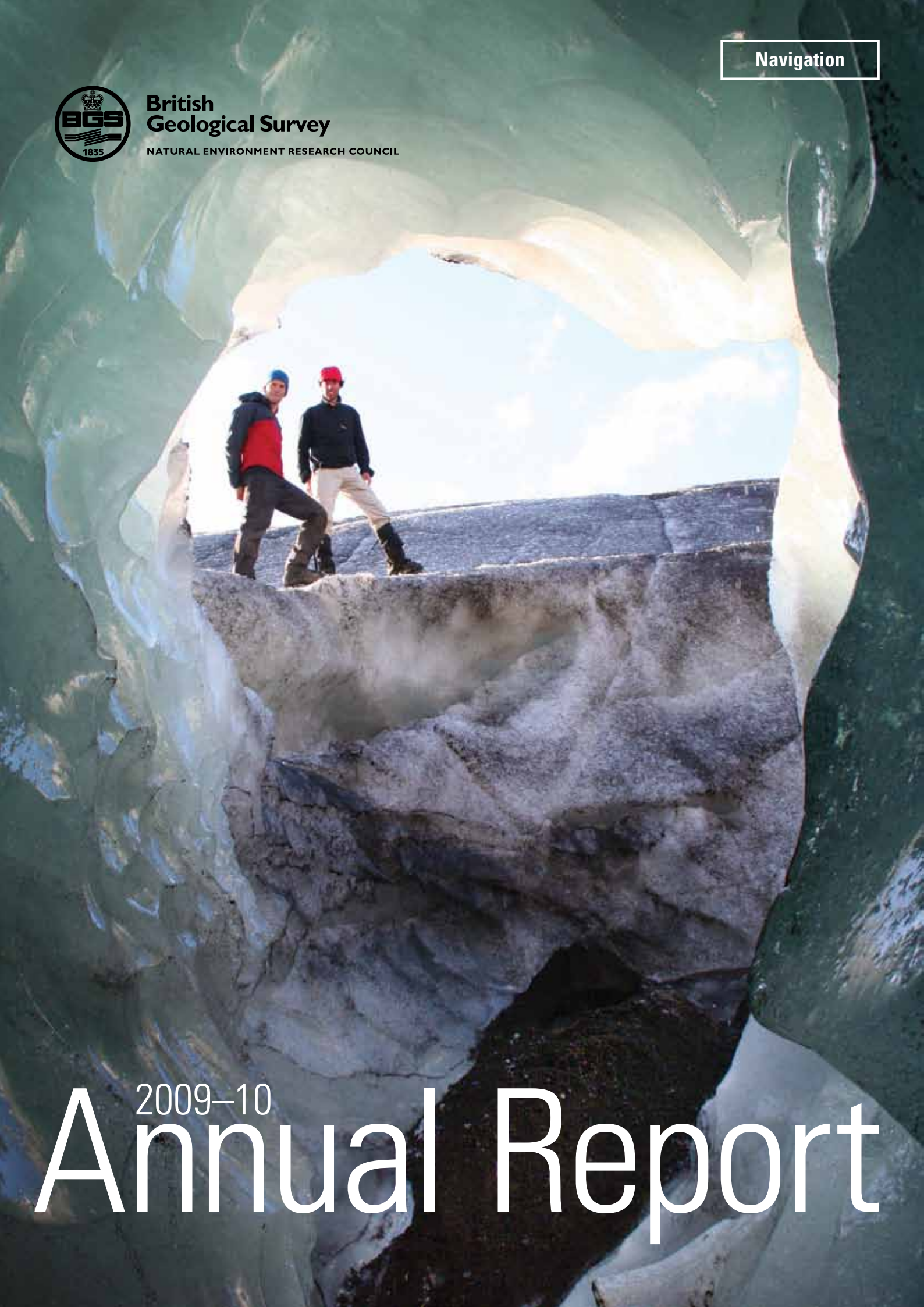
Navigation

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



2009–10 Annual Report

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British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey Annual Report 2009–10

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

Cover: Abandoned glacial meltwater conduit at the BGS Virkisjökull Earth Observatory, Iceland (P766821).
BGS © NERC

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

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

It is 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.

Contents

Next Generation Science for Planet Earth

The BGS's programme is designed to help the NERC deliver its strategic goals

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, we develop the priorities that provide a focus for the marine, polar, atmospheric, geological, terrestrial and freshwater science communities. This research is often multidisciplinary and in collaboration with national and international partners.

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

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.

NERC has six major environmental research centres:

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.

Foreword

Chairman of the BGS Board
Professor Jon Gluyas

It gives me great pleasure to write this foreword and in doing so I wish to begin by thanking my predecessor Derek Davis who stepped down as Chair of the BGS Board in December 2009. Derek brought a steady hand to the Board, which benefited greatly from his experience and knowledge gained through service to the Department of Trade and Industry. My own background differs in that much of my career has been based in the oil industry until recently, when I moved into academia. I trust that my knowledge and skills will complement Derek's and those of my current Board.

Of the many highlights this year, a key event was the opening of the William Smith Building by Her Royal Highness The Princess Royal on 25 June 2009. It is greatly encouraging to see continued investment in the Keyworth site with the award of capital funding for phase 2 of the redevelopment programme, including a new computer suite to serve both the BGS and the wider NERC community, and a second open-plan office building. I greatly welcome plans to extend the national core store facility, which will result in a top-class facility for core examination available for use by industry and academia. When it comes to consolidating the core collections from elsewhere, it will be important to take great care in the planning and execution of such moves to ensure the integrity of some of the more delicate and irreplaceable material.

The BGS has excelled in its role of advising government on issues of national importance this year, commenting with clarity and gravitas on world events such as the Haitian earthquake and Icelandic volcanic eruption. BGS scientists have been in great demand by the media for their expertise in explaining the background to such events to the public.

Of BGS's numerous scientific achievements, the launch of OpenGeoscience in December 2009 is particularly noteworthy. The great demand to access a wide range of data, image and education resources over the Internet, entirely free for non-commercial purposes, is indicative of the tremendous value of this outlet. Many examples of the extensive range of the BGS's work and its application to the world around us are given in this annual report and are readily accessible on the BGS website.

All of these successes were played out against a background of financial constraints, which will continue into the future with the squeeze on public finances. In these circumstances, it is to the BGS's credit that it has maintained its capability to deliver great science and meet its targets within a balanced budget. Given the excellent leadership and outstanding staff I have met during my few months as Chairman, I have no doubt that the BGS will continue to deliver in the future. ■

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The BGS Board 2009–10

The BGS Board was established to support the management and strategic direction of the Survey. Board members are appointed by the Executive Director and are ratified by the NERC. Membership comprises up to ten non-executive members from a broad cross-section of the BGS user community and the BGS Senior Leadership Team.

Board members: non-executive

Mr D Davis	Board Chairman, formerly of the DTI.
Professor J Gluyas	Director of Centre for Research into Earth Energy Systems, Durham University (joined Board as Chairman on 1 January 2010).
Mr P Bide	Department for Communities and Local Government (observer).
Ms T Henton	Environment Agency (joined 1 January 2010).
Mrs R Johnson-Sabine	Vice-President of Exploration, Tethys Petroleum.
Mr D Lovell	Executive Director, EuroGeographics.
Dr R Missotten	Chief, Global Earth Observation Section, UNESCO (joined 1 January 2010).
Mr E Nickless	Executive Secretary, Geological Society of London.
Dr S Paterson	Consultant, formerly Shell (joined 1 June 2009).
Professor S Sparks	Director, Bristol Environmental Risk Research Centre, Bristol University.
Professor P Styles	Director, Environmental, Physical Sciences and Applied Mathematics Research Institute, Keele University.
Professor L Warren	Emeritus Professor Environmental Law, Aberystwyth University.
Professor A Thorpe	NERC Chief Executive or his representative.

Mr Davis's tenure as Chairman ended on 31 December 2009 when he was succeeded by Professor Gluyas. Mrs Johnson-Sabine and Professor Styles retired from the Board at the end of 2009, having served a maximum term of eight years.

BGS Senior Leadership Team

Professor J Ludden	Executive Director.
Professor D Peach	Chief Scientist.
Mr I Jackson	Chief of Operations.
Dr A Howard	Director of Science Programmes.
Dr R Hughes	Director of Information and Knowledge Exchange.
Mr J Murray	Director of Administration.
Mr D Ovadia	Director of Resources and Business.

The Secretariat is provided by the BGS's Senior Leadership Team Co-ordination Unit.

The BGS Board, October 2009 (from top left):

A Howard, I Jackson, P Bide, R Hughes, J Murray, D Ovadia, D Lovell, J Ludden, D Peach, E Nickless, T Henton, S Sparks, S Paterson, R Johnson-Sabine, P Styles, J Cook, D Davis, L Warren (J Gluyas and R Missotten are not pictured).

Introduction

Executive Director
John N Ludden

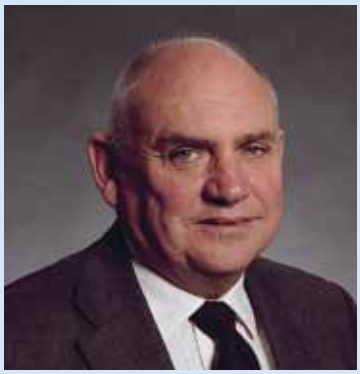
This was not an easy year for the BGS as the UK, in common with much of the world, was in, or starting to recover from, the deepest recession for some time. As we have a mixed funding model, with income from the Research Council, other parts of government, international funding agencies and industry, we have a certain amount of built-in resilience and managed to end our year on budget for resources, with a slight underspend on capital. We achieved this through reducing hiring rates and focusing only on key replacements. We will need to adopt a similar approach in 2010/11, resulting in an overall decrease in the total number of BGS staff, in anticipation of reductions in government spending.

Despite being a smaller organisation we have continued to meet our output targets, with increases in research papers, web hits and new web products. All of this has been coupled with an increasing reliance on the web for delivery of our science in general. We launched the OpenGeoscience site in December 2009 (**www.bgs.ac.uk/opengeoscience**), which proved to be an extraordinary success. Anyone in the world can now access and view our map information at the 1:50 000 scale. We are increasingly making data available for free while, at the same time, focusing sales on high-end specialist products.

Summer 2009 saw the opening of the William Smith Building by HRH The Princess Royal and confirmation of funding from the Natural Environmental Research Council (NERC) to further modernise the Keyworth site and replace or renovate the majority of the existing 1970s buildings. By the end of 2011 NERC will have spent about £25 million in estate development at Keyworth. We will also have moved the contents of three core repositories into a single world-class facility in Keyworth, while maintaining a teaching collection for universities in Scotland and digitising much of the offshore archive.

This volume lays out many of our science highlights from this year. We occupy a unique position in that we are part of a government research council rather than reporting directly to a ministry as most geological surveys do. This provides a challenge, as we need to balance our public good role, such as providing ground stability information for the public, with an applied geosciences research role. Through restructuring of the NERC we are increasingly defining our place in science delivery following the launch of the BGS strategy for 2009–14. The NERC has encouraged its parent department in government, the Department for Business, Innovation and Skills (BIS) to create a BGS Government Advisory Panel in 2009. By meeting with chief scientific advisors from relevant government departments and devolved governments within the UK, this panel serves to advise BGS on the relevance and value for money of our activities on behalf of the nation.

In all of the areas where we operate there is a spectrum from research, through national capability to national good and it is difficult to categorise our science under only one of these headings. Our work on natural hazards during the year provided



" This was the first year of our new strategy and I am pleased to see the engagement of our staff in the creation of a national environmental modelling platform "

Denis Peach, Chief Scientist

" 'Open' would perhaps be the word for this BGS year. OpenGeoscience, a world first, made our core geological datasets accessible to the world. 2009 also saw the completion of a new open-plan building for up to 200 scientists, another significant step taking forward our multidisciplinary approach to geoscience "

Ian Jackson, Chief of Operations

a good example of the interconnections between our national capability in long-term monitoring activities, our pure research and the practical application of these in guiding policy. We were able to draw on our expertise in giving front line advice to government on responding to major earthquakes overseas (for example in Haiti) and the volcanic ash cloud hazard from Iceland; at the same time our scientists were working at the cutting edge of research to understand the distribution and trend in aftershocks from major earthquakes and the physical and chemical controls on the dispersal of volcanic ash. Similarly our geological mapping, despite an increasing focus on targeted strategic mapping, underpins development in key urban areas while simultaneously we are developing new mathematical ways of interpolating the map data in order to make scientific predictions about processes within the bounds of specific rock strata. For example, we have been able to predict the distribution of porosity in Permo-Triassic strata with its implications for water resources and for carbon capture and storage (CCS).

Increasingly, minerals and energy supply are part of government's agenda and, through our specific Minerals, Energy and Marine Science programmes and our international activities, we have been raising the profile of our expertise in these areas. We have made significant progress in building our networks in CCS, both nationally and internationally, and we are developing our expertise in critical raw materials (mineral and aggregates) for Europe. Internationally we have ongoing activities in Nigeria, the UAE and Papua New Guinea, although the volume of work for the World Bank is diminishing. We are reviewing our international strategy in view of changing markets and a developing emphasis on environmental problems.

In the future the UK will be influenced by changes in weather patterns in addition to the stresses imposed by an increasing population. Our research in climate change science, subsurface water resources and shallow marine systems increasingly focuses on the impacts of global change. This work can only be carried out with partners such as the universities, and through a much closer collaboration between research centres and agencies. In particular we are developing increasingly close ties with the NERC Isotope Geosciences Laboratory (NIGL), which is co-located with BGS at Keyworth and a summary of its activities is included in this report.

I strongly encourage you to visit our website where, as described at the start of this introduction, all of our science is now delivered through increasingly innovative approaches. These services include information and knowledge for the specialist, the public and in general learning and development in schools and universities. I would like to thank our staff and our supporting funding and governance bodies for their work in maintaining the BGS at 'the top of its game' through a very difficult year. I hope you enjoy reading through this impressive report which includes only a small selection of our activities for the past year. ■

Science

The BGS Science Programme provides up-to-date knowledge on the geology, environment and natural resources of the UK landmass and continental shelf, and carries out monitoring and research to understand environmental processes and contribute to forecasts of the impacts of natural hazards and climate change. We collaborate with national and international research partners and clients to combine the geoscientific 'evidence base' with high-impact applied research, delivering outcomes that promote the sustainable use of land, energy and natural resources, and living with environmental change.

Programmes

In March 2010, the world's media began to show spectacular and beautiful images of lava fountains from a new fissure eruption in Iceland. By early April, a second phase of eruption had started in a nearby caldera buried beneath the Eyjafjallajökull glacier. Superheated magma and glacial meltwater combined explosively to blast a plume of fine volcanic ash high into the stratosphere. The ash, highly dangerous to jet aircraft, was carried south-eastwards across Europe by the jet stream. Airspace was closed for days, thousands of passengers were stranded across the globe and airlines faced huge financial losses.

We were contacted by the Cabinet Office Civil Contingencies Secretariat on 15 April 2010 for advice on the likely course of the eruption. Subsequently, we have operated at the heart of a multiagency, interdisciplinary team involving the NERC National Centre for Atmospheric Sciences, UK and Icelandic Meteorological Offices, and several universities, to advise government, air traffic control organisations and the media on potential impacts of further eruptions. New concerns are focusing on the neighbouring, much larger Katla volcano, which presents a significantly greater risk of major disruption. Working with the Icelandic Meteorological Office, we have installed new seismic and GPS sensors on Katla to provide early warning of a potential eruption.

The events in Iceland show that geological hazards have no respect for national frontiers. Global population growth, urbanisation and the complex interdependencies of economies, communications and transport systems make society more vulnerable to natural hazards than ever before. Better preparedness and improved risk management requires concerted worldwide effort, and our contribution to international monitoring and research networks in seismic, space weather and volcanological hazards continues to grow. We contributed to the Haiti earthquake relief efforts by assessing secondary hazards posed by landslide reactivation and building damage, using remote sensing data provided through the International Space Charter. In the UK, although earthquakes are considered a comparatively moderate hazard, the risks posed to critical infrastructure such as dams and power generation and distribution systems remain significant, and our monitoring networks have been augmented during the year with microseismic sensors on sensitive structures to provide clearer quantification of risk.

Radioactive waste management and carbon capture and storage present potential opportunities for future, low-carbon energy security in the UK and worldwide. Internationally collaborative research and exchange of know-how is essential to address the key scientific questions on integrity of subsurface containment. We are leading new European projects to assess the role and fate of gases in, or adjacent to, radioactive waste repositories, and to design new systems to monitor real-time carbon dioxide transport through rocks and soils. Newly published research, supported by our unique laboratory capability to simulate biogeochemical conditions in the deep subsurface, has shown that biogenically precipitated minerals can reduce permeability in the rocks surrounding a deep subsurface waste repository and aid containment of hazardous fluids.

The GSI3D consortium was launched during the year to share our groundbreaking developments in 3D modelling software and methodologies among the international geological community. In the UK, modelling has focused on the Thames and Clyde basins and the South Wales coalfield, where a new 3D model is supporting an EU project to evaluate clean coal resources and carbon storage potential. Other models have supported assessments of underground gas storage capacity in north-west England and Northern Ireland, and potential geological reservoirs to store Scotland's carbon dioxide emissions, and have also contributed to the major incident investigation on the Buncefield oil terminal explosion.

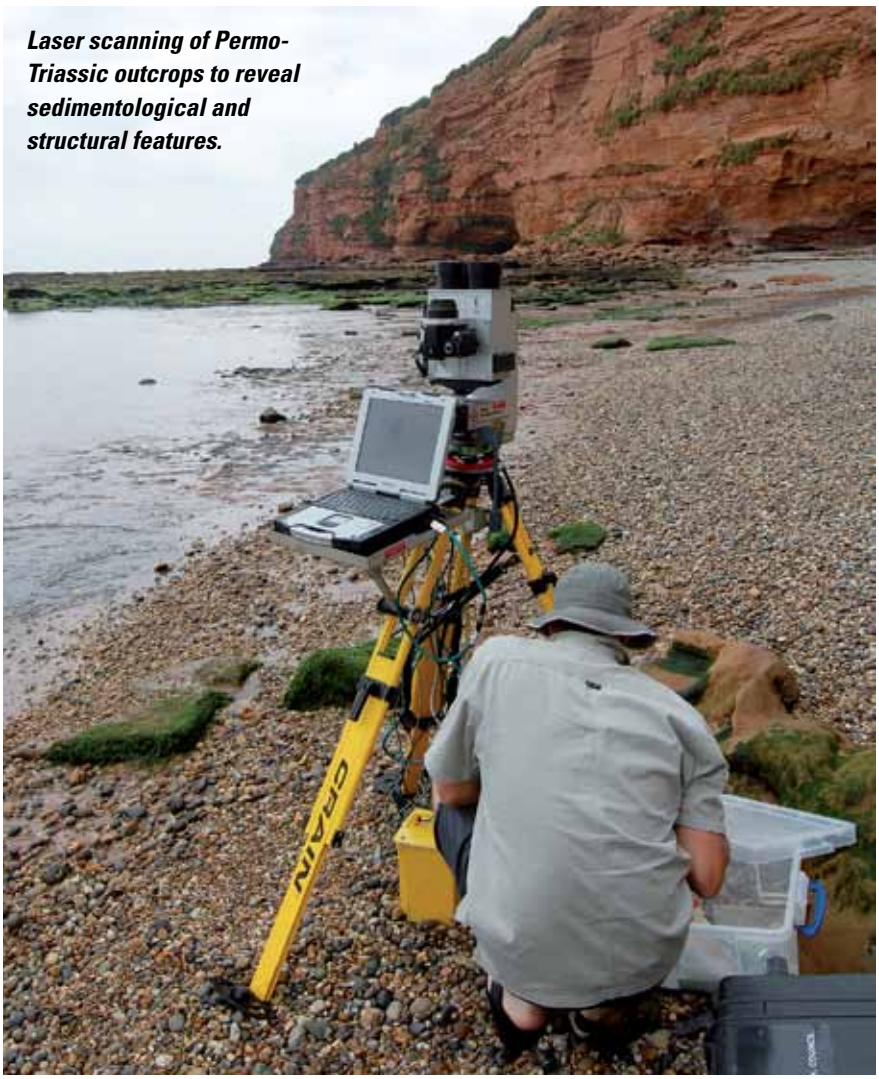
Using our extensive knowledge of global mineral statistics, we have been uniquely placed to make a leading contribution to European assessments of future supply of critical minerals, including rare earth metals. These assessments require strategic forecasts of future supply and demand, informed by foresight of the changing raw materials needs of new technologies.

The nearshore zone is highly sensitive to environmental change including weather and climate, sea-level change and both natural and man-made contamination. Our newly commissioned research vessel, *White Ribbon*, provides new national capability to plug critical knowledge gaps in the nearshore zone, especially seabed sediments, bedforms and shallow geology. New knowledge will enable us to unravel the sensitive record of environmental change preserved in this environment, to inform new scientific research, coastal and estuarine management and conservation strategies, and deployment of marine renewable energy systems.

Our projects to forecast regional impacts of climate change on groundwater resources in Africa have been followed up by recommendations on sustainable water supply systems that are sympathetic to the resources and culture of local communities and to the environment. Follow-up has ensured that international aid has successfully reached its target and delivered the recommended improvements at community level. The ultimate objective of Applied Geoscience for a Changing Earth must be successful outcomes for society and the environment. The following pages emphasise the wider impact of our science programme highlights over the past year. ■

Science Programmes

Geology and Landscape



Laser scanning of Permo-Triassic outcrops to reveal sedimentological and structural features.

The Geology and Landscape programme is the National Capability activity responsible for onshore multidisciplinary surveys including the shallow and deeper subsurface. It provides baseline information targeted on applied geological research. These data are critical for understanding mineral and energy resources, landscape, the potential impacts of climate change and the protection of water and of the natural and built environment. Survey data are released as geological maps and, increasingly, as attributed 3D models. Key activities include the survey of urban and catchment environments, sedimentary basins and superficial glacial deposits.

Geodiversity

We were commissioned by Natural England to survey the geology of Roade railway cutting, a geological Site of Special Scientific Interest (SSSI), near Northampton, which lies on the West Coast main line between London and Birmingham. The cutting is over 1.5 kilometres long and 20 metres deep, and provides an exceptional exposure of the Middle Jurassic Blisworth Limestone Formation. However, portions of the cutting sides were judged to be unstable, compromising the rail communications and signalling infrastructure, and the necessary engineering works proposed by Network Rail, including netting, will make access to the exposed strata virtually impossible in the future.

To preserve scientific knowledge of the protected site, experienced BGS geologists completed a full description of the geology of the cutting, including lithological and biostratigraphical sample collections, and close-up and systematic photography. In order to minimise disruption to rail services, access to the sections was limited to Sundays, generally the early morning hours, using a special, floodlit mobile elevated working platform. The study provides a permanent record of this important Jurassic locality, and has revealed the considerable lateral variability of the Blisworth Limestone Formation. ■

BGS geologist recording the Roade railway cutting section at night; white blobs are snowflakes!

The Menai Suspension Bridge is underlain by a strand of the Menai Strait Fault System; one of the fundamental structural lineaments which record a punctuated history of geological movements throughout the Phanerozoic.

Ancient crustal dynamics in North Wales

New bedrock surveys of Anglesey have focused on the Ordovician succession that underlies much of the central part of the island. Previously surveyed in 1920, and largely unstudied since the 1960s, these rocks lie unconformably on an older subduction–accretion complex and record a history of subsidence along the outer continental margin of what is now southern Britain. The deposits themselves preserve evidence for the complex coupling between a downgoing oceanic slab, subducted beneath southern Britain, and the overlying continental plate and are analogous to modern tectonic processes in south-east Asia. New surveys by BGS geologists have recognised both north-west and south-east margins of a strongly structurally foreshortened basin as well as remnants of the geological succession deposited in the deep basin centre. The overall aim of the fieldwork, in combination with application of modern biostratigraphical tools, is to develop a new dynamic stratigraphy for this succession and to elucidate the complex Ordovician evolution of Anglesey. In combination with a high-resolution airborne geophysical survey of the island completed by the BGS in summer 2009, the geological survey will provide a modern geological and environmental baseline in support of future planning and development needs. ■

Investigating new coal technologies

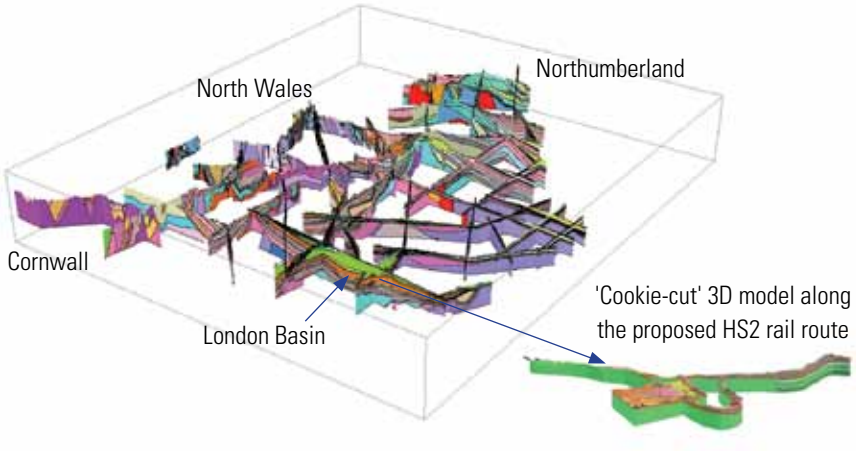
Developing sustainable energy supply is a high priority for the devolved regions of the UK and there is renewed interest in developing clean coal technology, not only for traditional extraction, but also for novel resources and processes such as coal-bed methane and underground coal gasification.

With this renewed interest, a 3D model of the South Wales coalfield basin has been constructed, based on re-examination of boreholes and other subsurface data. Currently, the focus has been on identifying the base of the Coal Measures and correlating two important and laterally extensive coals; the Nine Foot seam and the Five Foot seam. Allied to this has been a study of the British Coal archive to identify physical and chemical properties for inclusion in a new BGS coal properties database which is currently under development. This study has led to the BGS becoming an important partner in SEREN, a major five-year research project led by Cardiff University to investigate the low carbon economy, carbon capture and storage in coal seams and the utilisation of new technologies to exploit coal resources. The South Wales Valleys are an EU Convergence Region and SEREN is funded by the Wales European Funding Office which administers the EU structural funds on behalf of the Welsh Assembly Government, with the aim of providing new employment opportunities. SEREN provides additional opportunities to enhance coalfield geology expertise and engage with the industrial and commercial sectors in Wales to encourage both job creation and provide for a more sustainable future. ■

Understanding the third dimension

We were commissioned by the Environment Agency (EA) to produce a fence diagram 3D model of England and Wales to a depth of about two kilometres. This will enable their scientists and engineers to understand better the major subsurface aquifers, so important for modelling groundwater flow and abstraction management. The model was built using bespoke BGS 3D modelling software (GSI-3D) by a team of experienced regional geologists and modelling experts using geological data in the BGS archives.

Understanding the third dimension is important for national and local engineering schemes such as the proposed High Speed Rail Link (HS2) between London and Birmingham, and beyond. The inset 'cookie-cut' model illustrates our capability to produce bespoke, 'ribbon-like' models of the geology (green is Chalk; brown colours are overlying Tertiary deposits) to assist engineers and planners in making informed decisions on engineering the route. These regional studies and detailed field-based mapping research on the Chalk Downlands feed into our major multidisciplinary projects in the Thames Basin, which focus on detailed 3D modelling to inform development and planning decisions in this densely populated region. ■



Fence diagram 3D model of England and Wales.

Permo-Triassic 3D

During Permian and Triassic times the UK was traversed by a system of rift valleys which formed sites for the accumulation of sand and gravel transported by wind and water under semi-arid climatic conditions. Today the pore space that exists between pebbles and sand grains in these ancient Permo-Triassic sedimentary rocks provides an important underground source of groundwater and natural gas resources and, of increasing importance, a potential underground repository to store the carbon dioxide produced by burning fossil fuels. We are seeking to improve our knowledge of pore space distribution though a greater understanding of the 3D structure and stratigraphy of Permo-Triassic rocks, both onshore and offshore of the UK. The work integrates seismic and borehole interpretation, laser scanning of outcrop and petrographical examination of diagenetic and pore fabrics to understand the complex structure of these deposits at all scales. ■

Appraisal for carbon capture and storage (CCS)

Scotland's First Minister Alex Salmond announced in May 2009 the findings of a study of the opportunities for carbon capture and storage around Scotland. The appraisal of carbon dioxide sources and potential offshore storage sites, options for transporting carbon dioxide and economic models for CCS projects was funded by a consortium of the Scottish Government and industry stakeholders with interests in carbon dioxide capture, transport and geological storage. The BGS, as a member of the Scottish Centre for Carbon Storage (SCCS) with Heriot-Watt University and University of Edinburgh, joined with researchers from Aberdeen and Strathclyde universities and consultants from the oil and gas, engineering and energy sectors to complete the collaborative research. At the high-profile launch event at Edinburgh Castle, the First Minister described the findings as groundbreaking and said 'This report, a unique collaboration between a range of partners from business, universities and research facilities, signals a milestone in Scotland's energy policy'.

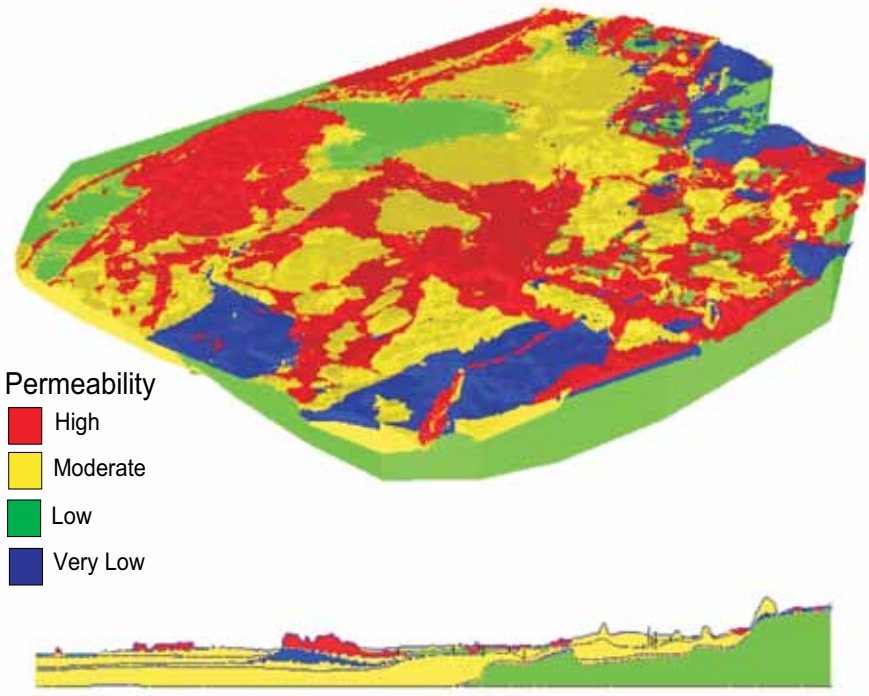
Alex Salmond with report of a study into the opportunities for CCS around Scotland.

The success of the consortium collaboration between researchers at the SCCS, Scottish Government and industry has continued. A second study to accelerate the implementation of operational offshore carbon storage was established in August 2009 and, again, BGS staff have a key role in both the leadership and scientific contribution to the research, which is to be completed by December 2010. ■

High-resolution 3D geological model for flood analysis

Potential river flooding around the town of Forres in Morayshire in the north of Scotland has prompted the construction of the first bespoke linked field survey and 3D geological framework model in Scotland. This was completed by the Quaternary Mapping and Modelling Project and published in the BGS subsurface viewer. The model has combined the results of commissioned studies of site investigations and re-evaluation of pre-existing subsurface data. Early results of these studies have influenced the planned design of flood alleviation measures within the flood-prone ground.

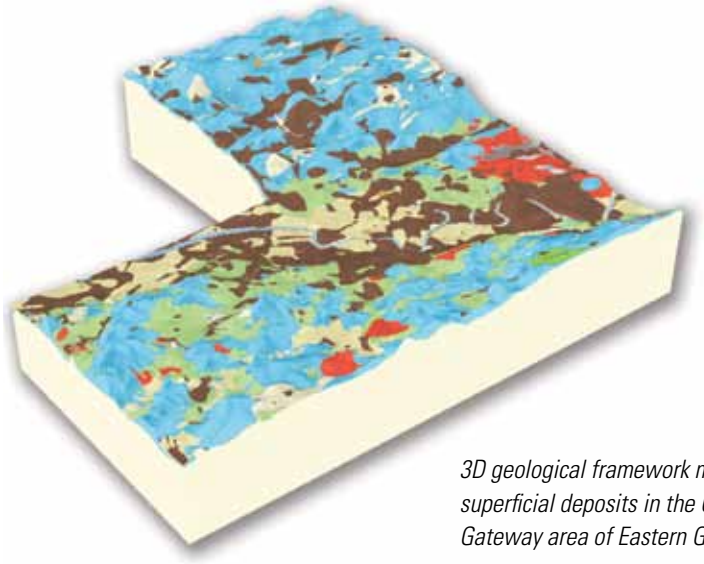
Targeted field investigations by a team of land survey, hydrogeology and engineering geology staff enabled a complex 3D geological framework baseline model to be produced. This is being used to investigate the shallow groundwater component of flooding within the Lower Findhorn catchment. This collaborative research, which enabled grouping of the superficial deposits in terms of their volume and permeability, was fundamental to construction of a detailed shallow groundwater model. This approach provides a template for investigating the role of shallow groundwater in flood-prone areas with complex subsurface geology that is widely applicable across the UK. ■



The Forres 3D geological framework model reattributed for permeability.

Glasgow and the Clyde Basin

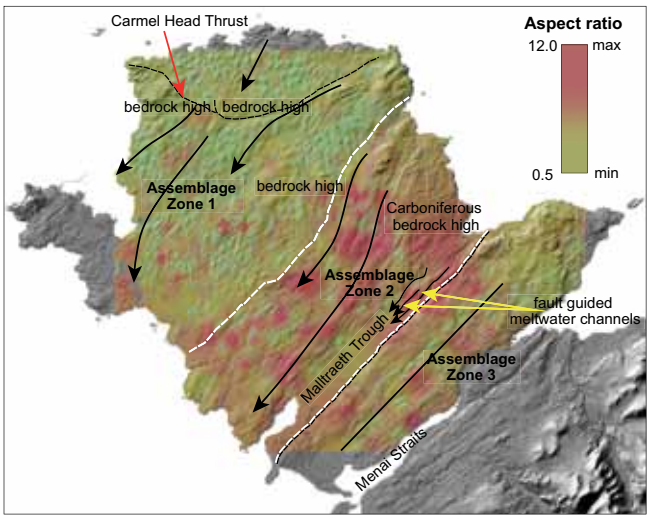
The lower Clyde Valley is Scotland's national regeneration focus. We have continued to support local authorities and others with geoscientific data in various forms, including 3D geological framework models, to help inform their decision-making and achieve cost savings. The Clyde Basin Project team provides the essential 3D modelling input to our multidisciplinary Glasgow and Clyde Basin project, itself a key component of our strategy for 2009–14. The team completed an attributed 3D model of the superficial deposits and bedrock for most of the Glasgow conurbation, covering 600 square kilometres and including key development areas. A separate bespoke model was also developed within the Glasgow area for a consortium of local authority and other partners to cover the areas of the Clyde Gateway and sites for the Commonwealth Games 2014, to be hosted by the City of Glasgow. This was used to provide the framework for a conceptual hydrogeological model of central Glasgow which will be refined and extended as more data become available. The 3D models can be used to view and interrogate the subsurface geology and help planners to make key decisions linked to the development and regeneration of the area. In addition, a regional framework of cross-sections has been constructed across the Clyde Basin in preparation for a catchment-scale model that will be used to advance understanding of the hydrogeology of the basin. Scientific studies using the models in combination with a Digital Terrain Model of the land surface (based on NEXTMap® Britain elevation data) and targeted fieldwork have led to a key scientific paper that identifies several large-scale changes that occurred during the build-up and decay of the last British Ice Sheet in the north-western UK. The next stage is to use the data in numerical simulations to help our broader understanding of how ice sheets evolve. ■



3D geological framework model of superficial deposits in the Clyde Gateway area of Eastern Glasgow.

Glacier dynamics of the Irish Sea Ice Stream

During the last ice age, known as the Late Devensian period, which began some 30 000 years ago, Britain and Ireland were plunged into 'deep freeze'. The extreme climatic conditions, which lasted for approximately 20 000 years, led to a large part of the land and surrounding seas being covered in a thick layer of ice and snow known as the British and Irish Ice Sheet. This ice sheet was not static, but was drained at various times during its life by a number of fast flowing corridors of ice or ice streams. Ice streams play an important role in regulating the size, shape and thickness of modern ice sheets, for example in Antarctica, by transporting ice from its centre to the floating ice shelves and glaciers which fringe its margins. Similar zones of fast moving ice have also been recognised draining the margins of the British and Irish Ice Sheet. Anglesey, in north-west Wales, occupies a unique position as it occurs close to the eastern margin of one of these palaeo ice streams, the Irish Sea Ice Stream. The low-lying, gently rolling hills of the island preserve the unique 'fingerprint' left on the landscape by this fast moving corridor of ice. The landforms, such as egg-shaped drumlins, and glacial sediments left as the ice retreated provide a record of the processes occurring beneath the Irish Sea Ice Stream. Work by the BGS has shown that the variation in the morphology and distribution of the landforms demonstrates that the speed of the overriding ice was highly variable within this part of the Irish Sea Ice Stream. Marked changes in landform morphology have been shown to have been locally controlled by large-scale faults and/or major lithological boundaries within the bedrock, with less durable lithologies controlling the location and lateral extent of relatively faster flowing portions of the Irish Sea Ice Stream. This provides important evidence for the potential control exerted by bedrock geology on the location and size of ice streams draining contemporary ice sheets. ■



The colour graduated raster image draped over the NEXTMap™ Digital Elevation Model of Anglesey highlights the variation in the morphology and distribution of glacial landforms and changing pattern of ice flow across the island. Changes in the shape of the landforms are thought to record the speeding up or slowing down of the Irish Sea Ice Stream as it overrode the island, with the red areas highlighting areas of faster flowing ice, and yellow, relatively slower moving ice.

Science Programmes

Marine Geoscience

The Liftboat Kayd *off the coast of New Jersey.*

© ECORD/IODP

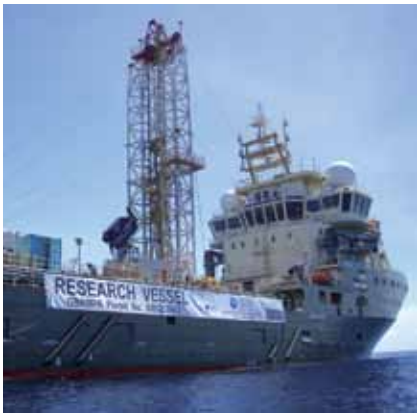
Marine Geoscience provides three-dimensional information on the geology of the seabed and the shallow subsurface, plus deeper tectono-stratigraphic analyses of the underlying geology. Basin analysis research is focused on the Atlantic Margin. Seabed mapping and modelling is centred on areas with new high-resolution multibeam data. Significant improvements have been made to our 15-metre seabed rockdrill capability and our new inshore survey vessel RV *White Ribbon* was commissioned during the year.

Regional hydrocarbon prospectivity

The BGS continued to provide the Department of Energy and Climate Change with independent assessments of the geology and hydrocarbon resources of the UK and support and advice to the Falkland Islands Government, where the second offshore exploration drilling programme began in early 2010. ■

Integrated Ocean Drilling Program

In 2009/10 the BGS-led ECORD Science Operator partnership completed two mission- specific platform expeditions for IODP. The first, in the summer of 2009, used a jack-up liftboat on the New Jersey margin and collected cores to support research into Neogene sea-level change on the United States' Atlantic margin. A second expedition to Australia, using a new drill ship was completed in the spring of 2010. Cores were collected from former reefs (where the corals are no longer living) that developed within the Great Barrier Reef system to look at the evidence of sea-level change and impacts on the reef during the last deglaciation. ■



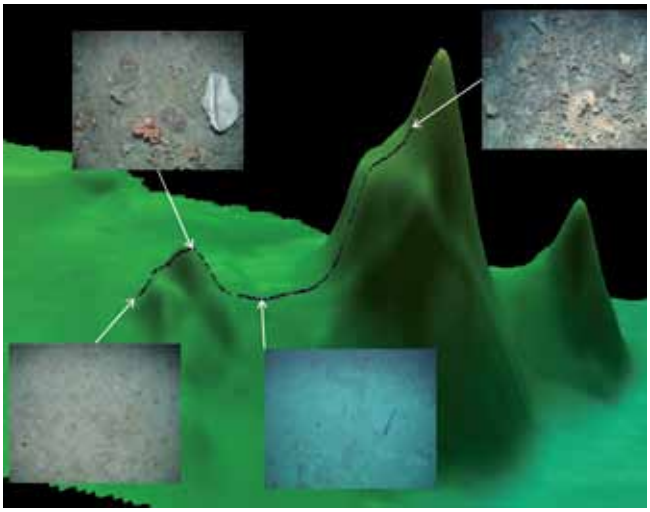
© ECORD/IODP

The Greatship Maya *ready to collect cores in the Great Barrier Reef area.*

Marine geology

A major reassessment of our seabed sediments data was completed with support from DEFRA, the Scottish Government, the Department of Environment Northern Ireland and the Welsh Assembly. A new digital map was produced highlighting areas where rock or hard substrate is at or very close to the seabed. The primary use of the map was to aid the recognition of key habitats, but it will also inform site investigations for new offshore developments, including renewable energy infrastructure.

In 2009 we managed a survey for the Joint Nature Conservation Committee examining areas on Anton Dohrn Seamount and Rockall Bank for consideration as Special Areas of Conservation. This revealed a wide range of seabed features including three pinnacles, probably of volcanic origin, lying downslope of the north-eastern flank of Rockall Bank. These topographical highs are favoured sites for the development of cold-water coral reefs, a habitat important under the European Habitats Directive, but vulnerable to some deep-water trawling methods.



Multibeam echo-sounder image from the eastern flank of Rockall Bank showing a series of pinnacles, likely to have a volcanic origin, and now a favoured site for the development of cold water corals.

We co-ordinated the production of the first integrated seabed sediment map of north-west Europe supported by funding from the European Commission through the EMODNET (European Marine Observation and Data Network) project, in collaboration with partners from geological surveys from all the surrounding countries. Further work may include the compilation of information on coastal erosion, mineral resources and geological events such as submarine slides in the same area. The maps will be made available through the OneGeology-Europe portal.

A new initiative called MAREMAP (Marine Environmental Mapping Programme) was established, which will integrate marine mapping expertise across the BGS, the National Oceanography Centre and Scottish Association for Marine Science. Seven research themes will be developed:

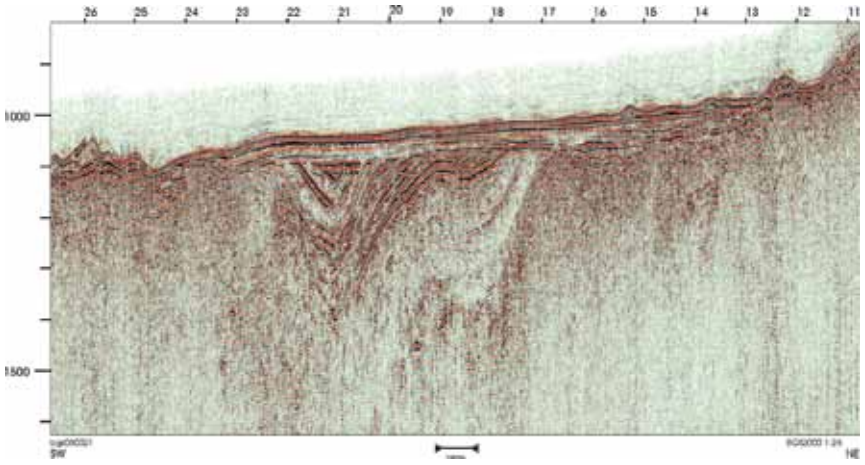
- Coastal and shelf geological and habitat models.
- Deep-water geological and habitat models.
- Submarine geohazards.
- Sediment mobility and 4D monitoring modelling.
- Technology and techniques.
- Heritage and archaeology.
- Data and products.

The main element of the research programme will be to produce detailed geological and habitat maps and models based on multibeam echo-sounder data. ■

Continental margins

The Faroe–Shetland Basin Consortium, comprising the BGS in partnership with the Faroese Earth and Energy Directorate and eleven oil company sponsors, completed a major tectono-stratigraphical analysis of the Cretaceous succession within the Faroe–Shetland Basin and surrounding area. New 3D potential field models of the region, with control on the post-basalt succession provided by seismic interpretation, were also developed on behalf of the consortium.

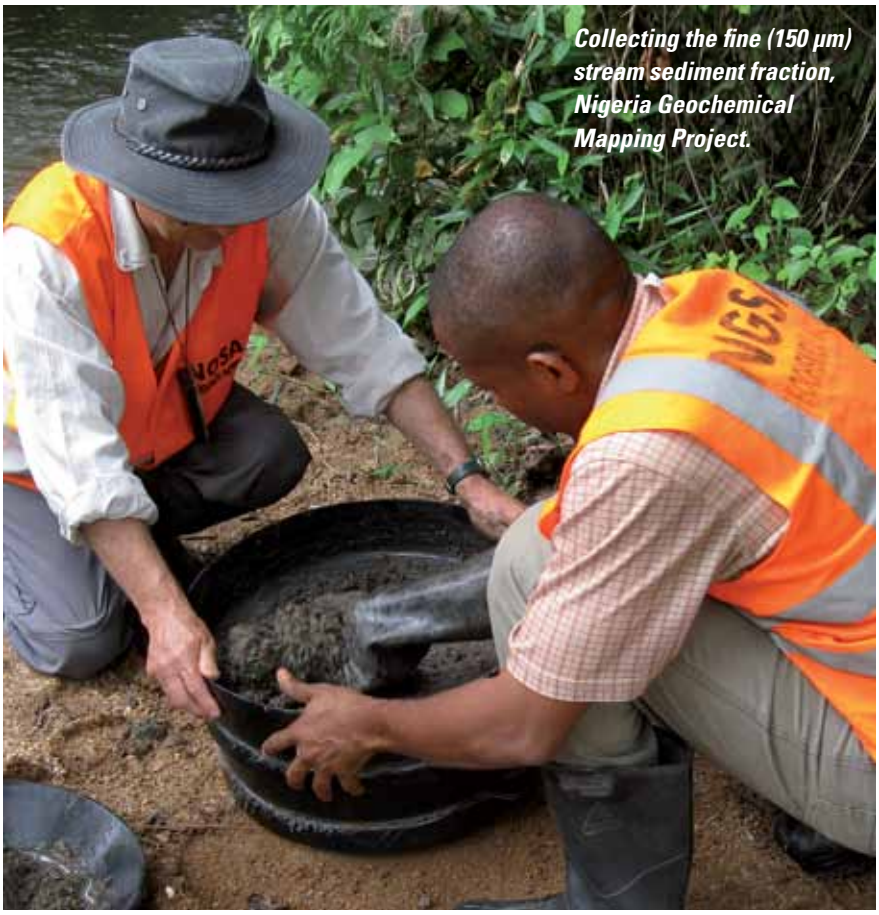
The Rockall Consortium, comprising the BGS, the Department of Energy and Climate Change and three oil company sponsors supported a cruise using the RRS *Discovery* to acquire site survey data in both UK and Irish waters as the first stage of a proposal for stratigraphic drilling under development with the Petroleum Affairs Division of the Irish Government's Department of Communications, Energy and Natural Resources. Detailed sparker data and gravity cores were collect at 13 potential sites. ■



Proposed drill site for stratigraphic drilling on Hatton Bank. BGS seismic data.

Science Programmes

Environmental Geoscience Baselines



Collecting the fine (150 µm) stream sediment fraction, Nigeria Geochemical Mapping Project.

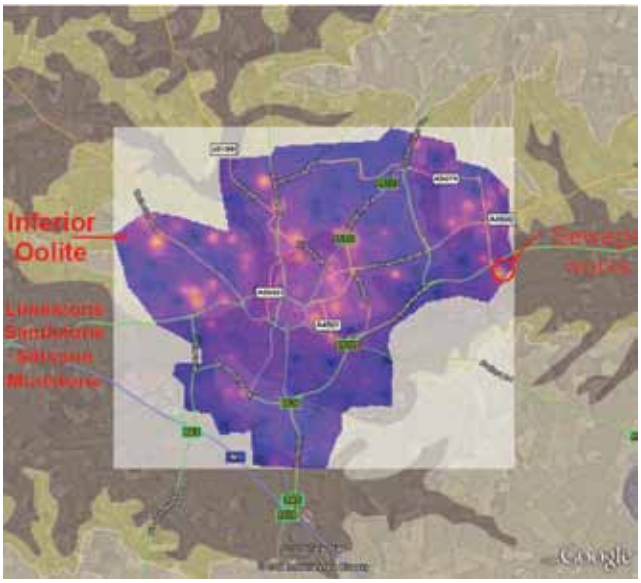
Environmental Geoscience Baselines generates information about the chemical and physical properties of the Earth's surface and subsurface and underpins research and decision-making for healthy and sustainable environments. Baseline mapping helps to distinguish between natural and anthropogenic impacts on the environment and provides a reference point for monitoring and forecasting changes over time.

Geochemical baseline mapping in the Thames and Clyde Basins

The Geochemical Baseline Survey of the Environment (G-BASE) project has completed a comprehensive geochemical survey of Greater London and surrounding areas, contributing to our Thames Basin project. This survey — known as London Earth — collected soil samples from 6600 sites, which have now been analysed for over 50 elements including potentially harmful elements such as arsenic, lead and nickel. These data will allow the BGS and the wider research community to trace and identify impacts on the environment brought about by urbanisation and industrial activities in Britain's most populous city, enabling new understanding of interactions between people and ecosystems and supporting decision-making on protection of critical soil and water resources. London Earth also included pilot studies investigating the distribution of mercury and persistent organic pollutants (such as PAHs and PCBs), which are potentially harmful to ecosystems and human health.

A catchment-wide soil and stream-water survey covering over 3000 square kilometres is currently under way in the Clyde area, Scotland, which will form a major contribution to our Clyde Basin project. This comprehensive survey, encompassing important former industrialised areas, will allow us to produce integrated products that address key environmental issues such as sustainable development, contaminated land, contaminant migration and ecosystem impacts, and to complete integrated groundwater–surface water modelling. Baseline geochemical maps for the UK and regions are now being delivered digitally on our website. ■

GBASE sampling team in the Clyde Basin.



Bioaccessibililty of arsenic in Northampton soils ranging from 0 (dark blue) to 10 (yellow) mg kg^{-1}. Northampton has high levels of As in soils because of the underlying Inferior Oolite (shown in pale yellow).

Bioaccessibility of harmful substances in soil and dust

The Environment and Health Project has continued to study human exposure to potentially harmful substances in soil through research into ingestion bioaccessibility. In collaboration with the Bioaccessibility Research Group of Europe (BARGE), a validated laboratory testing protocol has been developed which is now recommended by the Chartered Institute for Environmental Health (Unified Barge Method — UBM). The new method is now being applied to archived G-BASE soil samples as a first step in producing bioaccessibility hazard maps for arsenic, cadmium and lead in UK soils.

A method for measuring the bioaccessibility of polyaromatic hydrocarbons (PAH) in soil has been completed in conjunction with the University of Ghent, the University of Nottingham, National Grid:UK Gas and the consultants Parsons Brinckerhoff. The study has been published and work on applying the new method to samples from the London Earth project is now under way.

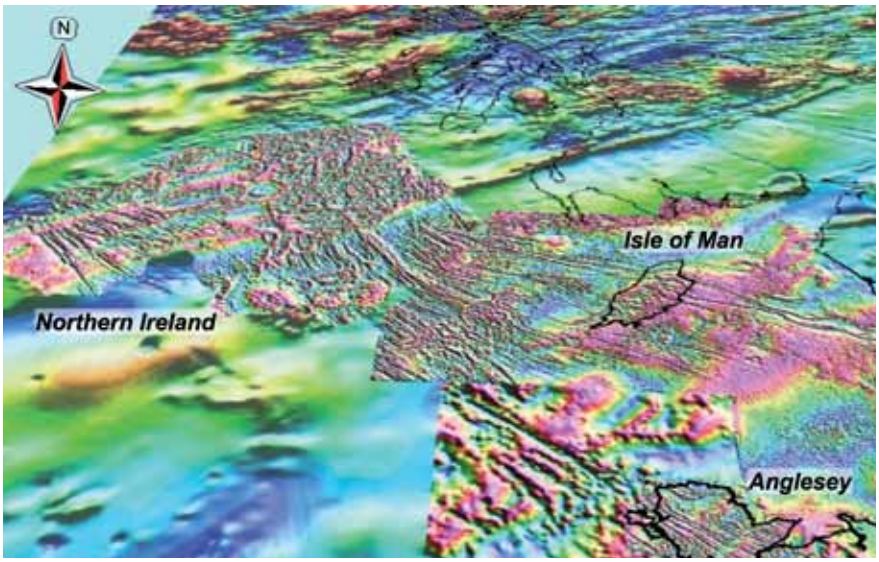
New research on human exposure to airborne dust is in progress.A pilot study on dust filters from Northampton has produced a successful method for identifying sources of dust over a 24-hour period. Research into the development of an inhalation bioaccessibility test for dusts is now under way in conjunction with the INERIS institute in France. ■

Nigerian Geochemical Mapping

The BGS-led World Bank-funded Nigerian Geochemical Mapping Project completed the initial sampling phase in December 2009. Stream sediment samples were collected from two large areas totalling about 51 000 square kilometres in western Nigeria. Following initial sample preparation in Nigeria, the samples were sent to BGS Keyworth for ICP-MS analysis for 57 elements and to Canadian laboratories for fire-assay determination of gold, palladium and platinum. Training of over a hundred counterpart geoscientists from the Nigerian Geological Survey Agency (NGSA) continued throughout the year — during the fieldwork and sample preparation work in Nigeria, through attachment to our G-BASE fieldwork programme in the south of England, in our laboratories at Keyworth, and in several specialist training sessions in Nigeria and Keyworth. NGSA now has the skills and equipment to realise the geochemical mapping of the whole of Nigeria and produce baseline data that along with other geoscience information will encourage the development of non-hydrocarbon mineral resources. ■

Anglesey from above

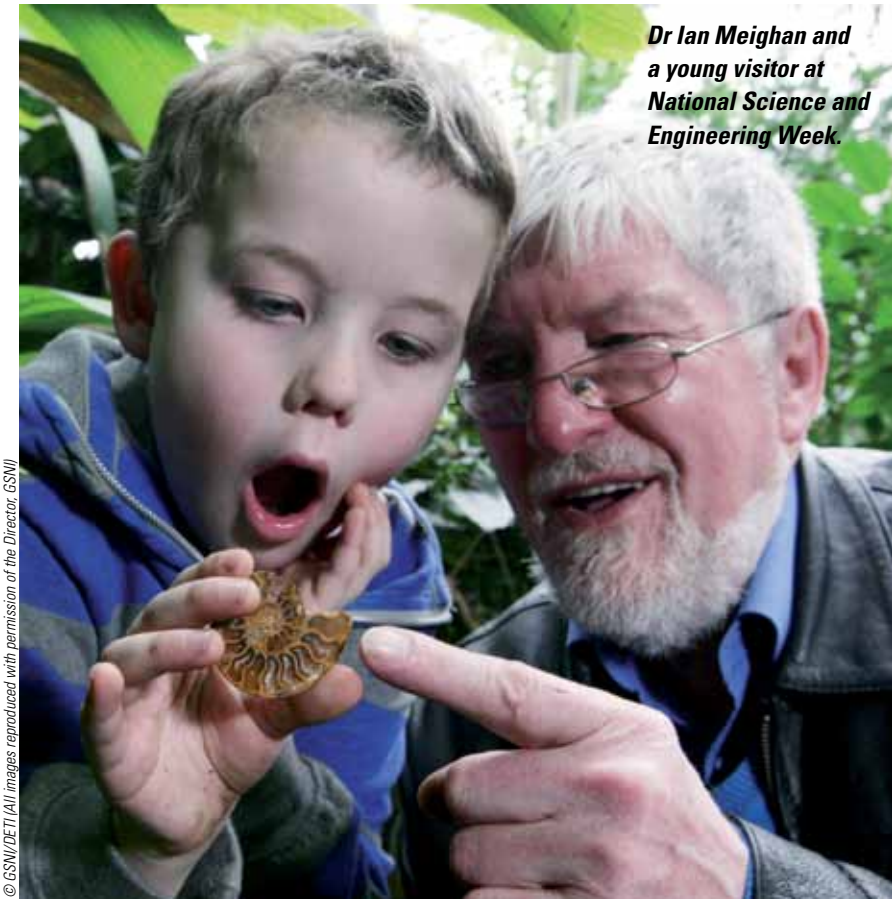
A High Resolution Resource and Environmental Airborne Survey (HiRES) was flown in June 2009 across Anglesey (Ynys Môn) and adjacent parts of the Welsh mainland. The survey is a contribution to regional, environmental geoscience surveys and research in north Wales and covers some of the oldest rocks in the British Isles. Current work on the datasets is revealing the shallow and deep (mid-crustal) structural configuration of the rocks while the radiometric and electromagnetic data are being used for shallow environmental, land-use and resource assessments. The survey was flown at low altitude (200 metres) and attracted considerable media interest. The survey delivered over 6000 line-kilometres of magnetic, radiometric and electromagnetic data, which are currently being processed for public release to support future environmental research in the region. ■



The image shows a compilation of magnetic survey data that incorporates the new Anglesey and Northern Ireland HiRES data sets. The processing has been tuned to show the regional extent of the shallow Palaeogene dyke swarms of the North Atlantic igneous province across the UK.

Science Programmes

Geological Survey of Northern Ireland



Dr Ian Meighan and a young visitor at National Science and Engineering Week.

The Geological Survey of Northern Ireland (GSNI) is part of the Department of Enterprise, Trade and Investment (DETI). It is staffed by BGS scientists under contract to DETI, which allows the GSNI to call on expertise from other parts of the BGS. GSNI also undertakes tasks for other Northern Ireland government departments and liaises closely with the Geological Survey of Ireland (GSI).

Public engagement

In association with the Royal Irish Academy and the GSI, the GSNI organised a conference on Carbon Capture and Storage. Working with the Ulster Museum and Queen's University Belfast, we organised the 2010 Irish Geological Research Meeting which attracted 170 delegates.

A new *Building Stones Map of Ireland* was published in collaboration with the GSI and distributed throughout Ireland.

As part of National Science and Engineering Week, GSNI organised 'Go Get Science' at Belfast's W5 Science Learning Centre. Media coverage from the event reached an audience of almost half a million people. ■

Information delivery

We focused on delivering data and information to government, industry and academia and launched three new data-delivery websites during the year. The new GeoIndex and GeoRecords sites dedicated to Northern Ireland bring together all of the GSNI's data in a coherent and integrated delivery vehicle. GeoIndex presents index maps of boreholes, geology, geochemistry, geophysics and mines data. GeoRecords delivers information from the database of 30 000 boreholes. In collaboration with Action Renewables, the GSNI launched a postcode-based website where summary reports of geological and thermal characteristics can be downloaded. This will support the uptake of ground source heat pumps in Northern Ireland.

To complement these new methods of information delivery, we installed a large 3D visualisation system, using the GeoVisionary technology developed by jointly by the BGS and Virtalis Ltd. This innovative facility enables the integration and analysis of multiple datasets, superimposed on digital models of terrain or seabed. The facility has met with wide acclaim across government, private sector and academia in Northern Ireland and has prompted increased collaboration. ■

Energy and minerals

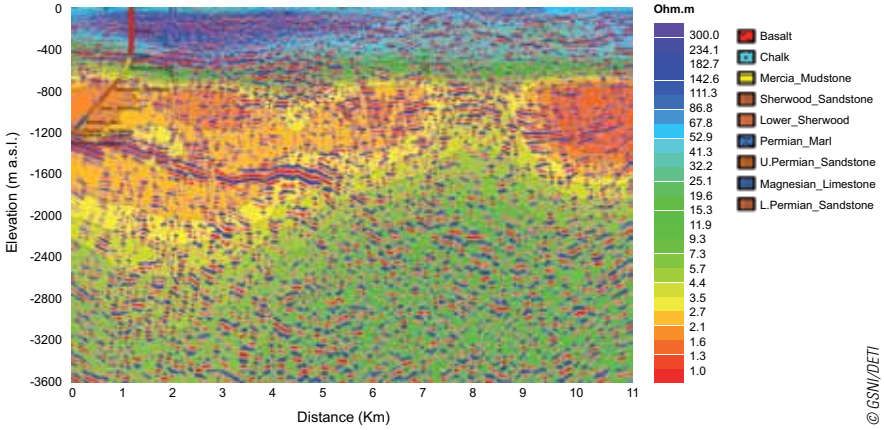
The GSNI helped bring the development of the Curraghinalt gold deposit closer by introducing a company with a proven exploration and development track record into Northern Ireland. We have provided valuable technical expertise and data to companies embarking on exploration for salt deposits suitable for the storage of natural gas and compressed air energy in underground caverns in the Larne area. In hydrocarbons, we have worked closely with DETI to prepare new legislation which should herald a new phase of exploration for onshore Northern Ireland. We continue to provide support to DETI on the development of policy for carbon capture and storage. ■

Research alliances and academic collaboration

The GSNI continues to focus on strategic alliances with an increasing range of academic and private sector organisations to provide applied geoscientific research to benefit economic development in Northern Ireland. Much of the research stems from geophysical and geochemical data collected during the Tellus project.

Research projects, supported by the Northern Ireland Innovation Fund, have yielded valuable new information about deep geothermal energy resource potential and the distribution of offshore salt deposits that have the potential to be used for gas storage. The former used innovative techniques integrating magnetotelluric, seismic and other geophysical data to produce improved 3D models of the geothermal reservoir targets. Alliances have been established with the Dublin Institute of Advanced Studies and the University of Birmingham to extend the geothermal research and develop interpretation techniques.

Postgraduate research on the Tyrone Igneous Complex, (with the University of Southampton and the Natural History Museum), and on Cenozoic tectonics (with University College Dublin) continues to provide new information on both mineralisation potential and basin development that will refine hydrocarbon exploration models. The GSNI also supports postgraduate students at Queen's University Belfast researching possible linkages between soil geochemistry and human health and modelling the Lagan Valley aquifer that supplies water to the Greater Belfast area. Further doctorate projects were established with the University of Ulster on soil geochemistry and glacial till provenance, and with the University of Birmingham and the Scottish Universities Environmental Research Centre on Late Caledonian magmatism. ■



Seismic reflection data superimposed on resistivities from magnetotelluric survey, Lough Neagh Basin. Orange to red colours indicate sandstone aquifer deep geothermal targets.

Garth Earls with DETI Minister Arlene Foster MLA at Marble Arch Caves Global Geopark.

Geology and landscape

We contributed to the development of a regional-scale, onshore and offshore 3D geological model for Britain and Ireland. This model is designed to form the framework into which other models can be integrated. Subsurface 3D models of Belfast and Londonderry are well advanced and will contribute to decision making in environmental, geotechnical and planning issues.

The GSNI continued its close involvement with the growing international Geoparks movement and assisted in the redrafting of the guidelines and application procedures for membership of the UNESCO Global Geoparks Network (GGN). Our scientists were involved in several GGN and World Heritage Site field inspections and also participated in the Natural Sciences discussion at the UNESCO General Conference in 2009.

Locally, we formed new partnerships with organisations in the Sperrin, Strangford and Mourne regions with a view to developing new geological tourism products and were involved with GSI in the production of a new geological field guide to the Cooley, Gullion, Mourne and Slieve Croob area. ■

Environment and hazards

Planning-related issues constitute 25% of enquiries and we continued to provide technical support to the Planning Service in relation to planning policy and development. Most of the technical assessment relates to developments such as a salt mine, quarries, landfill sites, wind farms and infrastructure projects. We also provide advice to developers at all stages of environmental impact assessment scoping.

The GSNI assisted the Northern Ireland Environment Agency meet EU Water Framework Directive compliance targets; in particular with the publication of the first River Basin Management Plan. We also installed monitoring equipment at two study sites, which now provide the focus for numerous research projects.

We developed a new abstraction licence reviewing process which provides a framework for undertaking assessments, while developing the conceptual understanding of a strategically important aquifer, without prohibiting economic development. ■

Science Programmes

Climate Change

JOIDES Resolution *in dock at Yokohama.*

Photograph by IODP-USIO

Some amount of climate change is inevitable. 2009 was the second warmest year since records have been kept, and the year capped the end of the world's warmest decade. Adapting to these changes means understanding how our environment, urban or rural, will respond to a different climate. What will happen to pollutants, to carbon, currently locked in soils and river sediments? What sort of weather comes with a rapid global warming event, and what was the world like when atmospheric CO_2 was as high as it will be in a few decades? These are the sorts of questions that the BGS climate change group tackles.

Rising sea levels — why the rush?

Sea-levels are currently rising faster than all but the most extreme climate model predictions. The rate at which sea-levels rise, however, is a complicated function that includes isostatic rebound of Earth's crust, the loss of gravitational attraction of ice-sheets, and thermal expansion of the ocean's waters. We are developing novel methods using biomolecular and isotopic signatures of sea-level to quantify the geologically recent rate of sea-level rise in different parts of the world. ■

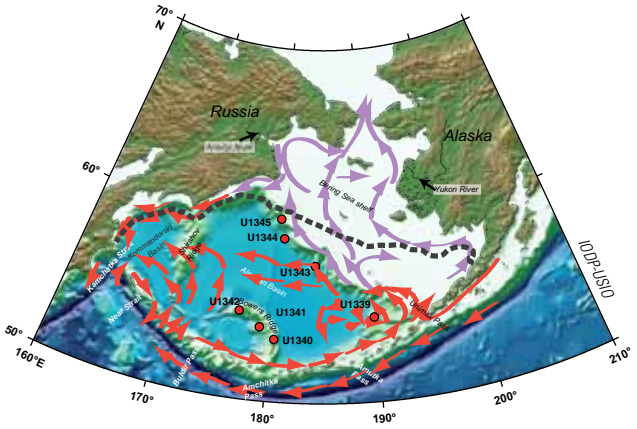
Pollutants in the Thames estuary

As with climate change, the impact of humans on our planet is most significantly tied to the Industrial Revolution and pollutants in the Thames estuary are a prime example. London has been the source of industrial and domestic waste in the tidal portion of the Thames estuary for over 1800 years. We have been measuring concentrations of persistent organic pollutants and heavy metals in the sediments with the aim of better understanding how these potentially dangerous chemicals may be remobilised and redistributed as a consequence of climate change. Although the water quality of the Thames has improved dramatically over the past 50 years, relatively little is known about the environmental quality of the near-surface sediments. Our findings, following from the determination of the molecular, isotopic and radionuclide chemistry of sediment cores obtained from sites between Teddington Lock (the tidal limit of the Thames) and the Isle of Grain on the Thames estuary, show that contaminated muds, deposited at the zenith of the Industrial Revolution, lie just beneath the surface and are vulnerable to physical disturbance and erosion. ■

Sediment cores being recovered from the Thames estuary.

Palaeoclimate of the Arctic region

In 2007, the surface area of Arctic summer sea-ice declined to an all-time minimum (during recorded history), and thick, multi-year ice continues to decline. The Arctic region is responding to climate forcing faster than any but the most recent climate models have predicted, and the consequences of those changes to conditions around the UK are likely to be significant. In 2009, a BGS palaeoclimate scientist participated in the first significant International Ocean Drilling Program (IODP) expedition to the Arctic region. The IODP scientific drilling vessel *JOIDES Resolution* spent two months coring deep-sea sediments in the Bering Sea, in order to uncover the palaeoceanographic and climatic history of the region. This international expedition consisted of over 30 shipboard scientists from 15 countries. We are now analysing cores, and early results show that sea-ice and deep-water properties responded dynamically to orbitally driven variations in Earth's climate in the past, published online at **www.iodp.org** ■

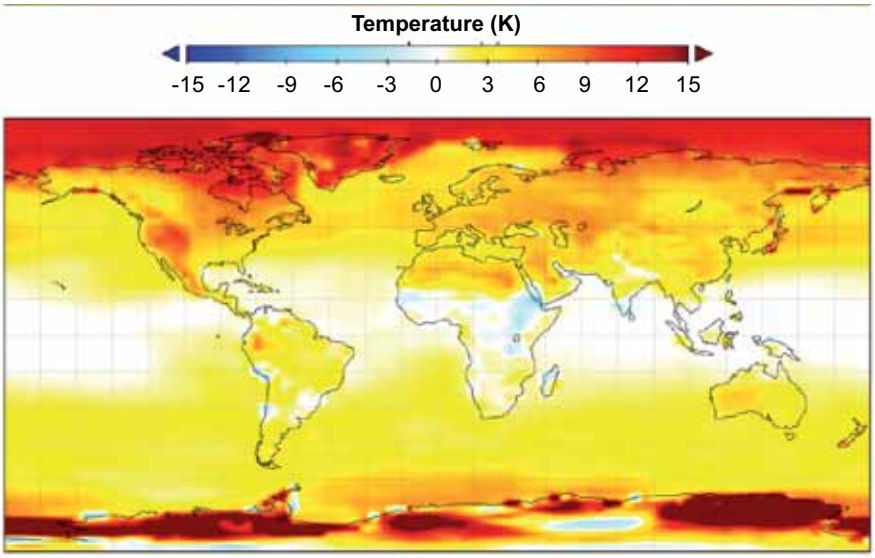


Map of the Bering Sea, IODP Expedition 323 drill sites, and ocean currents. Dashed line represents the extent of winter sea ice.
From IODP Prel. Rept., 323. doi:10.2204/iodp.pr.323.2010.

What would the Earth be like with high levels of atmospheric CO_2?

The BGS is investigating this question in partnership with the universities of Leeds and Bristol and the US Geological Survey Pliocene Research, Interpretation and Synoptic Mapping (PRISM) program. The last time the Earth's atmosphere had concentrations of carbon dioxide (CO_2) as high as 400 parts per million by volume was during the late Pliocene, about 3 million years ago. We are using evidence from the Pliocene geological record to test whether the UK Hadley Centre global climate models (GCMs[1]) used to forecast future climate change can replicate the climates thought to exist during the late Pliocene. These tests are important, because GCMs are being used to inform national policies and international agreements on mitigation and adaptation to climate change. The failure of earlier GCMs to model the rapid Arctic sea-ice decline emphasises the importance of rigorously testing their ability to replicate past high-CO_2 climates. Our preliminary results, using the best available field and proxy-based evidence of Pliocene climate and environments as inputs to GCMs, suggest that model predictions and observations may be converging. The next time the Earth will have Pliocene-like levels of atmospheric CO_2 will likely define a new geological time-unit: the Anthropocene, which marks the impact of humans in the geological record. ■

1 *more accurately: general circulation models.*



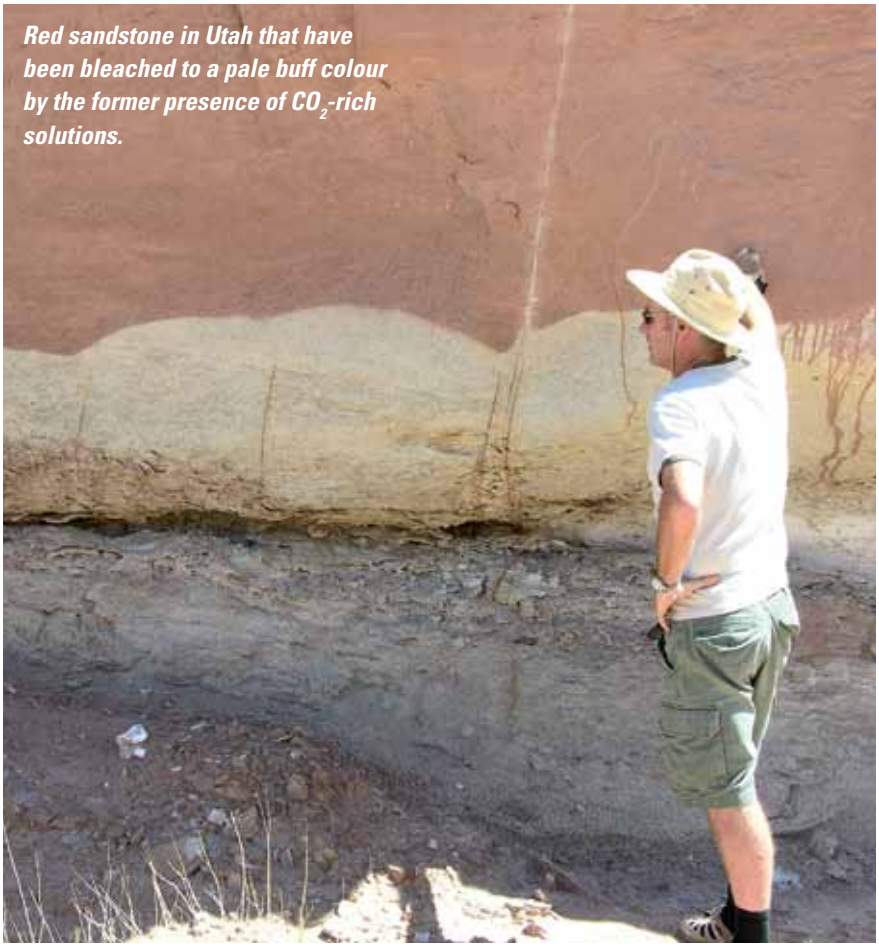
Temperature differences for the Pliocene, as compared to the present day. Average temperatures for the Pliocene are modelled to have been close to modern measurements close to the Equator, but to have been higher by 15 degrees or more at the Poles.
Based on USGS data.

Cold climate processes

The BGS has been examining the impact of Quaternary cold climate processes on the landscape and properties of surface materials within Britain. Periglacial aeolian deposits such as coversand and loess blanket much of southern Britain, but their distribution is poorly known. Soils developed on these deposits are typically nutrient-poor, susceptible to wind deflation, and may possess unstable ground conditions due to the common presence of interstratified peat. Using trace-element geochemistry we have discovered that aeolian deposits possess elevated concentrations of hafnium and zirconium and have used this finding to develop an 'aeolian deposit' map for eastern England. ■

Science Programmes

Energy Geoscience



Red sandstone in Utah that have been bleached to a pale buff colour by the former presence of CO_2-rich solutions.

The aim of the BGS Energy Theme is to help Britain become a low-carbon, secure energy economy by developing our renewable and home-grown energy, and by fostering carbon capture and storage (CCS). We work across Europe and in the emerging economies with diverse research partners to help support safe and economically viable implementation of CCS worldwide.

Carbon capture and storage

Our carbon dioxide storage research continued to grow and diversify this year. One of its most important roles is to provide specialist geological advice to the UK Department of Energy and Climate Change (DECC) on the competition to build a full scale CCS demonstrator. This will be one of the world's first full-scale CCS operations and will have a strong impact on the way CCS develops worldwide. BGS experts were involved in evaluation of the final bids of industrial consortia to build the demonstrator and are thus at the heart of the UK government's clean coal policy in this new and exciting area.

Fundamental CCS research also goes from strength to strength. Carbon dioxide injected into the deep subsurface can be safely trapped through a chain of chemical reactions in which it initially dissolves into the saline groundwater in the rock, and then precipitates as carbonate minerals. We are working in the CRIUS project with the universities of Cambridge, Leeds and Manchester to investigate these reactions to improve predictive computer models of carbon dioxide (CO_2) storage, including high pressure/temperature experiments. Our scientists have also been studying rocks in Utah as an analogue of a CO_2 storage site. Here, ancient natural CO_2-rich waters have reacted with sandstones and mudstones, and analysis of their composition can provide insights into likely future reactions within a deep geological store of CO_2.

We continue to work with the Energy Technologies Institute (ETI) to derive a robust and defensible estimate of UK CO_2 storage capacity, and in a new ETI- funded project to devise methodologies for site monitoring in the North Sea. In Europe, through the CO_2ReMoVe project, the energy team researches site performance prediction and monitoring, and through Project RISCS it is looking into potential impacts of leakage on land and marine ecosystems.

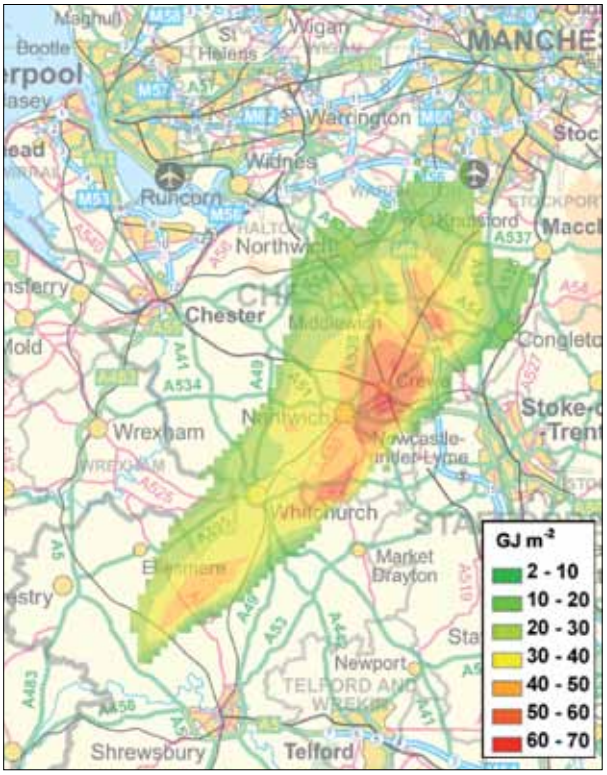
In collaboration with other NERC institutes and universities, the BGS won two NERC grants: one to research environmental impacts of CO_2 leakage and another to develop CCS whole-system geological, engineering and economic analysis. The BGS is a partner in the recently-formed Norwegian BIGCCS Centre and is continuing to analyse time-lapse seismic from the world's first CO_2 injection project in the North Sea Sleipner gas field. The monitoring shows that time-lapse seismic can be used to detect layers of CO_2 just one metre thick, even 1000 metres below the seabed. Importantly it also shows no detectable leakage of CO_2. ■

Unconventional gas, renewable heat and deep geothermal

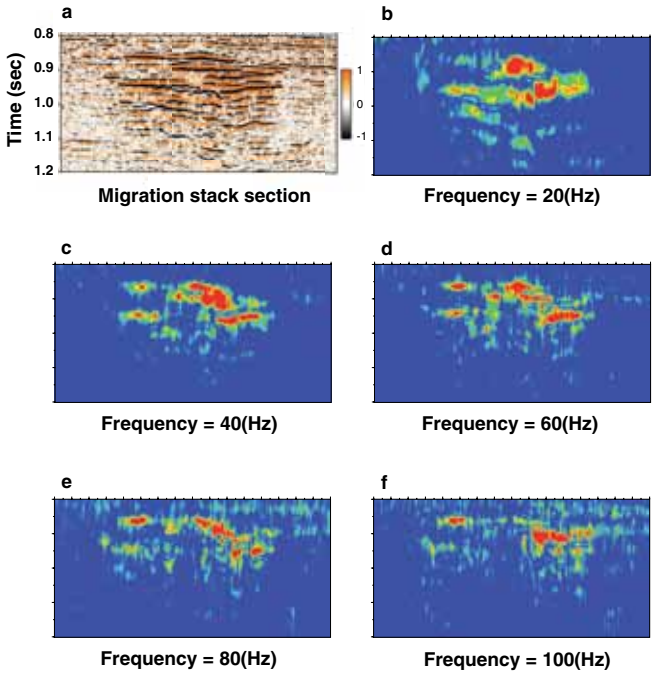
Renewables and energy security research is focusing on shale gas and coalbed methane, which have the potential to produce significant quantities of UK-sourced gas. Databases and prospectivity studies of these resources have been completed, and a scoping study has been started to look at the potential of UK Cambrian shale gas, which has not yet been considered by gas exploration companies.

The exploitation of renewable heat is expected to substantially increase with the introduction by the government of the Renewable Heat Incentive in April 2011. Preliminary modelling work has been completed on the sustainability of closed-loop ground source heat pump systems. The potential of disused mine workings beneath Glasgow as an enhanced thermal resource for ground source heat pumps is being investigated and the old workings are being modelled in 3D to aid visualisation. This will establish not only the void space that exists, but also the interconnections with the permeable geological formations. A geographical information system has been created from which targeted geothermal resource assessments can be made.

There is public and government interest in developing deep geothermal resources, but strategic knowledge of national resource potential is needed to underpin future of regulation and licensing. Preliminary modelling has assessed the effect of past climate change on heat flow. Initial results indicate that deep geothermal resources have been underestimated, especially in the north of the UK. ■



Geothermal resource (the heat 'in place') of Permian sandstones in the Cheshire Basin in gigajoules per square metre. The resource is concentrated in the south-east of the basin against the main bounding fault and is centred on Crewe.



Frequency-dependent AVO inversion utilised to characterise the distribution of CO_2 at the Sleipner gas field in the Norwegian North Sea. Time-lapse seismic data were acquired after the CO_2 was injected into the rock. (a) Shows the conventional seismic image. (b) to (f) show different frequency images of the plume gained from frequency-dependent AVO, revealing the higher CO_2 concentrations.

Edinburgh Anisotropy Project

The Edinburgh Anisotropy Project (EAP) uses seismic wave analysis and modelling for imaging and assessing deep hydrocarbon reservoirs. The research is carried out in partnership with the University of Edinburgh and is supported by a growing oil and gas industry consortium, involving most of the world's major oil companies. Our research allows us to detect the density and orientation of fractures in rocks, as well as telling us about aspects of the fluids that the rocks contain. This means that oil companies can understand their all-important oil or gas reservoirs even though they may be thousands of metres below the surface.

This year, the project team made significant progress in the analysis of frequency-dependent variations of seismic amplitudes with offset (AVO), which can be used to characterise the distribution of CO_2 in deep underground stores. An inversion scheme was developed for the first time, and applied to the Sleipner gas field in the Norwegian North Sea, one of the largest stores of CO_2 in the world, containing over 10 million tonnes of CO_2. The results shows that frequency dependent AVO inversion can be used to detect and quantify fluid saturation in reservoirs deep below the surface. This exciting development has attracted wide interest from the exploration geophysical community and is likely to be important in new carbon CCS technology where imaging CO_2 is vital for regulation of CCS and for public acceptance. ■

Science Programmes

Minerals and Waste

Rare earth elements are a critical raw material used in the manufacture of environmental technologies such as wind turbines.

The need to maintain a secure, sustainable supply of minerals and energy in the face of population increase and environmental change drives the science carried out by the BGS Minerals and Waste theme. Working with partners from government, academia and industry, the BGS Minerals and Waste portfolio includes research on the life cycle of minerals and metals. We are investigating metallogenesis of raw materials for environmental technologies. Global mineral production is monitored and analysed to inform policy on security of supply. We also provide information on, and carry out research to underpin an effective spatial planning system for domestic mineral supply. As the UK embarks upon the construction of new nuclear power plants, we are carrying out a range of world-leading generic research on the safe geological disposal of the resultant radioactive waste, with a focus on transport properties.

Critical raw materials

European economies are highly dependent on imports of many strategically important minerals and metals. The supply of these materials is increasingly affected by market distortions resulting from growth in global consumption of primary resources. Simultaneously, mineral exploration and extraction within Europe faces growing competition from different land uses and a highly regulated operating environment. In response to these challenges, the European Commission launched the Raw Materials Initiative (RMI) in late 2008. The RMI aims to produce an integrated response to securing reliable and undistorted access to raw materials from both international markets and European sources, and to boost overall resource efficiency and recycling to reduce consumption of primary raw materials and decrease import dependence. Over the past year, we have had a key role in the working groups convened as part of the RMI to define critical raw materials and to investigate exchanging best practice in land use planning, permitting and geological knowledge sharing.

Reports from the two working groups have now been published with the intention of informing EU policy and research priorities. These expert contributions are underpinned by continuing research into critical minerals. A new commodity profile on rare earth elements has been published. Used in a wide variety of industrial and consumer applications, including vital environmental technologies such as wind generators and electric vehicles, rare earth elements clearly fulfil the criteria for criticality, as they not only have significant economic importance but are also potentially vulnerable to supply disruption as global production is currently highly concentrated in a single country. Major emerging economies, such as Brazil, Russia, India and China, are responsible for much of the growth in demand for minerals. An analysis of the role of these nations as producers and consumers of minerals has been produced to help assess mineral supply security for the UK and Europe. ■

Subsurface aggregate resources in south-east England

Recent research by the BGS and others has identified potential problems in the long-term supply of primary crushed rock aggregate to London and the south-east of England. Although high-quality materials suitable for crushed rock aggregate and accessible by conventional quarrying are virtually absent from south-east England, there are indications that substantial resources may be available at depth, although these could only be accessed by underground mining. In a study funded by the Aggregates Levy, we worked with Camborne School of Mines (University of Exeter) to investigate the feasibility of underground mining of aggregates in south-east England. We undertook a preliminary evaluation of subsurface aggregate resources in south-east England based on available borehole and other evidence. The study concluded that substantial subsurface resources of Carboniferous Limestone (south Midlands, East Sussex, Kent) and igneous rocks (Berkshire, Oxfordshire, Cambridgeshire) can probably be inferred from existing data. However, information is sparse and a targeted drilling programme would be needed to improve our knowledge of the extent and quality of these rocks, allowing assessment of their significance to long-term supply of aggregates in England. ■

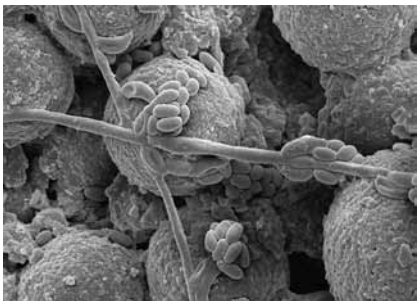
This transport tunnel (centre right of picture) linking two quarries in Leicestershire shows the possible above ground appearance of a mine portal required to access subsurface aggregate resources from an existing open pit.

Influence of biological processes on contaminant migration

Understanding the migration through rocks of contaminants, including radionuclides, is crucial in quantitatively assessing the effectiveness of repositories for the deep disposal of radioactive wastes and continues to be the focus of our radioactive waste disposal research.

The Biological Flow Apparatus developed by the BGS BioTran project last year has been used successfully to generate microbial biofilms in two rock types, diorite and mudstones, under temperatures and pressures which will be found in deep geological environments. Biofilms are aggregations of microbes growing on a surface, such as the wall of a fracture, and are frequently embedded within a self-produced extracellular matrix. Results show that these biofilms, and associated microbial activity, can change rock mineralogy and alter the transport properties of the rock. These include changes to the surfaces of the grains that make up the rocks where the microbial activity may promote mineral dissolution or deposition. The biofilm can also clog up flow paths. Thus microbial activity appears to reduce the movement of contaminants in the test rock materials. These preliminary results have implications for other areas where the performance of a geological containment system needs to be understood, such as in the disposal of toxic waste; and in carbon capture and storage. We are extending the scope of this work by working collaboratively with a number of British universities and the Japanese Atomic Energy Agency. ■

The BGS Biological Flow Apparatus is able to simulate temperature and pressure conditions found in deep geological environments.



Scanning electron microscope image of biofilm grown an a fractured mudstone in BGS laboratories.

Science Programmes

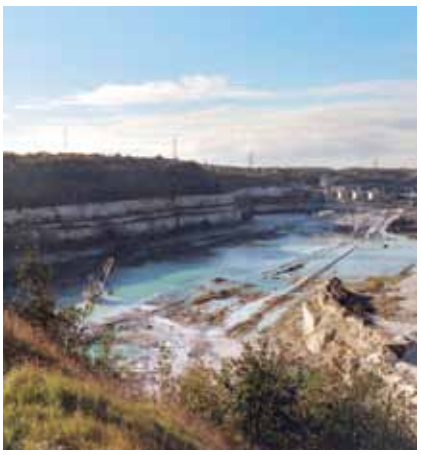
Groundwater Science

The River Lambourn at Boxford, near Newbury, Berkshire.

Groundwater plays an essential role in meeting human demands for water around the world. It is also vital for maintaining flows in rivers and supporting both aquatic and terrestrial ecosystems. As a result conflicts can arise. Pressures on groundwater are also increasing through population growth, increased land development and pollution. Our groundwater research programme investigates groundwater resources and quality and studies groundwater processes, as well as applying innovative monitoring and modelling techniques to improve understanding of groundwater issues. Our work contributes to improving the scientific evidence base and serving government and public needs.

Application of environmental tracers

Until the early years of the twenty-first century, the large quarries of the Swanscombe area of north-west Kent were an important source of chalk for cement production. Deep excavations meant that the quarries acted as a 'sump' for local groundwater drainage, necessitating the pumping of up to 40 000 cubic metres of water per day into the nearby River Thames. When the time came to infill the former quarries as part of the Thames Gateway redevelopment, the local water company proposed to intercept and use the groundwater by drilling boreholes to the south of the quarries. An ecologically sensitive chalk stream, the River Darent, approaches to within three kilometres south-west of the quarries so it needed to be established that pumping from these boreholes would not adversely affect flow in the river. Using 'environmental tracers' such as stable isotopes and chlorofluorocarbons we were able to demonstrate that no significant underground drainage routes existed between the river and the quarried area. This has enabled the water company to use the resource without fear of depleting a valued local amenity. ■



Chalk quarrying for cement at Swanscombe, north-west Kent.

Groundwater — surface water interaction

We have recently completed an investigation of the interaction between groundwater and surface water at a study site on the Chalk aquifer. At the site, the River Lambourn (a tributary of the Thames) flows over river sediments which are underlain by Chalk. The investigation involved installation and monitoring of boreholes and multiple piezometers alongside the river and beneath the river bed. A large number of samples were taken and analysed for water chemistry during the course of the work and hydraulic data were automatically recorded over several years.

The results of the work have been used to create a conceptual hydrogeological model of the site based on the 3D geological understanding and the long-term monitoring data. This showed that the interactions between groundwater and the river are complex and vary over space and time. It was found that groundwater in the sediments alongside and underlying the river flows in a variety of directions while groundwater flow in the Chalk at the site is generally separate from the overlying sediments. This work will contribute to the BGS Thames Basin Project which aims to combine process understanding with observations and modelling to develop catchment management solutions. ■

Investigating a borehole used as a drinking water source in Ethiopia.

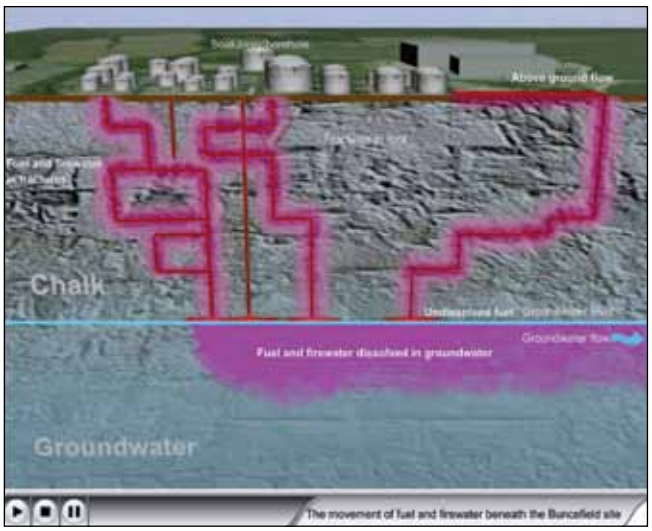
Potential corruption in aid-funded water projects

Our researchers have developed a method to assess the levels of corruption in aid-funded water projects in Ethiopia. The country has the highest number of people without access to improved water supply and sanitation in Africa, and the consequences are dire. Every year, about 250 000 children die from diseases related to poor water and sanitation and many others face the daily grind of collecting water from distant sources. Therefore, new investment in rural water supply is at the heart of the Ethiopian government's poverty reduction efforts. Yet little is known about how effective this investment is.

The World Bank commissioned us to investigate the potential for corruption down the water supply delivery chain from government policy to the actual construction of water points and the experience of the local communities. After several months of detailed research (involving dismantling and checking water supplies, detailed interviews with drilling companies, government, donors, NGOs and communities) the broad conclusions were reassuring. The BGS has also recommended to the Ethiopian government various ways of further reducing risk of corruption. ■

Buncefield explosion

It is over four years since the Buncefield oil depot explosion and fire but its impact on groundwater continues. The release of 250 000 litres of fuel from the damaged tanks and use of fire-fighting foam has led to contamination of the groundwater beneath the site. To enable the subsurface impact to be understood, we have constructed a three-dimensional model of the geology and hydrogeology in the vicinity of the site (near Hemel Hempstead) and a simplified visualisation of contaminant transport through the Chalk aquifer. This work was commissioned by the Environment Agency. The project developed the model using borehole records held in the BGS National Geosciences Records Centre and incorporated groundwater levels derived from the hydrogeology map for the area and Environment Agency data. An animated model of contaminant movement beneath the site has been developed to help communicate the complex information in a user-friendly way. The animations include a fly-through of the site, and show movement of groundwater below the site and development of the contaminant plume. ■



Screenshot of animated model showing the potential migration pathways for fuel and fire water beneath the Buncefield site.

Science Programmes

Land Use and Development

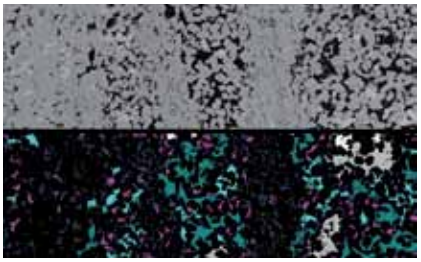
Urban development and its impact on the subsurface.

Land Use and Development comprises four thematic research teams — Shallow Geohazards, Geo-engineering Properties and Processes, Urban Development, and Sustainable Soils. Working closely together, these teams carry out an integrated programme of mapping, sampling, testing, monitoring and modelling that aims to describe the physical properties of the UK landmass and provide the underlying information and expertise that supports decision making in fields such as government policy, extreme event response, sustainable development of cities, and food supply.

Analogues for Permo-Triassic reservoirs

To improve our knowledge of the engineering and hydrogeological properties and behaviour of UK Permo-Triassic reservoirs and aquifers both onshore and offshore, we have surveyed outcrops of the Permian Penrith Sandstones in the Vale of Eden (Cumbria), using novel techniques such as Terrestrial Laser scanning. By combining this information with traditional fracture mapping surveys, outcrop-scale models are being developed to evaluate the relationship between fracturing, sedimentology, diagenesis, engineering properties and fluid flow.

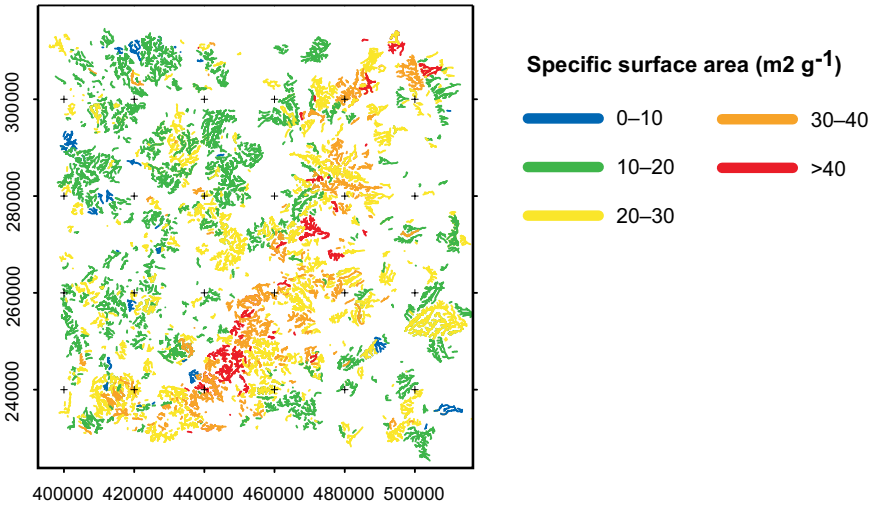
Our new high-resolution FEI QUANTA 600 environmental scanning electron microscope has been used to define the porosity and permeability characteristics of the Permian Penrith Sandstone, as well as helping to evaluate its diagenetic and fracturing history. This characterisation has demonstrated that these highly permeable aeolian sandstones are significantly affected by 'swarms' of low-permeability 'granulation seams' which strongly influence porosity and permeability, serving to compartmentalise fluid flow within the aquifer on a local scale. These observations provide new understanding of the controls on reservoir properties and fluid flow and their influence on hydrocarbon and groundwater resources, and on the potential of similar aquifers offshore for safe and effective storage of carbon dioxide. ■



Backscattered scanning electron microscope image (top) and binarised image after petrographical image analysis with interconnected porosity colour highlighted (bottom), from a polished thin section through a granulation seam in the Penrith Sandstone, Vale of Eden.

A new method for estimating surface area of fine sediments

Surface area — or, more precisely, specific surface area — is a fundamental physical property of rocks and minerals. Specific surface area controls the reactions at the surfaces of particles and so is closely related to a range of chemical properties which determine processes such as contaminant transport but also influence biological processes. Measurements of specific surface area are expensive because samples have to be prepared very carefully and the analysis requires a complex instrument. We have measured the surface areas of sixty stream sediment samples and, using the chemical composition of each, have developed a statistical model capable of predicting their surface areas. The model was then used to estimate the surface area (in units of square metres per gram) for more than 1800 sediment samples for which we also had chemical data. We were then able to investigate the importance of bedrock geology in controlling this property. From this it was found that the geology accounts for more than 40% of the variation in surface area of stream sediments across the East Midlands region. Sediments over some bedrock types have larger surface areas than others and these typically have greater amounts of certain clay or iron oxide minerals in them. This new approach improves our understanding of the physical properties of geological materials and can be extended across the UK. ■



Map of stream sediment surface area across the East Midlands region. This can be overlaid on the geology.

SubCity 3D

New, integrated 3D geological models have been developed to characterise the zone of human interaction beneath towns and cities. The shallow zone of human interaction is a term used to describe the legacy of past settlement, urbanisation, land use change and industrialisation. Its composition and properties reflect the use of the subsurface and its resources to support population growth and the expansion of towns and cities through time. Because of these historical changes in land use in cities, the subsurface is becoming increasingly congested with artificial ground, tunnels, basements and utilities. Working with partners including the University of York and the Norwegian Geological Survey, archaeological deposits are also being included to characterise the combined geological and anthropogenic urban shallow subsurface in 3D, using the Thames, Clyde and Mersey basins as demonstration projects. The innovative nature of this work was highly commended by the judges in the 2010 AGI Award for Innovation and Best Practice (in Central Government). ■

Research into geohazards affected by climate change

Our changing climate is affecting the stability of the ground. With hotter, drier summers and warmer, wetter winters forecast, clay formations such as the London Clay will shrink and swell to a greater extent. Using site investigation data, underpinned by new laboratory measurements, we are modelling shrink–swell susceptibility and how it varies in both surface distribution and depth. Allied with climate change forecast information, maps have been produced forecasting the severity of change for 2020 and 2080. The modelling has shown the importance of higher temperatures and increased transpiration on the process of shrink–swell. Similarly, we are looking at the effect of climate change on landslide and karst geohazards. ■

The landslide response team have been trained in using the new landslide recording interface on the BGS•SIGMAmobile field equipment. They can now record digitally and immediately upload new landslide information to the National Landslides Database.

Science Programmes

Earth Hazards and Systems

A plume of volcanic ash from the eruption of Eyjafjallajökull, Iceland.

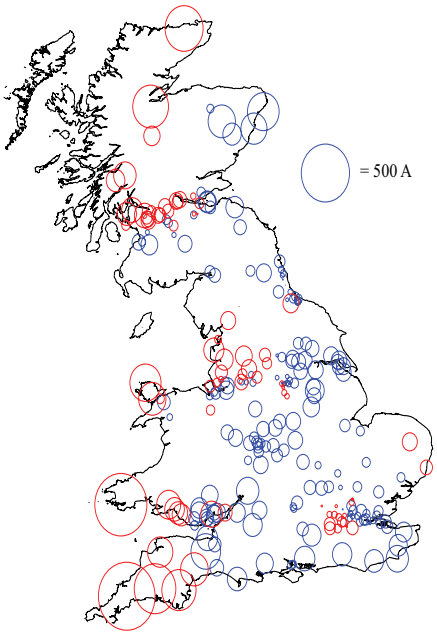
The BGS runs the national seismic and geomagnetic networks providing data that support research into natural hazards. Our networks are components of global systems monitoring the solid Earth and its surrounding space environment. Recent events have highlighted the importance of applying hazard research to assess risk and to protect life and livelihoods.

Volcano monitoring from space

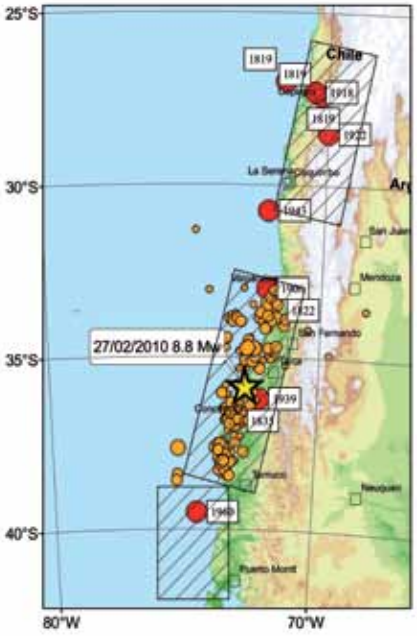
We successfully completed our part of the ESA-funded Globvolcano consortium, compiling the user requirements of volcano observatories for high resolution thermal data from new satellite-based sensors. The BGS is a member of a new European-wide consortium aiming to provide ash, sulphur dioxide, radar and thermal data to volcano observatories and other users, including Volcanic Ash Advisory Centres, in the event of a major transborder volcanic event. This project will respond directly to the lessons learned from the recent eruption of the Eyjafjallajökull volcano, Iceland, and will coordinate with major European initiatives such as the Monitoring Atmospheric Composition and Climate service. ■

Risk to electricity distribution systems

A new high-voltage power grid model for the UK mainland has been constructed through a BGS-funded Ph.D. studentship at the University of Lancaster. This, in combination with a 3D model of UK electrical conductivity and a new time-varying model of electrical currents in the ionosphere, has been used to explore space weather risk to the UK electricity distribution system. Scenarios, using historical geomagnetic storms and hypothetical events have been produced to investigate the response of the power system, in particular where 'hotspots' may develop. It has been shown that transformers both at the extremities of the system and at points inland are susceptible to risk from large geomagnetically induced currents. ■



Estimated geomagnetically induced currents in major transformers at the peak of the October 2003 magnetic storm. Spot size is proportional to current; red/blue indicates current to/from the Earth.



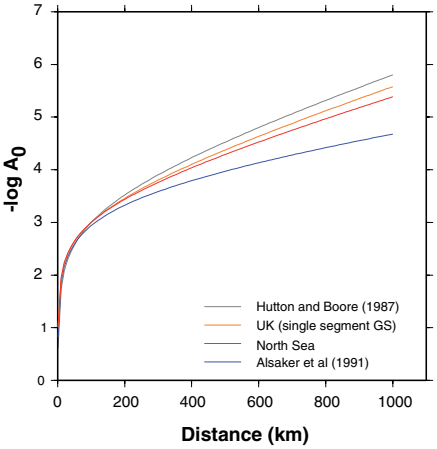
The offshore Chile earthquake rupture was over 700 km long, as mapped by the aftershocks, with slips of up to 10 metres on the fault plane.

Earthquake seismology

On 12 January 2010 the Haitian capital Port-Au-Prince was devastated by a magnitude 7 earthquake. Within 10 minutes BGS systems automatically detected and located the earthquake and alerted our seismologists by SMS who then contacted agencies later involved in rescue missions. In the immediate aftermath of the earthquake our staff assisted in assessing damage to buildings and infrastructure using satellite and aerial photographs. This information was used by the World Bank to assess reconstruction costs. In Haiti, around 230 000 were killed, over 300 000 injured and 1 300 000 people were displaced. This contrasts with the impact of the magnitude 8.8 earthquake in Chile on 27 February 2010, where the death toll was around 500. In Chile, earthquake resistance has been designed into buildings and the emergency services and the general population were much better prepared than in Haiti. ■

Revising the local earthquake magnitude scale for the UK

Local earthquake magnitude (ML) as first defined by Richter in 1935 is derived from seismic wave recordings, applying corrections for the distance of the seismometer from the earthquake epicentre, and for site effects at individual stations. Until recently, the BGS has used correction factors derived for southern Californian earthquakes to estimate the magnitudes of UK earthquakes.

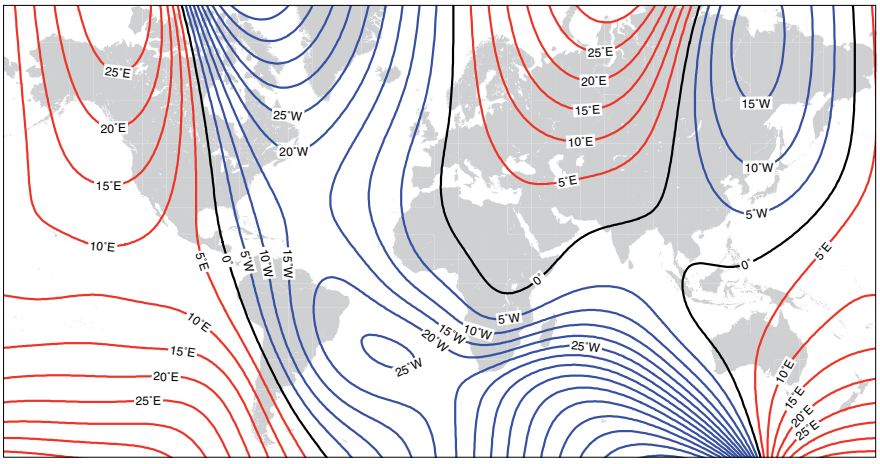


Distance corrections for calculating the local magnitude of earthquakes for the UK and southern California.

However, the tectonic regimes of southern California and the UK are quite different and improvements have been made by analysis of data from 57 well-recorded earthquakes located in the UK and its offshore regions. Distance corrections for UK data are systematically smaller than for southern California. The differences are minor at short distances (less than 50 kilometres) and have little effect on magnitude estimates for smaller events. However, recalculated magnitudes for larger recent British earthquakes are significantly smaller. For example the magnitude of the Market Rasen earthquake of 28 February 2008 has been revised to 4.5 ML from 5.2 ML. These results have important implications for seismic hazard assessments for seismically sensitive installations in the UK. ■

The World Magnetic Model 2010

The World Magnetic Model 2010 (WMM) is employed extensively for navigation and is embedded in the software of many military and civilian attitude and heading referencing systems. Users include the UK Ministry of Defence, the US Department of Defense, the North Atlantic Treaty Organization and the International Hydrographic Organization. The BGS and the US National Geophysical Data Center worked together to produce the 2010 model for release in December 2009, with funding from the UK Defence Geographic Centre and the US National Geospatial Intelligence Agency. The WMM represents the core and large-scale crustal magnetic fields. It consists of a 'snapshot' of the Earth's magnetic field at 2010 and an estimate of the mean rate of change for 2010 to 2015. The Earth's core magnetic field changes are difficult to predict and the model is revised every five years to maintain the accuracy required for general navigation. ■



Compass variation at 2010 from the World Magnetic Model.

Science Programmes

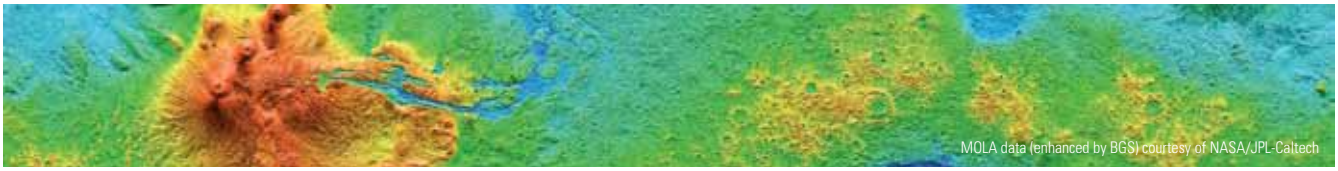
Spatial Geoscience Technologies

Spatial Geoscience Technologies develops satellite, airborne and ground-based observation and monitoring technologies and 3D geoscience modelling and visualisation systems. Our aim is to increase mapping, monitoring and modelling efficiency and improve the information content, quality and consistency of maps and models delivered to stakeholders. Our technologies meet, and in some cases help to define, international standards and best practice guidance.

Earth and planetary observation and monitoring

Considerable progress was achieved in making our technologies available beyond the BGS. In July 2009, we put our digital field mapping system BGS•SIGMA*mobile* on the BGS website as a free download. Nine months later, 560 licences had been downloaded by professionals, amateurs and students worldwide. Feedback has been excellent and one organisation plans to translate the system into French. We also launched version 1.0 of our immersive 3D digital landscape visualisation system, GeoVisionary™. Co-developed with Virtalis Ltd, this is now used routinely in BGS research and commissioned projects alike. The system is also sold internationally, providing royalties to the BGS and consolidating our position as world leaders in 3D geoscience visualisation.

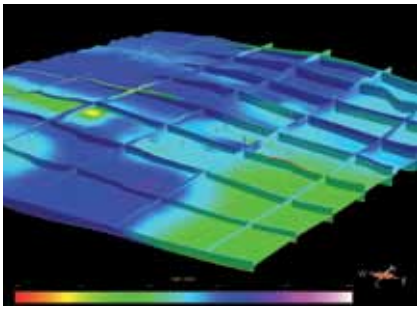
Our strong pedigree in Earth Observation helped us to win a contract from the European Space Agency to transfer our terrestrial tools and skills to planetary mapping. In this pilot project, we collaborated with partners from universities in Britain and the Netherlands, and the Netherlands geological survey to analyse and map the geology of the Nili Fossae area of Mars. This is a potential landing site for future missions to Mars, so the ground conditions must be characterised accurately and science opportunities identified. A new digital geological map of Nili Fossae was created. We also developed a prototype data-management system, to enable planetary scientists to discover, explore and access Mars data on the internet. ■



Martian topography, colour-coded to show elevation.

Standards and properties

3D geological framework modelling is now a fundamental part of the BGS's work. Given this penetration into our science, we resolved to capture best practice in 3D modelling to ensure consistency, repeatability and consolidate the lessons learned. This has been done in a unique report, directly synthesising the expertise and experience of many geoscientists in a 'recipe-book' that ensures all 3D geological models are made to the highest standard and represent best value to users. This document is currently used to guide our modellers but we are contemplating its wider publication. Alongside renewal of the BGS Rock Classification Scheme, we believe this means that our specialist customers and the general public alike now get the most reliable and understandable 3D geoscience information on Earth.



Sherwood Sandstone model colour-coded to show porosity variation.

New tools have been developed and tested for modelling the physical and chemical properties of heterogeneous geological units within models. Refinement of the 'PropBase QueryLayer' concept now allows rapid discovery and serving of property data to allow easy identification of available data. Our first models built using this system have concentrated on the economically important Sherwood Sandstone Group in the East Midlands, resulting in 3D porosity variation models due for publication during 2010. This technology will be of considerable benefit to new 3D modelling applications, such as assessing reservoirs and aquifers for future carbon capture and storage potential. ■

Modelling systems

In collaboration with INSIGHT GmbH, the BGS has developed its world-leading GSI3D geological framework model-building software over several years. This system is now used routinely in our projects and in early 2010 it was made available to external researchers, through the launch of a not-for-profit research consortium (**www.GSI3D.org.uk**).

These recent developments in 3D geological modelling methods and visualisation are also providing unique resources for teaching geoscience in the twenty-first century. Today's geoscience students use a variety of cognitive processes and spatial skills, and digital 3D geological models allow students to visualise and interrogate geology better than ever before. They reinforce spatial skills, facilitate student recognition of geological principles in the field and encourage students to think about geological processes and properties. In particular they assist students when they convert 2D field, map and GIS outputs into 3D geological units, a widespread conceptual and practical difficulty for all students of geology.

A questionnaire was identified as the most direct data collection instrument for gathering and evaluating information from UK universities offering earth science courses on the potential of our 3D models being used in undergraduate teaching. This was supported with visits to several universities and attendance at a geoscience education conference. Universities felt that 3D models would be useful when teaching structures, sedimentary rocks and tectonics, as well as GIS techniques and as a complement to field excursions. Potential exercises that the models could aid were those comprising faults, dip and strike and cross-sections. We are now building 3D geological models for these teaching purposes, incorporating education strategies to develop geospatial skills, alleviate problems that some students experience and so help develop the next generation of geoscientists. ■

Geophysical tomography

Ground-based observation and monitoring for contaminated land remediation, groundwater protection, mineral exploration and monitoring shallow geohazards continued to be underpinned by our world-leading, BGS-designed ALERT technology. ALERT allows complex earth systems and processes to be monitored remotely in real-time using permanent, *in situ* sensor networks and wireless telemetry. Grants were won from the Engineering and Physical Sciences Research Council (EPSRC), NERC, the Department for Environment, Food and Rural Affairs (Defra) and the East Midlands Development Agency (EMDA) which significantly extended the ALERT technology concept and improved our image reconstruction algorithms.

One new ALERT application is to provide early warning of carbon dioxide (CO_2) seepage from underground storage sites. Anthropogenic CO_2 emissions to the atmosphere pose one of the most important threats to the stability of the Earth's climate. The capture, injection and storage of this CO_2 in deep geological formations is an emerging and promising mitigation strategy, but further research is needed to address the possibility that the CO_2 may leak back to the atmosphere, rendering storage ineffective. Our proposal to use ALERT technology to detect and track the migration of CO_2 from deep storage at a field demonstration site, in Svelvik, Norway was successful in winning European (Eurogia+) endorsement and extensive funding from a consortium of industrial and academic partners in Norway, France and the UK. ■

Permanent, unmanned ALERT technology monitoring an active landslide at Hollin Hill, Yorkshire.

Information and Knowledge Exchange

The management of digital and analogue geoscience data, creation of national baseline and value-added geospatial datasets, delivery and exploitation of BGS science in the community, publications, and the provision of IT systems and network infrastructure services are the responsibility of the Information and Knowledge Exchange Directorate.

The receipt of substantial capital funding in mid-2009 for redevelopment of the Keyworth site has had major benefits and impacts. The construction of a new, purpose-designed extension to the existing National Geoscience Data Centre core store will enable the consolidation of existing core store facilities across the UK, and will future-proof for many years our capacity to store strategically and nationally important core collections. A new and highly energy-efficient computer server suite will replace the existing ageing facility, providing additional capacity to meet future BGS and NERC IT requirements. The refurbishment of other parts of the site has required some consolidation of library hardcopy stock and relocation of palaeontological collections. These new facilities provide a more cost-efficient way of guaranteeing access to these nationally important collections for the foreseeable future.

Version 1 of a national geospatial dataset illustrating hazard potential from non-coal underground mining was released in 2009. This dataset can be integrated with coal-related hazard information provided by other agencies to create complete UK coverage of mining-related hazard potential for the first time.

The launch of the OpenGeoscience website in early December 2009 was a significant milestone in data, information and science delivery. OpenGeoscience has been very warmly received by the user community. The website makes available a vast range of data, images, educational resources, software, and more, entirely free of charge for non-commercial purposes. A 'flagship' geospatial dataset delivered through OpenGeoscience is the BGS's DigMapGB-50 digital mapping. This makes the UK the first country in the world to have national, 'street-level' resolution, vector-based geological mapping delivered through a web map service.

Economic impact analyses of BGS information and advice services are essential in demonstrating the socio-economic benefits of our work. During the year analyses were undertaken into the benefits of the BGS's 3D modelling work, and our flooding geospatial datasets. The results, to be published on our website, show very clearly that the benefits to the UK economy of this work run into tens of millions of pounds annually, realising a very significant return on investment.

Staff continue to play active and prominent roles in representing the BGS, NERC and the Research Councils on national and international information-related organisations and bodies. These include the UK Location Council, the IUGS Commission for the Management and Application of Geoscience Information, the Association for Geographic Information, European INSPIRE-related working groups and data specification drafting teams, and the Geological Society of London's Information Management Committee. ■

The new core store extension at Keyworth, under construction in January 2010 (right); completed, and with mobile racking installed, awaiting transfer of core from Gilmerton and Loanhead stores in Edinburgh (opposite).

Information and Knowledge Exchange

Information Management

A typical student visit to the Keyworth core store.

The Information Management programme is responsible for all the BGS's records, digital data and material collections. Our goal is to manage the information in a coherent, integrated way, ensuring that high quality data and information are available to the citizen, government, industry, and the environmental science community.

OneGeology

OneGeology now has 116 participants and ever-increasing amounts of data served in the OneGeology Portal. There are currently 197 data layers being served through the portal as part of 85 web services, six of which are continental.

The portal receives 4500 to 6000 visits per month and a new version was released in June 2009. It now provides access to the first ever national 1:50 000 scale geological map data (for the UK), validating OneGeology's capability to provide access to high-resolution data. The GIS software company ESRI have offered participants a non-exclusive grant to support the technical backbone of the OneGeology initiative.

Communication and outreach continue to be a high priority and include newsletters, presentations, articles and a regularly updated website. A number of mutually beneficial areas for co-operation have been agreed with the Geoparks and YES networks. OneGeology has also been officially recognised as a sub-task in GEO/GEOSS, contributing to the Global Datasets Task. New web pages, 'OneGeology4Kids' were released in January 2010, receiving much positive feedback. This is a fun introduction to geology aimed at children under 10 years old. Multilingual versions will also be available. ■

GeoScenic

GeoScenic (**www.bgs.ac.uk/geoscenic**) was launched in December 2009 as part of the 'OpenGeoscience' initiative, providing a new interface to our vast collection of geoscientific images. Its launch was featured on the BBC News website, which included a slideshow of our geological pictures. GeoScenic provides access to selected photographs, organised into collections such as: landscapes, fossils, rocks and minerals, geological hazards, images from the archives, and earthquakes and volcanoes.

The images are downloadable at a size of 1000 x 1000 pixels free of charge for non-commercial use. Registered users can use a personal 'lightbox' to assemble their own collections of BGS images. The GeoScenic launch was complemented by the launch within BGS of a new geological images database which staff can use to store and manage their photographs. ■

From BBC News at bbc.co.uk/news

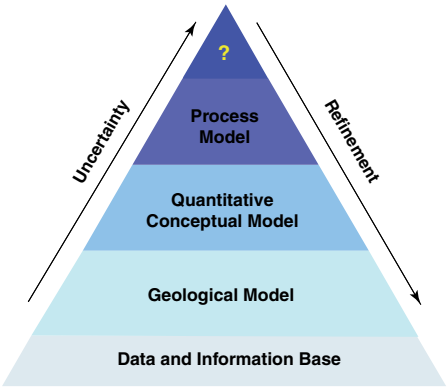
The launch of GeoScenic as featured on the BBC News website.

Environmental modelling

In order to answer the most pertinent questions of the age, such as climate change and security of sustainable and natural resources, we need to model whole Earth system science, bringing together climate, ecological, hydrological, hydrogeological, geological and socio-economic models, to provide a basis for planning and decision-making.

Within the BGS this need for model integration is clearly recognised as we seek to interlink a wide variety of differing geoscientific models to understand the subsurface. To this end the 'Data and Environmental Modelling' Scoping Study was commissioned to assess the current situation and make some preliminary recommendations on how an integrated approach to environmental modelling could be developed.

The study recommends the development of an Environmental Modelling Platform (EMP). This platform would include underpinning elements such as strategies for appropriate data management, and investigating the semantic relationships between different types of data. A key element in establishing the EMP will be the creation of methodologies to link existing models. Significant resources will be required to create the EMP, and we aim to develop and lead a community of best practice in environmental modelling. ■



Modelling pyramid: showing progress from data and information, through a series of steps, to environmental process models.

Building stones

Historic buildings in Britain are at increasing risk from damage due to the effects of climate change on the weather and a lack of suitable stone for conservation, repair and new build. The UK Building and Decorative Stone Collection has been built up by the Survey over many years. Its origins were in a nationwide survey to find stone to rebuild the Houses of Parliament, following a devastating fire in 1834. During the 1980s, when the BGS moved to Keyworth, the building stone collection remained in London with the Natural History Museum. Acquisition of building stone samples continued at Keyworth, and during 2009/10, the British building stones were transferred from London to Keyworth on long-term loan. We now manage a collection of 20 000 historic building stones that are invaluable to those conserving and restoring our stone-built heritage. ■

GeoSciML

GeoSciML is an interchange standard for geoscientific information that is being developed through international collaboration of geological surveys under the auspices of the International Union of Geological Sciences Commission for Geoscience Information. The BGS is playing an active role in this initiative and chairs the CGI working group responsible for the development. Close links were established between GeoSciML and the OneGeology-Europe project which led to a new release of GeoSciML, version 2.1, designed to meet project requirements. GeoSciML enables schematic interoperability, but for many applications semantic interoperability is also required. To address this, a Concept Definitions Group has been set up to develop common vocabularies. This activity was also closely linked to the OneGeology-Europe project, which is producing a semantically harmonised 1:1 million-scale map of Europe, leading to new and extended versions of several vocabularies, in particular one for simplified lithology. ■

Integrated core store database

A database integration project to bring together data on our holdings of core and sample material at Keyworth and at the Gilmerton and Loanhead core stores in Edinburgh has been successfully completed to support the relocation of the Gilmerton and Loanhead core collections to Keyworth.

The project has involved the development of a unified data model which takes into account the information recorded for all relevant sample types, including onshore borehole samples, cores and cuttings from hydrocarbon wells, and a variety of seabed, shallow-core and sediment-grab samples derived from marine surveys. A new suite of software applications has also been developed to enter, locate and retrieve the data held.

This new system will provide improved access to information about core and sample material. It will be an important underpinning component of the new core store facilities being developed at Keyworth to house the sample material previously held at our Gilmerton and Loanhead core store facilities in Edinburgh. ■

Support for students

In recent years, the Keyworth core store, part of the National Geoscience Data Centre, has been used by an increasing number of universities to support the training of petroleum geoscientists and petroleum engineers. Imperial College, London has used the facility for many years, but more recently Derby University and Manchester University have arranged core workshops, with almost 200 students attending during 2009/10. We also loaned sets of cuttings and provided borehole geophysical logs for extended student exercises in their own departments. An advantage of working with onshore borehole material is that a day at Keyworth can accompany a day in the field to view the same formations at outcrop. ■

Information and Knowledge Exchange

Information Products

Mid twentieth-century ironstone workings, an example of the former mine workings highlighted by the new Mining Hazard Dataset.

Information Products creates national datasets that underpin research and knowledge exchange for BGS. Our datasets cover the range of the BGS activities from geology, soils, natural and mining hazards to flooding, radon and energy resources. During 2009 flooding and superficial thickness models have been updated and there has been a new dataset released of non-coal mining hazard potential.

Derived products

Derived products deliver geological and geo-environmental data, interpretations and knowledge for the shallow subsurface within the UK in forms which are accessible and understandable to those that need them most. This year has seen new methodologies developed for GeoSure which is now partially automated and wholly vector-based, also the release of a new soil chemistry dataset which includes national data on arsenic, cadmium, chromium and lead. A new version of the groundwater flooding susceptibility dataset which now includes Scotland was released in 2009.

A major highlight was the development and release of a non-coal mining hazard dataset, which provides information on underground mine workings. Former underground workings, particularly where shallow, may collapse and cause surface settlement. Mining of coal is excluded from this dataset because the Coal Authority has statutory responsibilities in respect of past coal mining. The dataset covers Great Britain at a scale of 1:50 000 and evaluates some fifty different mineral commodities that have been worked underground, including metals, oil shale, building materials and salt. It combines the geology, which constrains the distribution of the potential hazard, with records obtained through extensive literature searches. Expert knowledge has been used to assemble, interpret, and organise this information using a geographical information system (GIS). ■

Baseline products

Baseline products are the core datasets that provide the starting point for many of our geoscientific research activities; they also underpin our range of derived datasets and the enquiries service. This year has seen a review of these datasets, in terms of production methods and data-enhancements, primarily aimed at making them easier to create, maintain and then develop into new products. New methodologies have been introduced for DiGMapGB-50, the Superficial Deposit Thickness model and the Geological Indicators of Flooding model, the latter two datasets subsequently being released mid-year with enhanced content. The improved production techniques will allow greater flexibility in developing the datasets and include capabilities for change-only updating, as well as easier deployment through new routes such as the OpenGeoscience data portal.

Annual improvements to the DiGMapGB-10 dataset were released, and it now includes over 2000 high-resolution tiles, mostly in and around many of our urban centres. Developments of the Soil–Parent Material Model focused on engineering descriptions of strength and excavatability, as well as drainage capability, mineralogy and pH. *(continued opposite).*

Thick sand and gravel resources are vital for the construction industry, the superficial deposits thickness model plays a role in identifying areas of hidden resource.

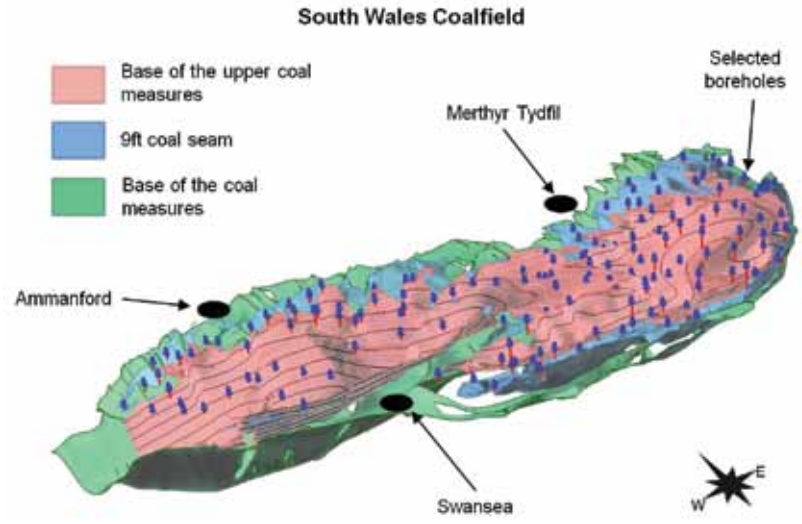
A significant development this year was the move to enhancing our core data by creating improved attribution of glacial till. Till covers approximately 30% of the land surface and forms the majority of the Quaternary cover of Great Britain. It is a highly heterogeneous deposit and can present some challenges in describing its geological and geotechnical characteristics; typically this results in a generic description of the unit. However, recent improvements in classifying the lithostratigraphy of till have resulted in a new dataset being created for use in (GIS). The dataset contains over 70 new till subdivisions, each with enhanced lithological attribution. These new data will be built into future products to improve assessment of geological, hydrological and engineering properties. ■

Data capture and best practice

In 2009/10 collaboration with the Mineral Resources and Policy team realised the completion of data describing the crushed rock resource for north-eastern England. This dataset gives planners and local authorities guidance on the potential source and composition of crushed rock, which is widely used as a roadstone and rail ballast, in addition to general construction.

Major progress has been made in our understanding of the South Wales Coalfield, utilising data from the former Coal Board,

Crushed rock aggregate is extracted and processed at Mountsorrel Quarry, Leicestershire, from Ordovician granodiorite.

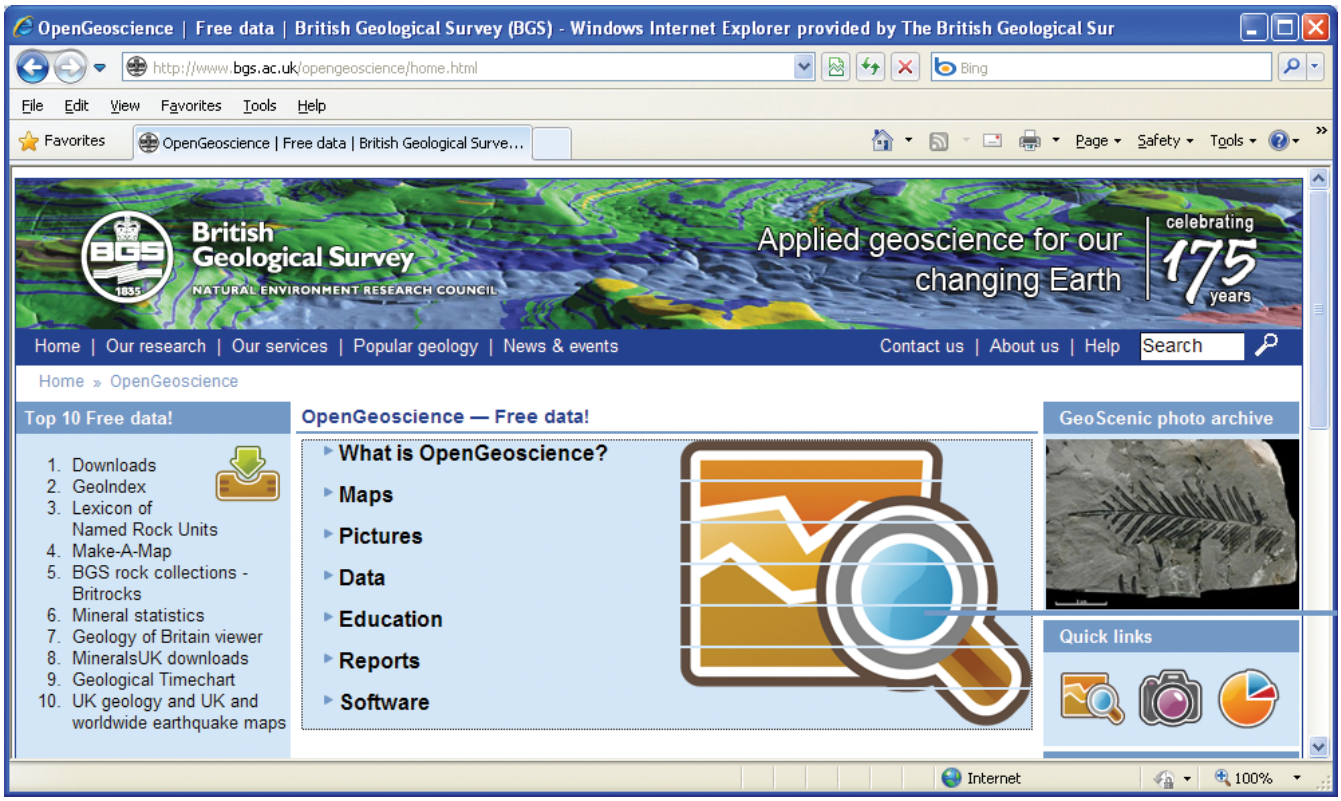


BGS 3D models aid policy decisions for minerals and energy resource, and regional development. This model shows the structure of the South Wales Coalfield and location of principal coal seams in the subsurface.

along with borehole and other records to construct and refine a new 3D model. This model, which incorporates stratigraphical surfaces including coal seams and marker beds such as marine bands, along with geological faults, allows the structure of the coalfield to be viewed and understood. This will provide a basis for future research into novel gas extraction and storage techniques such as underground coal gasification (UCG), coal-bed methane (CBM) and carbon capture and storage (CCS) in the coal basin. ■

Information and Knowledge Exchange

Information Delivery



The Information Delivery programme links BGS science to the wider community through a portfolio of information and knowledge services. This includes the corporate website, web services and online shops, media and outreach activities, and a range of enquiry, sales, library and licensing services.

Web Systems

The year's major release was the new OpenGeoscience website, providing a wealth of free, open-access geological materials, including maps, photos, data, reports and software. This includes innovative Web Map Services (WMS) providing viewing access to street-level (1:50 000) scale geological mapping for the whole of Great Britain, and free access through the GeoScenic service to 50 000 high resolution geoscience photographs.

The online shops were updated, including a major revision to the GeoReports service which provides advice for the site investigation industry in the form of geoscientific reports. Information systems have been developed for the Geological Survey of Northern Ireland to improve access to their spatial data holdings, particularly their borehole records. The BGS Intranet was redesigned to improve the efficiency with which business and scientific information is accessed by staff.

Rapid progress has been made on 'virtualising' the computing infrastructure that underpins our web systems. This has enhanced the resilience of the infrastructure while at the same time, reducing the number of servers required, thus contributing to the implementation of greener computing. ■

The GeoScenic interface on OpenGeoscience provides access to a huge resource of geoscientific photographs.

Information Services

Data, information and advice are provided through four information services.

The Sales Service supplies BGS books, maps and other publications to customers through online sale, direct mail order, and book trade supply routes.

The Enquiry Service provides geoscientific advice to the public, research and business communities, and visitor access services to the National Geoscience Data Centre. Some 12 000 enquiries were recorded over the year. The GeoReports service was updated to a modular format to allow customers to tailor the reports to best match their site investigation requirements, as well as improving the cost effectiveness of the service.

The Intellectual Property Rights Service advises staff and external parties on the terms and conditions relating to the use of BGS materials. Some 500 new or existing end-user licences were administered. A new 'Innovation Agreement' was introduced to allow private organisations and the public to review and assess BGS materials free of charge, with a view to the possible development and reuse of derived products and services.

The Business Solutions service delivers BGS licensed digital materials to business, researchers and many other users, and our team continued to offer scientific and technical support to our many customers through the year. ■

The GeoReports site advice service was updated with a new online shop and modular report system.

Communications

This year saw a dramatic increase in scientific content on the BGS web pages (140 new pages) and this coupled with the launch of OpenGeoscience (30 million hits on the website) and successful media engagement has resulted in an increase in website visitor statistics by over 500 000 on the previous year. Website hits almost doubled over the same period.

We have expanded our web presence via social networking sites such as Facebook, Twitter and YouTube, attracting many followers and allowing us to reach new audiences and promote public dialogue. There were at least 2716 online media hits and feature articles in, for example, *The Times*, the *New York Times*, the *Guardian*, *BBC online* and the *Scotsman*. 26 press releases were issued.

A BGS session on Carbon Capture and Storage was organised by the communications team at one of Europe's largest science festivals, the British Science Festival, where we engaged the public and the press on this important new technology and gained national media coverage. Our STEM Ambassadors made over 70 visits to schools across the UK to run engaging interactive scientific activities for pupils of all ages and provide inspiring role models for young scientists.

The UK Schools Seismology Project continued to expand with many new schools signing up and training programmes being run for teachers. Our *Climate through time* poster, published in 2009, was Highly Commended by the Geographical Association in their Publishers' Awards for 2010 as 'likely to make a significant contribution to geographical education'. ■

Research Knowledge Services

Research Knowledge Services manages the BGS libraries and online research information services for staff and external commercial, public and academic users. A re-evaluation of journals provision led to a major shift towards electronic access. Library staff participated in the annual Archives Awareness Campaign at Keyworth and the Open Day event at Murchison House. The NERC Open Research Archive repository (NORA) has been ranked 135th largest amongst the world's institutional repositories and now has over 2000 BGS entries. ■

BGS is expanding its audiences through use of web networking sites.

Information and Knowledge Exchange

Publications

Flooding at Cockermouth, Cumbria–November 2009.

The Publications programme produces our formal output of maps, books and reports in hardcopy and digital format. We provide a data capture and quality control service to digital map databases such as the Digital Map of Great Britain (DiGMapGB), and the equivalent product covering Northern Ireland (DiGMapNI). We also carry out research and development on new-generation digital publications, such as eBooks and 3D interactive models.

Cartographic GIS

Using geographical information systems (GIS) we continue to capture geoscientific information to build the British Geological Survey's digital map databases *(DiGMapGB, see Baseline Products, page 42)* and to support 3D modelling activities *(see Spatial Geoscience Technologies page 36)*. We then enhance this cartographically to produce printed map products.

This year we have added to the survey-scale map database (1:10 000 or 1:25 000 scale) to provide 20% coverage of Great Britain. We have digitally captured around 80% of the 1:10 000 scale Northern Ireland geological information for the Geological Survey of Northern Ireland (GSNI). Survey data are quality controlled and enhanced to cartographic publication standards using our customised cartographic GIS 'SIGMA-publisher'. These data are available for licensing. With the addition of generalised vertical sections we can provide information for 3D modelling and print-on-demand maps.

Our cartographers have also been processing data mapped in the United Arab Emirates and have been stationed in Papua New Guinea outputting customised GIS and maps.

A wide range of illustrations, including 3D PDFs were produced for inclusion in BGS Publications and outreach activities as a result of applied cartographic GIS and graphic design skills. ■

Photographic

Further development to the Geoscience Imagebase continued with the addition of a new public-facing facility to deliver the National Archive of Geological Photographs (NAGP) using the Open Geoscience Portal. With GeoScenic, the general public can view and download from a collection of 45 000 geological photographs and download 1000 x 1000 pixel images, free for all non-commercial use in return for an acknowledgement. There are a range of special images collections, such as, 'Best of BGS images', the British Science Association's major historical collection of earth science field photographs and Dr R Kidston's Carboniferous plants (scanned from original glass plates). GeoScenic is linked to the internal Geoscience Imagebase via a 'Publish' facility so that images gathered by BGS photographers and geoscientists can be made available to the public quickly, subject to confirmation of ownership and metadata.

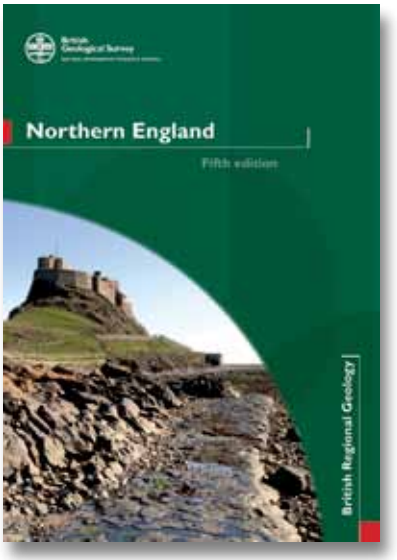
The Photographic section provided support to numerous projects in the field and with a wide range of studio and PR images. The images of the Cockermouth and Dumfries flooding were in high demand from local government agencies and the national press. ■

Graphic Communications

The Graphic Communications service contains graphic designers, a 3D animator, photographers, reprographics and print management staff. The team have worked together on all aspects of delivery for conventional and digital editions for publishing across the BGS. Traditional products are evolving into digital editions containing rich content such as hyperlinks, bookmarks and 3D interactive models.

The Graphic Communications team has also worked on the design and maintenance of the BGS's and hosted websites such as MineralsUK. BGS legacy Mineral Statistics publications have been digitised and delivered as eBooks on the Minerals UK website. Graphic Communications has developed digital workflows for scanning and delivering high quality editions of books in PDF format as well as providing a framework for categorising future scanning projects across BGS.

A full digitisation service is provided by Graphic Communications from project management and in-house capture to managing external scanning programmes. With a range of modern capture devices, the service has the capability to capture a variety of document originals from single objects to large complex programmes such as the archive collection of over 500 000 magnetogram originals dating back to 1840, which when delivered will underpin worldwide geomagnetism research. ■



The new Regional Guide for Northern England.

Output in 2009/10

Digital map and book data and printed media included:

- Over 600 5 x 5 kilometre tiles added to the 1:25 000 and 1:10 000 scale DiGMapGB database.
- Over 100 of these were cartographically enhanced to enable print-on-demand reproduction.
- 13 new lithoprinted maps were published for established series.
- Nearly 400 illustrations were prepared for inclusion in BGS books and reports.
- 45 000 images purposed for public download.
- 17 multimedia projects.
- 6 sheet explanations.
- 2 sheet descriptions.
- 1 memoir.
- 1 regional guide.
- 3 annuals.
- 8 reports.
- 86 brochures, leaflets and flyers, posters.
- 14 computer animations and 3D imagery.
- 200 legacy publications scanned to eBook or high quality PDF.

Editorial

The Editorial service has worked in the closest possible co-operation with Graphic Communications to provide copy-editing and proof-reading services on all our high profile publications, such as the Northern England Regional Guide, and on numerous sheet explanations, sheet descriptions and research reports. In addition, a member of the team has edited and developed the content of the highly successful BGS website on behalf of the Communications Team. ■

Systems & Network Support

Systems and Network Support (SNS) provides specialist scientific and general IT support to BGS staff as well as support for some of the NERC's corporate IT systems. Management of computer rooms, local area networks, systems administration and maintenance, database administration, IT security, and provision of IT equipment are some of the areas SNS covers.

SNS staff are regularly seconded to other sections of the BGS where they contribute skills and expertise in areas including project management and planning, development and installation of IT systems and networks both in the UK and overseas.

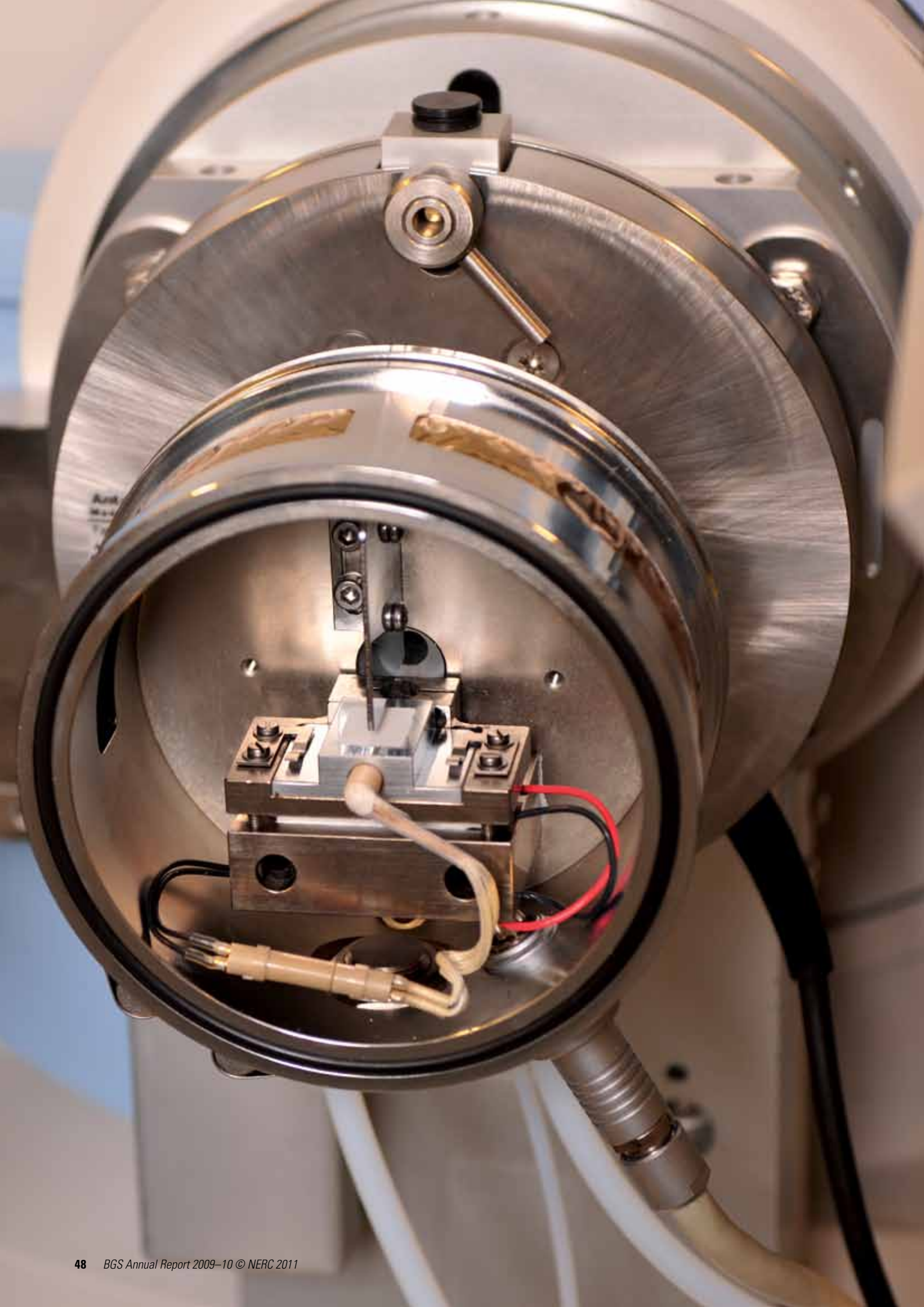
In preparation for the retirement of the senior manager of SNS in May 2010 the management structure was amended and SNS now works closely with staff from the NERC Information, Systems and Technology (IST) department. This has been a beneficial and efficient change and further savings and efficiencies are expected to develop.

Construction of a new computer room at Keyworth to house BGS and NERC corporate IT equipment began in autumn 2009. Reduced energy consumption and increased reclamation of heat from exhaust air will contribute to savings and efficiencies and reduce the carbon footprint of the BGS and NERC. Waste heat will be collected and used to heat the extended NGDC core store.

Email services for the whole of the NERC are provided by SNS staff; one focus of work in this area this year has been continuing improvements to email and development of staff calendars. Management of the underlying Active Directory is a joint effort between SNS staff and NERC IST staff.

Excellent progress with server virtualisation continues to be made, with nearly 90 systems virtualised in Keyworth and Edinburgh. Virtualisation of systems will continue prior to relocation of equipment in the new computer room during 2010/11.

Wireless network access is now available throughout Murchison House for both staff and visitors, and the Keyworth site has a steadily increasing level of coverage, governed largely by the continuing construction works on the site. ■



Resources and Business

The previous Science Resources Directorate was merged with the Business Development Directorate to form the new Resources and Business Directorate, under a single Director, from 1 April 2009. It combines the need to ensure that the right human and other scientific resources are available to deliver the BGS programme, with the ability to secure external income from commissioned research and grants.

Science and information staff are co-ordinated by Heads of Skills and Skills Leaders, who manage career development, training and allocations to projects of staff in the discipline for which they are responsible. Skills Heads and Leaders work closely with the Human Resources Department in the identification of needs, recruitment and staff appraisals. A separate Learning and Development team co-ordinates and delivers training to our staff, as well as to geoscientists from beyond the BGS through the GeoSchool and School of Field Geology initiatives.

The Directorate is responsible for running the Survey's many specialist laboratories and for the provision of geophysical equipment.

The Business Development function is responsible for corporate marketing, co-ordination of grant applications, supporting the BGS Board and the Senior Leadership Team, maintaining links with clients and stakeholders both in the UK and internationally and managing large, multidisciplinary overseas projects.

In our marketing role, we work closely with all parts of the BGS to promote capabilities, understand market needs, and engage with clients and stakeholders and to prepare bids and tenders. Marketing activities are supported by weekly bulletins of new opportunities, prepared in-house, and by a small team which produces and manages exhibition and promotional materials.

The UK Business Development (UKBD) team comprises a Team Leader and a number of sector marketing staff, who are based at all the principal BGS sites The team has devoted a large amount of effort to selling information products to current and new clients, including those in the insurance and home-buying markets. The slowdown in the housing market has inhibited sales volumes in this sector. UKBD organised several exhibitions and seminars across a wide range of sectors including oil and gas, water, minerals, environment, and information services. There has been continued engagement with devolved, local and regional government that has secured new externally funded commissions and heightened the BGS's profile. A priority has been to build stronger links with government, at all levels.

There are three regional managers for overseas work, whose responsibilities are based around language skills that are especially necessary in francophone and lusophone Africa. The main focus is institutional strengthening through geological mapping, natural resource exploration, natural hazard mitigation and data management, but which all place a great emphasis on training and knowledge transfer. Most projects are externally funded by clients such as the European Union, the World Bank, the Department for International Development or the government of the country.

The Grantsmanship team is responsible for co-ordinating the Survey's activities in Europe and, in particular, helping to win EU-Framework grants. It also prepared the ground for the BGS to bid into future NERC calls for Research Projects. This involved extensive classification of current activities, training in how to write grant proposals, and identification against the NERC's Theme Action Plans of priority areas for development of skills and capabilities. ■

Temperature humidity chamber for X-ray diffraction analysis (see page 55).

Resources and Business

International Development

A BGS field geologist with local guides, PNG Highlands.

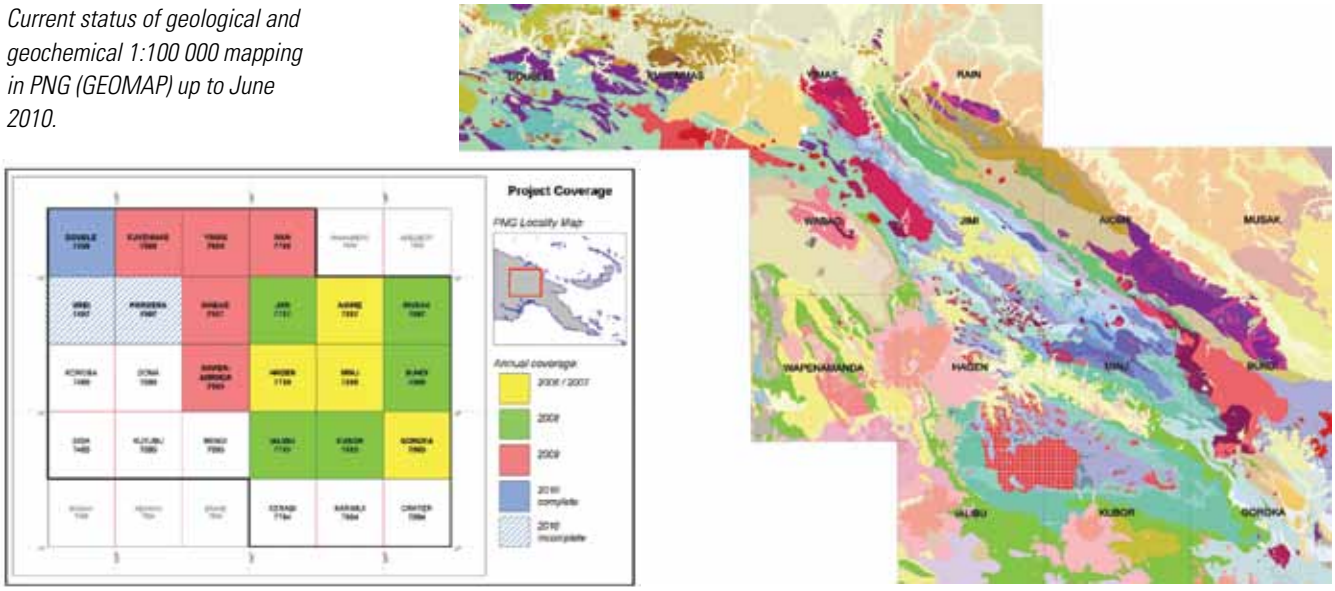
We undertake an extensive programme of high-quality international research, surveying and monitoring, including major institutional strengthening and capacity building projects throughout the developing world. Traditional regional multidisciplinary international activity was restricted to ongoing geothematic mapping projects in Papua New Guinea and the United Arab Emirates during 2009/10. Both projects are progressing successfully and on schedule to complete in 2011 and 2012, respectively. A second phase of short-term, basement-mapping training was completed in Tanzania. Opportunities for new projects have been much reduced, reflecting the cyclic nature of funding from the Development Banks. Bids submitted for major projects in Burkina Faso, Ethiopia, Nigeria and Sierra Leone all proved to be unsuccessful.

A field Geoschool in Tanzania

During August and September 2009 the BGS ran a field-based 'Geoschool' in Tanzania to train six graduate geologists, newly recruited to the Geological Survey of Tanzania, in the skills of medium-scale regional geological mapping in high-grade basement rocks. After three weeks of fieldwork the participants successfully completed a 1:50 000 scale map of a complex region of 600 square kilometres in south-west Tanzania. The area mapped forms more than half of the published 1:125 000 scale geological Chimala sheet and represents a marked improvement on the existing map of 1957. During the final week a geological report (sheet explanation) was written under instruction at the Survey headquarters in Dodoma. The trainee geologists were given the necessary experience, knowledge and self confidence to participate in an ongoing programme to revise older maps and complete the mapping of areas of the country for which no published sheets exist. ■

Newly-recruited trainees from the Geological Survey of Tanzania receiving instruction in geological field mapping techniques.

Current status of geological and geochemical 1:100 000 mapping in PNG (GEOMAP) up to June 2010.



Support for the mining sector in Papua New Guinea

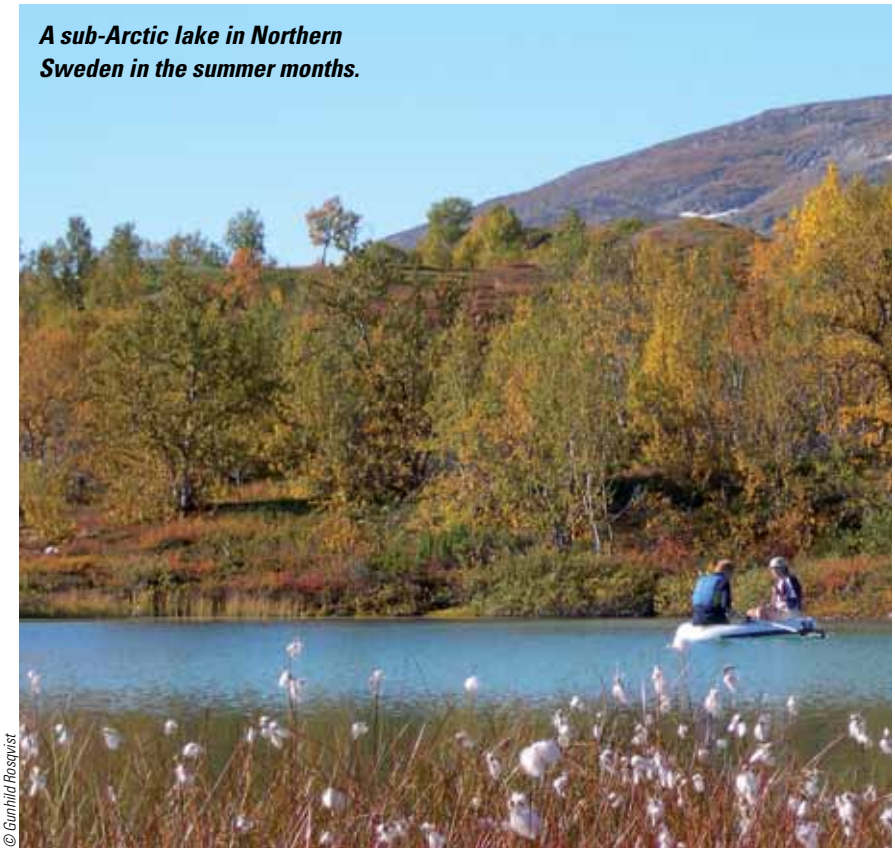
An EDF-funded geological mapping and mineral potential assessment project in the Highlands of Papua New Guinea (GEOMAP) has been progressing well since its launch in April 2006. To date, the project has collected several thousand rock samples, prepared some 2000 thin sections (many with detailed petrographical descriptions), approximately 370 whole-rock chemical analyses have been obtained, and 570 rock samples have been sent for palaeontological determination by a range of experts. In March 2010, GEOMAP handed over to the PNG Mineral Resources Authority (MRA) the fully validated (QA/QC) digital geochemical stream sediment analytical data which was released for sale in mid April. At the same time the final processed geophysical data from the Highlands region and the Papuan Peninsula became available. To date, several major exploration companies, including Harmony Gold, Rio Tinto, Newmont, Anglo American, Marengo Mining, Barrick, Khor, Eng Hock & Sons, Highlands Pacific Group, and BHP Billiton, have either bought or expressed an interest in buying the geophysical and geochemical data. The GEOMAP project, which is being undertaken in conjunction with the South African Council for Geosciences (CGS), Deutsche Montan Technologie GmbH (DMT) and the Mineral Resources Authority, is due to complete in March 2011 with the publication of fifteen 1:100 000 scale geological map sheets and associated multi-element geochemical maps. ■

Systematic geological mapping and mineral assessment in the United Arab Emirates

With funding from the UAE Ministry of Energy, the BGS has been commissioned to complete the geological mapping of the Emirates at a scale of 1:100 000. The finished output will include 30 maps and accompanying geological explanations, and builds on an earlier programme of work undertaken by the BGS in the north-east of the country between 2002 and 2006. In addition, new airborne magnetic data of the Western Desert, together with gravity data for the eastern part of the country, is being acquired. Existing seismic data is being reprocessed and interpreted afresh. Satellite imagery is being incorporated into the project's dedicated geographical information system (GIS), which will also record occurrences of mineral deposits. Particular emphasis is being given to the assessment of resources of limestone and dolomite, platinum group elements, and dimension stone. The project involves about 54 BGS scientists and technicians, some of whom operate in challenging terrain requiring extensive off-road driving over some of the largest sand dunes in the world. Work currently being undertaken in the region of Abu Dhabi, with its treacherous coastal sabkhas, sand seas and megadunes, has led to the discovery of ancient alluvial fans and lagoons together with evidence of river systems that flowed through Abu Dhabi between four million and six million years ago, complete with fossil elephants, camels and ostriches. More recent fossil sand dunes and wadis provide evidence of major climatic fluctuations during the Quaternary. The project has been running since 2008 and is due to complete in 2012. ■

A 'zeuge', or mushroom rock, the result of wind erosion in the Western Region of Abu Dhabi, United Arab Emirates.

NERC Isotope Geosciences Laboratory



A sub-Arctic lake in Northern Sweden in the summer months.

The NERC Isotope Geosciences Laboratory (NIGL) comprises two groups of analytical facilities complemented by a skilled scientific and technical staff:

- Stable Isotope Facility: isotope analysis of waters, carbonates, biogenic silica, phosphates, biomass in both organic and inorganic materials for the isotopes of H, C, N, O, S, and Si by gas-source stable isotope mass spectrometry.
- Radiogenic Isotope Facility: high precision U–Th–Pb dating using TIMS, and *in situ* dating by laser-ablation using plasma ionisation mass spectrometry (PIMMS); high precision isotope (U, Pb, Hf, Nd, Sr) analysis of solids and solutions using both solution and laser-ablation PIMMS, and TIMS.

The NIGL is a comprehensive 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 Ph.D. student training. The science addressed is interdisciplinary, aligned with NERC priorities, and involves problems where isotope analysis is pivotal. The NIGL serves many RAE grade 4 and 5 academic departments in the UK, and several NERC institutes, including the British Geological Survey. The NIGL is one of the NERC facilities for isotope research and is funded until 2014.

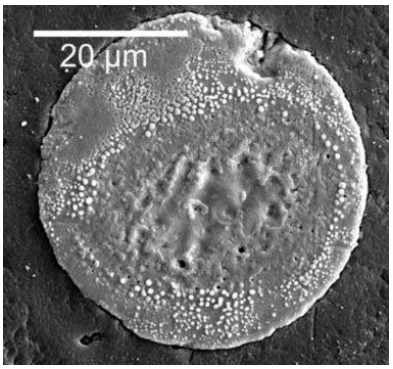
A modern calibration of oxygen and hydrogen isotopes from sub-Arctic lake waters

Lakes in sub-Arctic regions have the potential of retaining many different aspects of water isotope composition in their sediments which can be used for palaeoclimate reconstruction. It is therefore important to understand the modern isotope hydrology of these lakes.

The study looked at the significance of variations in water isotope composition of a series of lakes located in north-west Swedish Lapland. Climate in this region is forced by changes in the North Atlantic which renders it an interesting area for climate reconstructions. We compared $\delta^{18}O_{lake}$ and $\delta^{2}H_{lake}$ collected between 2001 and 2006 and showed that lakes in this sub-Arctic region are currently mainly recharged by shallow groundwater and precipitation which undergoes little subsequent evaporation, and that the $\delta^{18}O$ and $\delta^{2}H$ composition of input to the majority of the lakes varies on a seasonal basis between winter precipitation (spring thaw) and summer precipitation. ■

Depleted uranium contamination in up state New York

Uranium oxide particles were dispersed into the environment from a factory in Colonie (NY, USA) by prevailing winds during the 1960s and 1970s. The contamination footprint has been mapped northward from site, and at least one third of the uranium in a soil sample from the surface five centimetres, collected 5.1 kilometres north-north-west of the site, is depleted uranium. The distribution of contamination within the surface soil horizon follows a trend of exponential decrease with depth. Considering this distribution, the total mass of uranium contamination emitted from the factory is estimated to be about 4.8 tonnes. ■



Uranium oxide particle.

Monsoonal rainfall frequency near the East African Equator

This study has produced the first reconstruction of long-term variation in hydrological balance from near the Equator. Covering a period of 25 000 years, the data and age control yield insight into how tropical climate systems responded to the combination of changes in equatorial solar insolation and long-distance influence of high-latitude climate regimes. The location of this climate record in equatorial East Africa is crucial: the climate archive which accumulated in the bottom sediments of Lake Challa near Mount Kilimanjaro registered the dynamics of monsoon rainfall over the western Indian Ocean, where the zone of convergence between northern and southern hemisphere air flows undergoes the largest seasonal migration north and south of the Equator. ■

Isotope evidence shows decapitated individuals to be of Scandinavian origin

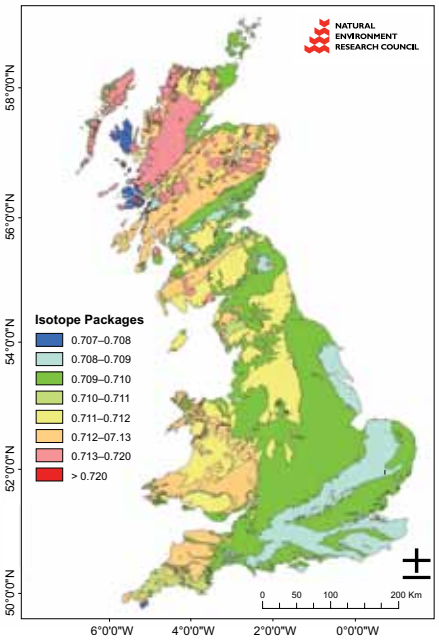
In June 2009 a burial pit was unearthed that contained the remains of 51 decapitated individuals. The men were carbon-14 dated to between AD 910 and AD 1030, a period of frequent Viking raids on Britain. Isotope analysis carried out at NIGL showed that all the individuals measured in this study had oxygen isotope tooth enamel values that were 'too cold' to be British and consistent with Scandinavian origin. It represents one of the largest Viking-age assemblages to be worked on. Up until now there have only been one or two confirmed Scandinavians of this period, found in the UK, using isotope techniques. ■

© David Score, Oxford Archaeology

Burial pit of skulls and bones.

New resource for human migration and provenance studies

The first $^{87}Sr/^{86}Sr$ isotope domain map of the UK was published this year. The map was based on direct measurements of the $^{87}Sr/^{86}Sr$ isotope composition of plants from across Britain. These data were used to characterise the major lithologies and a domain map was produced. This is now available as a reference data source for archaeological and forensic studies in Britain. ■



The first $^{87}Sr/^{86}Sr$ isotope domain map of the UK.

Export of iron from glacial terraines

Waters draining heavily glaciated terrain could provide polar oceans with an important source of iron — a possible limiting nutrient for phytoplankton. In one of the first studies of iron in glacial runoff, we examined waters draining a maritime Antarctic glacier basin on Signy Island. Using $^{34}S/^{32}S$ and $^{18}O/^{16}O$ isotope data we demonstrated that the oxidation of pyrite (FeS_2) was both a source of sulphate and of soluble iron. 80% of sulphate in water-draining talus and lateral moraines was found to be derived from pyrite oxidation (rather than atmospheric deposition), by bacterially-mediated reactions under suboxic conditions. Our study therefore identified specific environments (ice-marginal talus and moraine sediments) and conditions (suboxic waters associated with periods of low flow) as favourable for export of iron to the ocean. ■

© Andy Hodson

Signy Island, where specific conditions were identified for export of iron to the ocean.

Resources and Business

Science Facilities

Physisorption system and Vacprep.

During 2009/10, the remit of the former Laboratory Operations programme was broadened from the suite of laboratory facilities to encompass all of the BGS's science facilities, including marine and engineering operations; drilling facility; downhole geophysical logging; geophysics equipment; geophysical observatories; i3DVF and image analysis laboratories. The programme is responsible for the strategic and operational management of all science facilities, ensuring that they provide a high quality, cost-effective and scientifically well-aligned input to the BGS core strategic and commissioned programmes.

Analytical geochemistry facility

Over the past year, our geochemistry laboratories were consolidated from three locations into one integrated facility. One of the former laboratory areas is scheduled for demolition after the opening of the James Hutton Building on the Keyworth site; the other area was converted to office accommodation as part of major development of the Wallingford site by CEH. Following significant refurbishment of the remaining geochemistry laboratory area, the functions of all three former units have been combined into a single facility which has a smaller overall footprint but offers increased flexibility and efficiency of operation. ■

Hydrate and ices laboratory

We have recently invested in expanding our Hydrate and Ices Laboratory to a larger facility with dedicated 'walk-in' cold rooms. This new facility will allow a greater variety of experiments to be undertaken under precisely controlled conditions. Many important processes on the planet happen at low temperatures, and it is important that we can recreate these conditions in the laboratory to study them in detail. The laboratory will undertake studies on permafrost, which is important for predicting geological environments a long time in the future for research into disposal of radioactive wastes, and on gas hydrates, which contain a huge amount of methane and could be both a massive as yet untapped energy resource but also a potential driver of climate change if the methane escaped into the atmosphere. ■

New physisorption system

Surface area and porosity are important physical parameters when considering the characteristics of rocks and soils, particularly with regard to their engineering properties, industrial mineral use, water/hydrocarbon potential, gas storage and possible effects on soil quality and human health. The Mineralogy, Petrology and Biostratigraphy Facility's recently acquired physisorption system determines surface area and porosity from the amount of adsorbed nitrogen (or other inert gas) on a solid surface at monolayer coverage. By allowing the gas to condense in pore spaces under increasing pressure, the fine pore structure of a material may also be evaluated. The system has already been used on various BGS projects studying natural carbon dioxide storage analogues, the relationship between surface area and the elemental composition of soils and monitoring changes in reactivity and surface area through the critical zone. ■

Management and Development of Capability

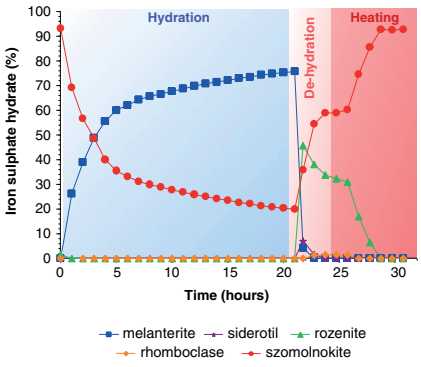
The Maintenance and Development of Capability programme comprises small to medium-scale initiatives that underpin the BGS's science programme. The main objective of the programme is to assimilate new scientific ideas and technological developments across a wide range of present and future activities. The programme is used to maintain our cutting edge capability through introduction of new methodologies and enhancement of existing capabilities.

TNT in seawater

Substantial dumping of unexploded ordnance at sea has occurred worldwide, with considerable amounts deposited in UK coastal waters, including the North Sea. Conventional explosives such as 2, 4, 6-trinitrotoluene (TNT) are toxic and represent a hidden threat to coastal and marine ecosystems. Our organic geochemists have developed a technique to emulate conditions commonly encountered in the North Sea by shaking seawater in the presence of clay- and sand-rich sediments to assess how quickly TNT degraded. Analysis revealed that TNT was rapidly attenuated by clay sediments and that the presence of microbes speeded up the loss of TNT. In contrast, the loss of TNT was slower when sandy sediment was present or when there was no microbial activity. This work showed that under winter conditions in the North Sea, TNT dissipated at a slower rate than previously reported. ■

Non-ambient X-ray diffraction analysis

Several mineral groups exhibit modification to their crystal structures as a result of a change in environmental conditions. For example, the structure of clay minerals and metal sulphate species strongly depends on the number of water molecules they incorporate. The addition of a temperature/humidity chamber to the Mineralogy, Petrology and Biostratigraphy Facility's existing X-ray diffraction system has enabled detailed studies of such phases. Experiments using this new capability have helped characterise and reveal the stability of hydrated iron sulphate species that are common constituents in sulphidic rocks and coal deposits. Such mineral species are highly soluble and known for their take up of toxic trace elements and generation of acid mine drainage. ■



Iron sulphate hydrate species concentration during hydration, dehydration and heating experiments.

Resistivity imaging

Micro-scale structures within rock petrophysical properties such as porosity and grain-size distribution control fluid flow, migration and the trapping of oil and gas within reservoirs. Both contact and non-contact (scanning) borehole micro-imaging tools have been developed in the BGS Physical Properties laboratories to study the fine-scale sedimentological structure of UK reservoir sandstones. Our contact systems can now produce fine-scale images with millimetric resolution, for example identifying the bimodal grainsize–porosity distributions associated with scour, granule lags and cross-lamination caused by wind-driven dune deposition and slumping in a desert environment where the reservoir rocks originally formed. These resistivity images enable high-resolution evaluation of the rock porosity controlling the hydrocarbon payload within a reservoir. ■

Fracture transmissivity

The Transport Properties Laboratory carried out a fracture transmissivity study using a bespoke designed apparatus to investigate the passage of fluid across an actively shearing artificial fracture surface in Opalinus Clay from Switzerland. Using very high-precision instrumentation, the experimental rig was able to shear the 60 × 60 mm sample as slowly as 1 mm per 3 months, resulting in detection of dilation of the fracture surface as small as 50 nm. The study showed that the permeability of the fracture changed as a function of the normal stress across the fracture and that transmissivity is a highly dynamic property during shearing. The use of fluorescein in the injection fluid showed that water propagation along the fracture surface was complex and concentrated along a limited number of pathways. ■

Resources and Business

Learning and Development

A training session in the use of GSI3D software.

During 2009/10 the BGS continued to provide staff training and development opportunities in support of the delivery of its science programme. Emphasis was placed on addressing skills gaps in growing areas of BGS science as well as on providing a broad range of development activities which contribute to a policy of continuous professional development and strategies for staff recruitment and retention.

Some of the highlights of the learning and development programme during 2009/10 included:

- In-house training to support the SIGMA digital data capture and data processing workflow, including courses in ArcGIS, SIGMAdesktop, BGS•SIGMAmobile and SOCET SET.
- BGS courses covering geological modelling software and 3D visualisation technology (GoCAD, GSI3D, GeoVisionary).
- Specialist training in the use of seismic modelling software (Petrel) for CCS work.
- BGS in-house training and guidance for researchers writing grant proposals.
- Training in various aspects of scientific communication including communicating science to the public, facing the media, press release writing, video production, writing for the web and publishing scientific papers.
- Specialist training in a range of laboratory techniques and instrument operation.
- Specialist training for IT developers working with web technologies (particularly JavaScript and Coldfusion), GIS (courses in Arc Server, Programming ArcObjects; and Visual Basic.NET) and Oracle database technologies (Oracle Spatial and Oracle 11g).
- BGS workshops and courses in hydrogeology, the interpretation of high-resolution airborne geophysical data, and geochemical data processing and interpretation.

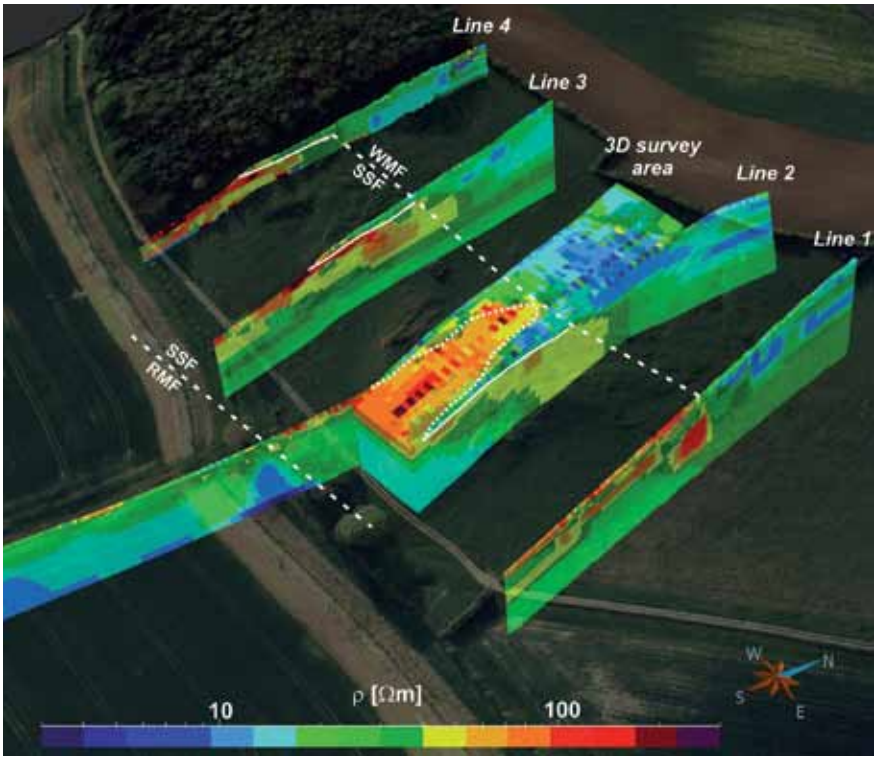
- Field-based training, attended by both BGS staff and university postgraduate students under the auspices of the School of Field Geology, covering geological feature mapping, mapping structurally complex geological terranes and interpreting and studying modern and ancient Quaternary landscapes.
- External training in a range of specialist topics including catchment management, ground physical property testing, solar terrestrial physics and multiphase fluid flow modelling.
- Leadership and management skills development including a series of NERC-organised events for senior staff under the L4N (Leadership for NERC) programme.
- Training in personal development and workplace skills, including courses in interviewing, presentation skills, project management, and mentoring skills in support of the BGS career development mentoring scheme.
- Health and safety training for staff working in hazardous environments or with hazardous equipment, including off-road driving, radiation protection, emergency and expedition first aid, fire awareness, personal survival techniques, quarry safety and the use of defibrillators.
- Support for the roll-out of new corporate IT systems including the RMS (Resource Management System) and the Oracle e-business system, through which staff interact with the RCUK Shared Services Centre.

Training in personal development and workplace skills and preparations for the RCUK Shared Services Centre 'go-live' were supported from NERC corporate funds.

Learning and development activities sponsored by the BGS during 2009/10 included classroom- and field-based training courses and workshops, e-learning (computer-based training), career development mentoring, coaching, on-the-job training and further education studies. Two staff successfully obtained bachelor's degree qualifications during the year with BGS sponsorship.

BGS training courses in seismic interpretation and GIS programming were arranged for external customers through the BGS GeoSchool and development work was undertaken to expand the portfolio of GeoSchool training available. ■

Field-based training in the use of BGS•SIGMAmobile.



An example of a GoCAD modelling exercise.

Finance

In the financial year 2009/10 we received just under £22 million of funding from the NERC to provide for both the funding of our core strategic science programme (CSP) and the contribution to our infrastructure. This accounted for approximately 47% of our non-capital funding. This funding was reduced from previous years as 'Unearned Income' relating to previous years' commercial work was used to displace science budget.

The NERC also provide capital funding and capitalised repairs. This included £16 million (over the life of the project) towards the second phase of the Keyworth site development, which will provide new open-plan office accommodation, an extension to the core store and a new computer room, to host both BGS and pan-NERC server facilities.

We earn the balance of our non-capital budget from external sources. This is from research commissioned by external partners and customers and from chargeable services, products and data licensing. The externally funded projects accounted for £16.9 million of the £24.7 million external income. These projects enhance the CSP through funding, ideas, data and review as well as making a vital contribution to our infrastructure.

In 2009/10, this income included revenue from varied sources including over £2 million from geomagnetism projects (including income from work undertaken in previous years) and over £2 million from work in the United Arab Emirates.

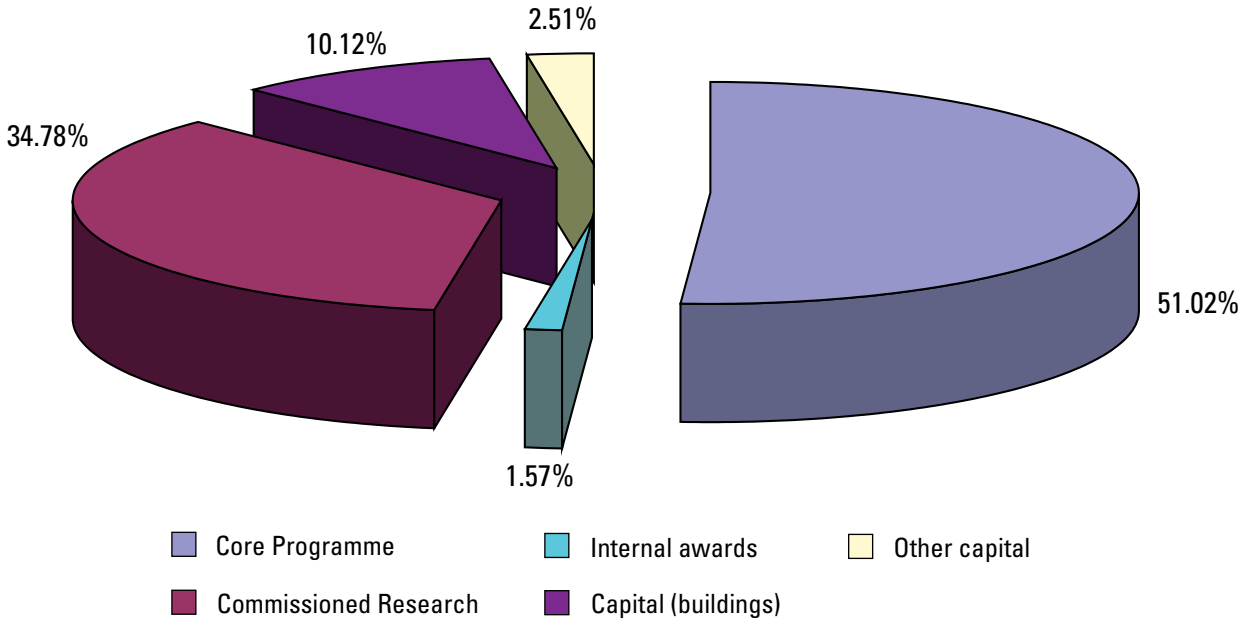
The income receivable from Value Added Resellers continued to be at lower levels than previous years as it is directly related to the housing market, which remains less buoyant than in recent years.

Developments

The new NERC funding and commissioning procedures (Funding Allocation and Budgeting) started from April 2009 and there were increased bids for NERC Research Programme bids.

The introduction of an RCUK Shared Services Centre (SSC) which will undertake many operational finance tasks slipped to start on April 2010 and preparation for this and, in particular, input into the various modules of the new SSC IT systems has taken up a significant element of the finance team time over the year.

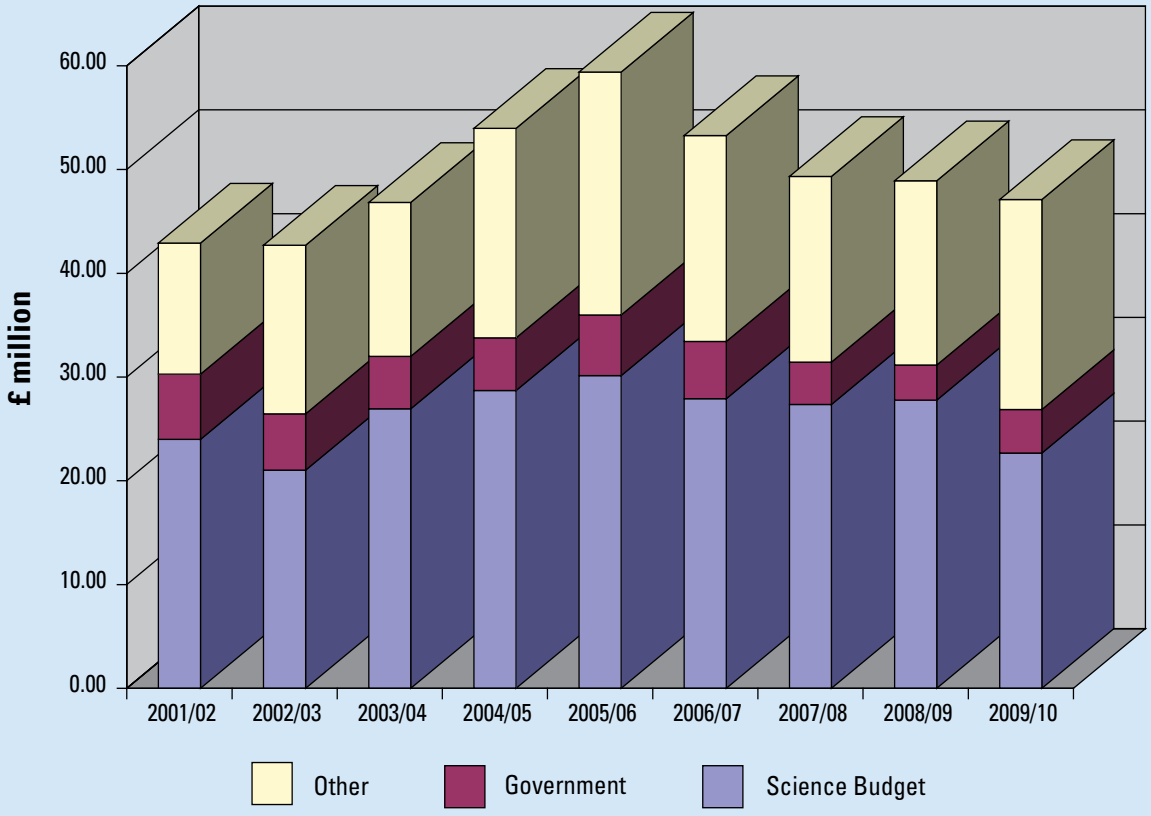
Local staff numbers have reduced significantly during 2009/10 in anticipation of the SSC, and further posts will be lost post go-live during 2010/11. ■



BGS expenditure during the financial year 2009/10.

BGS summary of income and expenditure 2009/10
(excluding the NERC Isotope Geosciences Laboratory)

Income	**£ million**
NERC Resource Allocation (Science Budget)	21.981
NERC Capital Allocation	8.873
Other Income	25.122
Total Income	**55.976**
Expenditure	
Salaries	31.695
Capital	6.841
Other Expenditure	15.991
Total Expenditure	**54.526**
Balance	**1.450**



Sources of income from 2001/2002 to 2009/10 (at 2009/2010 prices).

Estates, Environmental Management, and Health and Safety

Indicative design image of the James Hutton Building, reproduced with permission of Pick Everard

Estates

Following the completion, on budget, of the William Smith Building at Keyworth, NERC/BGS were successful in gaining funding for further redevelopment of the site. Consequently, three major projects have been running in parallel throughout the year:

- a new computer suite serving both BGS and the wider NERC community;
- an extension to the National Geoscience Data Centre (NGDC) core store; and
- the planning stages for the building of a new 100-person office block, the James Hutton building (JHB) together with the reconfiguration and refurbishment of the existing L-Block building to form a new reception and conference facility.

The new computer suite is a state-of-the-art facility which has been designed to provide the correct environment for the IT equipment it will house, while at the same time being extremely energy efficient. Some of the waste heat rejected by the building's cooling plant will be used to heat the new extension of the NGDC.

The extension to the NGDC is a core store which will house offshore drill core managed by the BGS on behalf of the Department of Energy and Climate Change and currently housed in Edinburgh. This move will allow all the core we hold to be managed as a single collection, with high-quality shared inspection facilities, and will subsequently permit the Edinburgh building to be disposed of with consequential long-term savings.

The JHB is an exciting project which will build upon the success of the William Smith Building, with the aim of further improving upon the sustainability and energy efficiency of that design. When it is occupied, some 300 of the Keyworth site's 500 staff will then be housed in modern, flexible open-plan accommodation. In parallel with the building of the JHB, which is due to start in September 2010, the refurbishment of L-Block will provide us with a modern reception and conference facility which will replace the outdated facilities currently in use.

On completion of these two projects, several more of the site's original 1960s buildings will be demolished and the site will be landscaped with a geological theme.

Other projects carried out by Estates include the creation of a much-needed coffee room area and a new meeting room at Murchison House in Edinburgh, the replacement of obsolete and inefficient boiler plant at Keyworth, and the application of an external-rendered insulation system to office blocks at Keyworth. The latter two investments will contribute significantly towards meeting the NERC's commitment

to reduce energy consumption by 40% by 2020.

Environmental management

The Survey's ongoing registration to the environmental accreditation BS EN ISO 14001 means we continually audit and develop how we apply current and new ways of managing environmental issues in our daily business. The NERC-driven Carbon Reduction Commitment and Carbon Trust Standard accreditation will be the priority over the next few years, and staff will be encouraged to attend planned briefings and information sessions to provide ideas and suggestions on how we can meet the aim of a 40% reduction in carbon emissions over a 10-year period.

Energy

Recent investments made in the Keyworth site heating plant have already started to make a small impact on our gas usage and this should improve over time. The Keyworth site electricity usage has increased over the past financial year but with the investment of submeters it is hoped to 'target' high-usage blocks and promote energy reduction in these areas. By using the information that can be gained from the new submeters and Building Management System, consumption data will be made openly available to staff to encourage them to take ownership of their areas and be proactive in the most efficient use of the sites power requirements.

Travel

The past year has seen no major changes in our business travel patterns. As finances get tighter, alternative methods of business communications will need to be taken, and the current vehicle fleet review will endeavour to encourage more meetings that are technology based as opposed to travelling to and from other sites.

Waste management

The recycling waste programme has been expanded at Keyworth, and is due to commence at Murchison House. The traditional office 'wastepaper' bin can now be used by staff to dispose of most recyclable items (paper, card, plastic bottles, and cans). These are sent to a waste handler who sorts the recyclables. Plastic laboratory waste also goes through the same waste flow. In addition, all waste from the sites that enters the waste stream is resorted at the waste transfer station and any additional recyclables are treated accordingly.

Biodiversity

While the ongoing building works at Keyworth temporarily disrupt the biodiversity of the site, plans are in place to develop and improve the landscape to exceed the current level of planting and grasslands. This will encourage wildlife to settle in the area while not encroaching on the core business of the survey. The annual site survey of the Keyworth grounds is about to take place, and works which affect the areas highlighted by the survey will be carefully moved and repositioned under the supervision of consultants.

The BGS Eskdalemuir site has recently had 500 additional trees planted, and Murchison House in Edinburgh recently won third prize in the Edinburgh city commercial garden section.

Health and safety

Our health and safety systems continue to be developed and implemented in line with NERC policies and guidance to ensure that the requirements of current legislation and best practice are met. Online systems have been developed which will assist managers and staff in meeting their health and safety obligations. Examples of these are project risk assessments, accident reporting and the requesting and purchasing of protective clothing and equipment. The team of Local Safety Advisers continues to work effectively and ensure that there is adequate cover at all sites.

Occupational health

BGS continues to provide occupational health support and advice via external professional suppliers. This has proved to be an effective way of delivering this service and the Health and Safety and Human

Resources teams work together to ensure that cases are identified and suitable action taken. Examples of the service provided include drop-in sessions for staff, medicals for staff going overseas and specialist clinics.

Accidents and incidents

Every effort is made to encourage staff to report accidents and near-misses and it is hoped that the new online reporting mechanism will help this initiative. Accidents, significant near-misses and occupational health occurrences are investigated and are reported at both BGS and NERC level. The aim within the Survey is to drive down the number of dangerous occurrences and accidents in line with the Health and Safety Commission's targets.

Health and safety training

Appropriate training is arranged for all staff to improve their skills and competencies where gaps are identified.

Audit and review

Health and safety advisers, in conjunction with trade union representatives carry out regular inspections and areas for improvement are identified and appropriate action taken. Such work is useful in raising the profile of health and safety with staff and is an effective way of gauging the way in which policies are being put into practice. ■

Administration and Finance

Human Resources

The year has seen continuing change as the Survey has responded to both external and internal influences in order to meet its strategy.

Following a skills review there was a minor restructuring. The cartographic and publications area was reduced with a number of staff leaving over a period of a few months on voluntary terms, as well as a small number of mapping geologists. The Survey also enforced a recruitment review that reduced the number of appointments during the year while increasing the number of existing staff being re-skilled. These actions resulted in the number of staff reducing again from the previous year, ending with a total of 734 full-time equivalent posts. This reduction is projected to continue in 20010/11 to below 700.

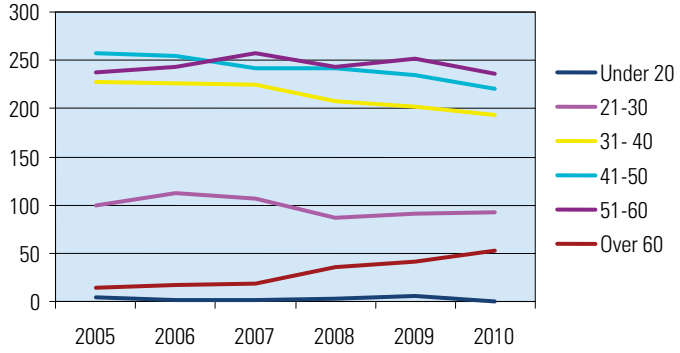
BGS staff continued to work towards the introduction of the Shared Services Centre (SSC) planned for Human Resources (HR) in April 2010. Local HR staff started leaving during a phased programme of administrative staff reductions in the year in advance of functions moving to the SSC in Swindon. As part of the SSC transition, more tasks will be delegated directly to managers and staff under the banner of 'self-service'. To assist with that process, a transition team was formed along with a staff support group to ensure comprehensive communication and management of the changes. There will be a profound cultural change for the organisation as traditional local administrative support is withdrawn and all staff required using centralised self-service processes.

At the beginning of 2010, a survey was undertaken to assess the health and wellbeing of our staff. The survey was based on the Health and Safety Executive's management standards and was completed by 71.3% of the staff. The results clearly showed that in a number of key areas staff felt in control and relationships were working well. However, change was seen as an issue and we will utilise the change facilitators to assist in reviewing this area. We have also started two initiatives that will assist staff with understanding their role. A review of the appraisal system will be undertaken ahead of the move to a new electronic system and individual career discussions will commence as part of the NERC's 'Deal' initiative.

Our Career Development Mentoring Scheme (CDMS) was launched in spring 2007. To date, 41 pairs of mentors and mentees have participated. The pairs are formally supported by the scheme for six months following completion of the training course. The scheme guidelines, training course and mentoring contract form the foundation of the mentoring relationship, and the participants are supported by the scheme co-ordinators. This year, a review of the scheme was undertaken and ten criteria were used to assess its success with staff. Nine of these criteria received a rating above four out of a maximum score of five.

The senior management team began a detailed review of our workforce planning. This started with a review of the existing Team Leader structure with a number of positions being re-advertised. Moving forward, the planning will include a comprehensive review of the skills within the organisation to identify the skills gaps and re-skilling required. This will enable flexibility to meet the strategic priorities during a difficult future of potential funding cuts. ■

Age profile (all employees)



	2005	2006	2007	2008	2009	2010
Under 20	4	1	2	3	6	0
21–30	100	112	106	87	91	92
31–40	227	226	224	207	202	193
41–50	258	254	242	242	234	220
51–60	237	243	257	243	252	236
Over 60	14	17	19	35	41	52
Total	**840**	**853**	**850**	**817**	**826**	**793**

Administration and Finance

Business Support

The Business Support group is responsible for support and guidance relating to operational activities such as project management, staff resource allocations and time recording. It also has a role in ensuring the good governance of the Survey by monitoring quality assurance, project risk management and business performance.

Governance and quality management

Further progress has been made to ensure that our management systems are both relevant and transparent in their application. Review and audit undertaken during the year by the British Standard Institute has resulted in ongoing accreditation to the ISO 9001:2000 quality management standard. Continuing UKAS accreditation for our laboratory operations has also been achieved.

A more holistic approach to audit has been established. Further development of the internal audit function, working to a mandate from our Quality Assurance Committee has ensured our corporate assurance and quality management activities are better focused. We have made progress in co-ordinating external accreditation with Research Council audits and BGS self-governing activities. We have also established further indicators to benchmark performance against external and internal standards. A longer term objective is to establish a single, integrated business assurance 'roadmap' that proves best practice for governance and quality management and, in so doing, better complements and enhances our capacity for science.

Resource and project management systems

The BGS implemented the NERC Resource and Project Management System (RMS) during the year. This was necessary to ensure a standard platform across NERC business systems that will interact with those employed by the Research Councils Shared Services Centre (SSC) into the future. The implementation of the RMS within the BGS has presented challenges but the levels of functionality provided by previous systems have been delivered and enhanced. The RMS has added functionality for managing expressions of interest and also increased functionality to assist in assessing risks and opportunities. The business process around these functions, in particular their interaction with SSC services, is still providing challenges. However, with the training and assistance provided by the project support team, the RMS has been accepted into the organisation and the potential of the system to enhance our management activities in the longer term is recognised. The working processes around the review of project risk, its reporting and interaction with the corporate NERC register for Systems, Targets and Risks (STAR) is one example of an early business benefit.

One of the primary drivers in moving to a NERC-wide solution for resource and project management is not only to provide a single interface with the business support functions of the SSC, but also to provide systems functionality across the NERC Research Centres to enhance collaborative working. Although final achievement of the latter objective has been delayed, BGS Project Support staff have continued to engage with NERC colleagues in advancing towards a successful conclusion. ■

A selection of BGS science published externally in 2009*

* Based on the NERC Open Research Archive (NORA). BGS authors in **bold** type.

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