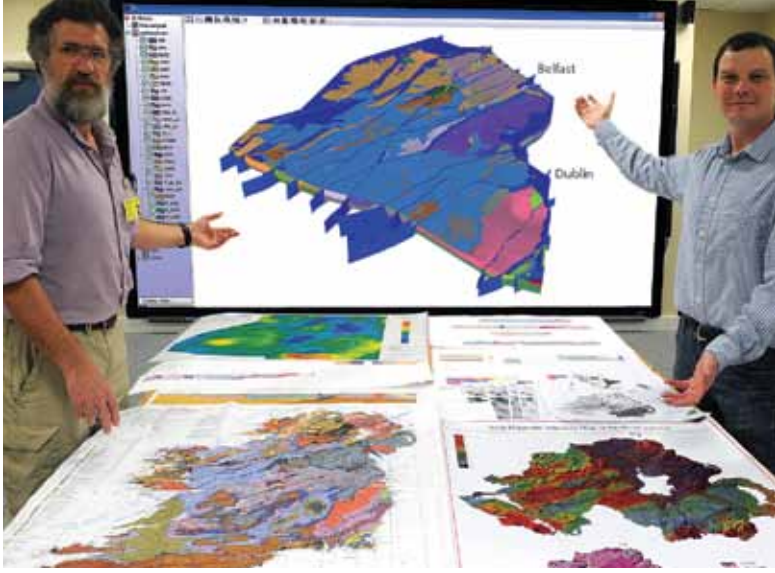
GeoVisionary

This software, which we developed jointly with Virtalis, enables the visualisation of Digital Elevation Models and allows other data to be overlaid on to it, along with three-dimensional models of geological formations, giving a complete three-dimensional picture of a geographical area. GeoVisionary is increasingly used in other geological surveys and private industry. Recent examples include:

- Tethys Petroleum, for exploration in southern Tajikistan.
- The French radioactive waste disposal agency to visualise and monitor over 3000 rock-experiment sensors in their underground research laboratory.
- Mapping the geology of Mars in a project funded by the European Space Agency.
- Vale Mining in Brazil and Anglo American in South Africa for mine management, including surface assets and 3D geological models.
- USGS Alaska Science Center for 3D environmental and geological data integration and virtual fieldwork in inaccessible areas.
- Scottish and Southern Energy in a project related to two pumped storage schemes in the north of Scotland.

Permafrost-CRI

With funding from a NERC Technology Proof of Concept research grant, we are working with the University of Sussex and University of Bonn to adapt our Capacitive Resistivity Imaging (CRI) technology for the remote spatial and temporal monitoring of permafrost. Permafrost is soil which has been at or below the freezing point of water for two or more years. Most permafrost is found in land close to the North and South Poles, but alpine permafrost may be found at a high altitude at lower latitudes. Melting permafrost is not only an indicator of global climate change, but also presents a threat to the stability of civil engineering infrastructure such as transport networks, buildings and settlements. In alpine regions, thawing permafrost can precipitate rock falls and related geohazards such as flooding. The thermal state of permafrost is controlled by the freezing or thawing of pore water. These processes can be directly related to changes in ground resistivity and can therefore be tracked remotely using permanent in situ sensors and wireless telemetry (GSM, GPRS) in a similar manner to our Automated Time-Lapse Electrical Resistivity (ALERT) field observatories.



The crustal-scale, 3D model of the north-eastern half of Ireland. © GSNI/DETI.

Proof-of-concept and prototype capability is being validated in laboratory experiments that simulate permafrost growth, persistence and thaw in bedrock. The project is adapting BGS-designed CRI technology as this uses non-contacting, capacitive sensors to image the subsurface. This approach eliminates the need for intrusive probes and overcomes the problem of the extremely high or variable contact resistances that are associated with frozen ground. Our existing CRI instrumentation was designed for one-off manual surveys with a small number of mobile sensors. Based on the results, a viable multisensor automated time-lapse CRI measurement system will be designed.

Crustal-scale 3D model

The Geological Survey of Northern Ireland (GSNI) in collaboration with the BGS and the Geological Survey of Ireland have built a crustal-scale, 3D model of the north-eastern half of Ireland. This first build was funded by the Tellus Project and was made using GSI3D software developed jointly by the BGS and INSIGHT GmbH. Currently, the model comprises a System-based stratigraphy, and an array of regionally important faults that divide the model into component blocks which share a recognised geological history. Stacked surfaces in the model represent the base and areal extent of individual geological units. The aim is to provide a model that can be used as a context for the widest possible range of larger-scale models relevant to geological survey, investigation, research and education. The model will also be a framework within which the geological community can communicate effectively with government and industry. A 3D pdf is available on request from GSNI and more information on the model and other Northern Irish 3D models is available at: www.bgs.ac.uk/gsni/geology/3d/

Information and Knowledge Exchange

iGeology

Our iGeology app was voted the Community Favourite Mobile app at the ESRI International User conference in San Diego, California in July 2011. The award was presented to the lead developer Wayne Shelley in recognition of the innovative approach used in its design. The app allows users to interrogate a geological map and related databases to help them understand the environment and landscape around them.

Darwin's lost fossils found

A 'treasure trove' of fossils including plant specimens collected by Charles Darwin, have been rediscovered. The fossils, which had been 'lost' for 165 years, were unearthed in a cabinet within our vast fossil collection by Dr Howard Falcon-Lang, a palaeontologist at Royal Holloway, University of London. They have now been registered and photographed and are available for viewing by the public through a new online museum exhibit. The discovery was reported extensively in the media, both in the UK and overseas, and a film crew from CBS News visited our Keyworth headquarters to report the find.

Improved user access to our data

We have redesigned the entry page to our data holdings to improve visibility and navigation. We are a data-rich organisation with over 400 major datasets in our care, including environmental monitoring data, digital databases, physical collections (borehole core, rocks, minerals and fossils), records and archives. Our data are managed by the National Geoscience Data Centre, and a catalogue of our data holdings is now available on the NGDC web pages at www.bgs.ac.uk/ngdc

Dr Howard Falcon-Lang interviewed by CBS News in the National Geological Repository at Keyworth about his discovery in the BGS collections of fossil specimens collected by Charles Darwin (left). One of the thin sections of fossil plant material prepared for Darwin and bearing his name inscribed on the glass (right).

Indicative atlas of radon in Scotland

In collaboration with the Health Protection Agency, we have produced an indicative atlas of radon in Scotland. The associated report (HPA-CRCE-023, available through www.hpa.rg.uk) presents an overview of the results of detailed mapping of radon potential in Scotland. This is defined as the estimated percentage of homes in an area at or above the radon Action Level. It is based on the measurement of radon in over 19 000 homes. There is also a digital map, which defines areas in Scotland affected by high levels of radon. This includes much more detail than could be shown in an atlas and is published as a dataset for geographical information systems. The estimated radon potential for an individual home can be obtained through the website www.UKradon.org

Soil Portal

The NERC Soil Portal provides a means of visualising the properties of soils in the form of maps. It includes our own Soil Parent Material Model, which looks at the upper two to three metres of the subsurface incorporating the weathered rocks or deposits from, and within which, soil has formed. In the UK these materials frequently provide the basic foundations of soil, influencing texture, structure, drainage and chemistry. Following its launch in March 2011, we have spent the past 12 months creating new and improved spatial data with CEH to underpin the portal and forthcoming smartphone application. The new content comprises updated soil-parent material attribution coupled with new interpolation of the countryside survey dataset, including new maps of microbial biodiversity and new joint habitat–geology maps. These new maps, representing the first models of the joint BGS-CEH ECOMAP project, were published on the portal in April 2012 alongside a number of other updates designed to broaden the range of available soil-related resources and to improve the functionality of the web pages.

Trace element deficiencies by iPad

The Geological Survey of Northern Ireland (GSNI) has developed a range of maps and a viewing application for Morton Seeds that displays soil geochemistry collected as part of the Tellus Project in order to demonstrate trace element deficiencies using an iPad. The application overlays customer details on maps of calcium, magnesium, pH and selenium and is used both for planning, and in the field, by Morton's sales team to make informed decisions on farming supplements used in agricultural industry.

Science facilities

Role of biofilms in fluid transport through rocks

Studies of the potential environmental consequences of carbon capture and storage technologies to address climate change and radioactive waste disposal focus, to a large extent, on their physical and chemical impacts within stable geological formations, with associated monitoring systems to assure that no significant carbon dioxide leakage occurs. The role of micro-organisms in subsurface transport, and biofilm formation in geological materials, are key considerations because of their potential to modify the way chemical elements move through porous and fractured rock materials. In a novel application by our Geomicrobiology Laboratory, synthetic groundwater is being inoculated with a biofilm-forming microbe, *Pseudomonas aeruginosa*. Samples are removed sequentially during

Private water supplies: field chemistry in east Cornwall.

the experiments, and biofilm colonisation is examined. A preference for bacterial colonisation on smooth surfaces and in more porous rock types has been observed. Associated biofilm typically traps rock fines that have been mobilised from other sample materials, indicating that initial bacterial colonisation occurs at sites with direct exposure to nutrients. This work shows that biofilms have a high capacity to bind to mineral surfaces and that rock pores can be blocked by biologically-derived material, altering the transport properties of geological materials.

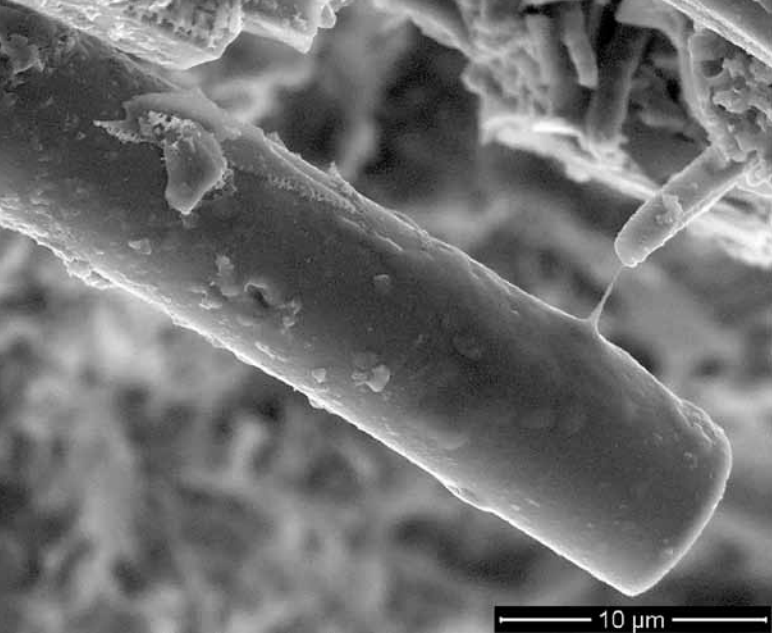
Biogeochemical gradients and radionuclide transport project

The current UK concept for the disposal of low and intermediate level radioactive waste involves a geological disposal facility (GDF) located hundreds of metres below ground. Large volumes of concrete and cement-based material will be used in any GDF construction and, after closure, the material will saturate with groundwater, which will eventually migrate into the rock surrounding the GDF. As part of the NERC-funded Biogeochemical Gradients and Radionuclide transport (BIGRAD) project, we are conducting a series of experiments to examine how evolving alkaline cement leachates react with the host rock surrounding a GDF. Fluid samples are collected throughout for chemical analysis, and solids examined on completion, so that changes in the chemical, mineralogical and physical properties can be monitored. Reactions occurring between the alkaline cement fluids and the rock will be critical controls on the behaviour and transport of the radionuclides within the waste, and thus need to be considered to ensure no radioactive waste escapes the GDF and poses a threat to the population and the environment.

Quality of drinking water in Cornwall

A survey of private water supplies in east Cornwall undertaken in 2011 with the Health Protection Agency and Cornwall Council has confirmed that the geology of Cornwall has contributed to increased levels of metals and minerals present in some private supplies. New private water supply regulations, which came into force in 2009, set out water quality standards and place a responsibility on local councils to complete an assessment of the risks to the quality of private drinking water supplies in their areas by January 2015. We collated historical water chemistry data and planned a survey campaign that was representative of the varied geology and geography across east Cornwall. The survey included collecting and analysing water samples and the production of interpretative data tools, including geology–water data maps. More than two-thirds of the supplies tested met standards set by the Private Water Supplies Regulations 2009, and in these cases householders received a letter explaining that no further action was required. Where water samples exceeded the standard, householders were given specific advice about next steps and health information. Thanks to this interagency scientific collaboration and follow-on investigative work, the partners aim to predict the areas where it would be prudent to test for substances such as nickel and arsenic, that have not previously been tested for in Cornwall. This in turn will allow householders and local Councils to assess the potential risks, and decide if there is a need to test for other parameters in the future.[10]

[10] www.hpa.org.uk/ProductsServices/ChemicalsPoisons/Environmental-PublicHealthTracking/ArsenicInPrivateDrinkingWaterSupplies/



Biofilms: SEM showing bacterial colonisation of a diatomaceous mudstone.

Bioaccessibility of arsenic and lead in soils

Research shows that, on average, we consume 100 mg of soil from our local surroundings every day. Soil contains a number of chemical elements that are harmful to human health; the two of most concern in the UK are arsenic and lead. Whether contaminated soils pose a human health risk depends on the potential of the contaminant to leave the soil and enter the bloodstream. As a result there is a clear need for a practical methodology to measure the fraction of the contaminant in the soil that, through oral ingestion, is soluble in the human body and is available for absorption (known as the bioaccessible fraction). Using data from testing of the archived soil samples from our Geochemical Baseline of the Environment programme, we have developed a methodology which combines data on bioaccessibility and soil geochemistry with soil–parent material geology to map the bioaccessibility of arsenic, lead and cadmium in England and Wales. This is gaining wide acceptance in Europe as a standard procedure. Another research project, commissioned by National Grid: Gas, on the development of a bioaccessibility test to aid in human health risk assessment and brownfield land reclamation recently won an innovation award at the Parsons Brinckerhoff 2012 Awards Ceremony.

NERC Isotope Geosciences Laboratory

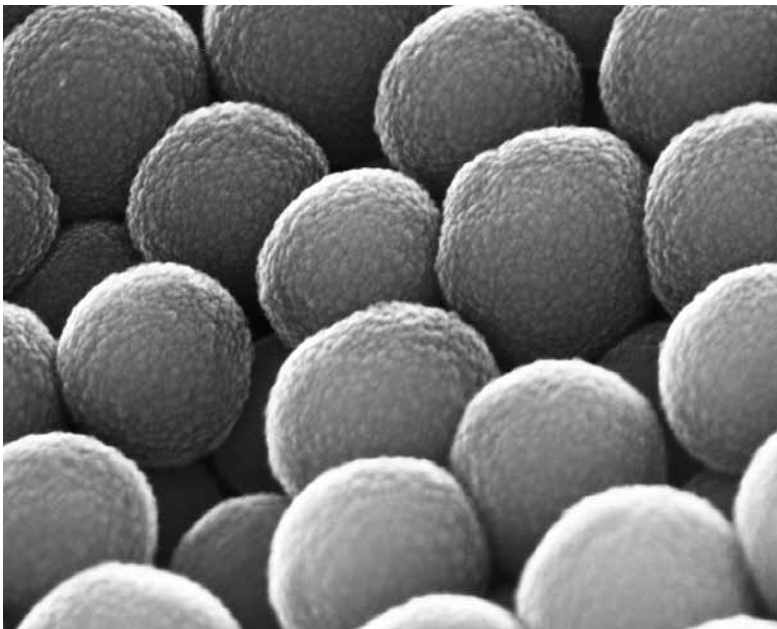
The NIGL is a stable and radiogenic isotope laboratory facility focusing on environmental change, chronology, and science-based archaeology, in a collaborative research environment, including a strong focus on training Ph.D. students.

International comparison of oxygen isotope compositions from biogenic silica

A recent paper by NIGL scientists compares the existing methods of oxygen-isotope analyses of opal-A and aims to characterise additional possible working standards to calibrate the oxygen isotope analysis of biogenic silica.[11] Six potential working standard materials were analysed repeatedly against the existing reference material (NBS28) by eight participating laboratories using their specific analytical methods. The materials cover a wide range of oxygen isotope values and include diatoms (marine, lacustrine), phytoliths and synthetically produced hydrous silica. Despite procedural differences at each laboratory, all methods are in reasonable agreement with a standard deviation for oxygen isotope analysis values between 0.3 and 0.9‰. Based on the results, we propose four additional biogenic silica working standards for oxygen isotope analysis, available on request through the relevant laboratories.

[11] http://nora.nerc.ac.uk/15784

The nano-structure of synthetic amorphous silica.



Mount Kilimanjaro from Lake Challa.

Long-term seasonality in equatorial climate

Multiproxy analysis of a well-dated 25 thousand year-old lake sediment sequence from Lake Challa, on the eastern flank of Mount Kilimanjaro in east Africa, reveals the climatic controls that govern both the lake's paleohydrology and the climate-proxy record contained in the mountain's receding ice cap.[12] The oxygen isotope record extracted from diatom silica captured dry conditions during the last glacial period and a wet late-glacial transition to the Holocene interrupted by Younger Dryas drought. Further, it faithfully traced gradual weakening of the southeastern monsoon during the Holocene. Importantly, our lake-based reconstruction of moisture-balance seasonality in equatorial East Africa also helps us understand the oxygen isotope record contained in the ice on Mount Kilimanjaro. Negative correlation between oxygen isotope ratios measured in Kilimanjaro ice cores and Lake Challa diatom silica implies that moisture balance is not the primary climate control on the long-term trend in those ratios observed in the ice core.

Sources of nitrate in Malta's groundwater

Levels of nitrate in Malta's groundwater are among the highest in Europe with median nitrate as nitrogen (NO_3–N) concentrations of 14 milligrams per litre in the main sea-level aquifer, and 37 milligrams per litre in the younger groundwaters of the perched aquifers. As part of a Rural Development Programme for Malta, we investigated the source of this nitrate, with specific emphasis on a combined study of the ratios of the isotopes nitrogen-15:nitrogren-14 and oxygen-18:oxygen-16. In addition to analysing a wide variety of groundwater samples, a special feature of the study was a determined effort to measure, rather than assume (as is common in many studies) those ratios in the major potential sources of nitrate: fertilisers, septic and sewage wastes, animal manures, and soils. The data allow the former two sources to be ruled out and, while some direct leaching of manure-derived nitrate cannot be discounted, suggest that soil nitrification is the major source of nitrate in the groundwaters.[13] Malta has a very long history of cultivation, during which time the soils may have developed high ratios of nitrogen-15:nitrogen-14 reflecting the greater mobility of nitrogen in soils with low carbon:nitrogen ratios. The nitrogen-15:nitrogen-14 and oxygen-18:oxygen-16 values of nitrate in the groundwaters suggest that it is derived by microbial nitrification of organic nitrogen in these soils, with virtually no reduction in nitrate levels by denitrification.

[12] http://nora.nerc.ac.uk/15829

[13] http://nora.nerc.ac.uk/16226

BGS and NERC offices

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environmental Science Centre,
Keyworth, Nottingham,
NG12 5GG
☎ 0115 936 3100

Murchison House,
West Mains Road,
Edinburgh, EH9 3LA
☎ 0131 667 1000

Maclean Building,
Crowmarsh Gifford,
Wallingford, OX10 8BB
☎ 01491 838800

BGS London, Natural History Museum,
Cromwell Road,
London, SW7 5BD
☎ 020 7589 4090

Columbus House,
Greenmeadow Springs,
Tongwynlais,
Cardiff, CF15 7NE
☎ 029 2052 1962

Geological Survey of Northern Ireland,
Colby House,
Stranmillis Court,
Belfast, BT9 5BF
☎ 028 9038 8462

NATURAL ENVIRONMENT RESEARCH COUNCIL

Natural Environment Research Council,
Polaris House,
North Star Avenue, Swindon SN2 1EU
☎ 01793 411500
www.nerc.ac.uk

NERC's research centres

British Antarctic Survey
☎ 01223 221400
www.antarctica.ac.uk

Centre for Ecology and Hydrology
☎ 01491 838800
www.ceh.ac.uk

National Centre for Atmospheric Science
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www.ncas.ac.uk

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☎ 0118 378 6728/8317
www.nceo.ac.uk

National Oceanography Centre
☎ 0151 795 4800 (Liverpool)
☎ 023 8059 6666 (Southampton)
www.noc.ac.uk

British Geological Survey
Environmental Science Centre, Keyworth,
Nottingham, NG12 5GG

Tel: 0115 936 3100 Fax: 0115 936 3200
www.bgs.ac.uk

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