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British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

2008–09 Annual Report

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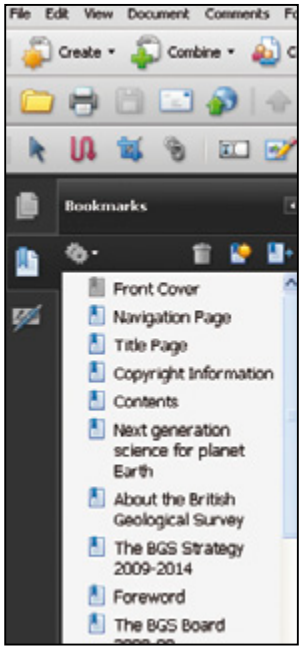

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British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey

Annual Report 2008–09

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

Cover: The atrium of the new William Smith Building at Keyworth.
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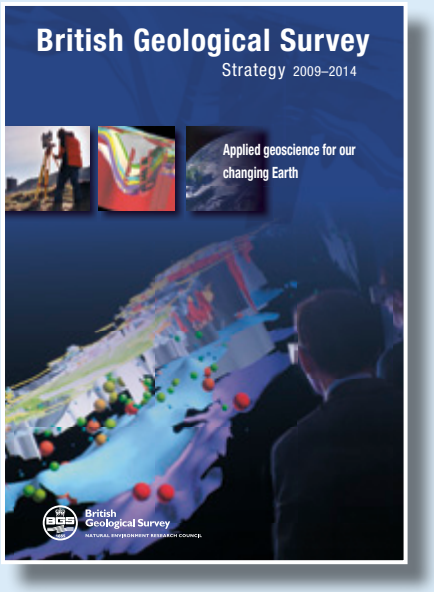
About the British Geological Survey

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

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

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

Our vision — to be a world-leading centre for applied geoscience.



www.bgs.ac.uk/about/strategy2009-2014.html

www.nerc.ac.uk

Next generation science for planet Earth

The Natural Environment Research Council (NERC) is a publicly funded organisation delivering world-leading environmental research and training the next generation of researchers. It is the UK's main agency for funding and strategically directing research, training and knowledge exchange in the environmental sciences.

NERC's strategic goal

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; and
- creating and supporting vibrant, integrated research communities.

The priorities the NERC develops with its researchers and stakeholders provide a focus for the marine, polar, atmospheric, earth, terrestrial and freshwater science communities.

The research is often multidisiplinary and in collaboration with other national and international partners. The NERC runs a fleet of research ships and scientific aircraft. It has bases in some of the world's most hostile environmnets and invests in satellite technology to observe environmental change on a global scale.

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

The BGS Strategy 2009–2014

The British Geological Survey (BGS) is a world-leading supplier of objective, authoritative and up-to-date geoscientific expertise and information supporting decision-making for government, commerce and the public.

In the next five years we will focus our activities on key strategic issues related to energy and environmental change. We will address complex environmental challenges requiring decisions in the short- and medium-term, including carbon capture and storage, radioactive waste management, natural hazards, resource security and environmental protection.

We will play a major role in the delivery of the Natural Environment Research Council (NERC) strategy — 'Next Generation Science for Planet Earth' and the 'Living With Environmental Change' (LWEC) programme. Through surveys, monitoring and research, in collaboration with the national and international community, we will develop a more holistic focus on modelling and the prediction of environmental change and its impacts.

We will deliver applied geoscience knowledge and services for the UK's national good. We will engage proactively with central and local government, their agencies, universities, the commercial sector and the public to meet their data and information needs, and become a major hub for environmental knowledge to inform policy, planning and regulation. We will further enhance our culture of commercial innovation to ensure that our knowledge is shared and exploited to deliver societal and economic impacts and benefits.

We will continue to improve the digital geoscience model and knowledge base of the UK and will endeavour to communicate more effectively their significance and benefits to our diverse stakeholders through excellent communication and leading- edge web delivery and visualisation technologies.

We will participate in and, where appropriate, lead major international projects, and will give priority to work in developing countries to exchange know-how and build capacity for alleviating resource poverty and living with environmental hazards. We will play a leading role in geological and environmental surveys of the UK, the North Atlantic region and Africa.

Successful delivery of our strategy will be founded on a proactive and inclusive approach to developing our skills and a timely response to changing drivers and needs. We will build on our national knowledge, capability and facilities to participate in the vibrant and interdisciplinary scientific and knowledge-exchange partnerships needed to understand and model our changing Earth and find solutions to the major environmental challenges facing present and future generations.

Foreword

Chairman of the BGS Board
Mr Derek Davis

This is my fifth and last Chairman's Annual Report foreword. It has been a challenging period for the BGS. Plans for a step-change increase in Science Budget funding proved unrealisable, necessitating adjustments in strategy, reopening old issues about the Survey's role and governance and stimulating innovative approaches to our science, data acquisition, management and dissemination and earning our external income. The Board has provided a steadying hand and played an important part in helping the BGS build on strengths, adapt to change and enhance an already long-admired contribution to geology across the planet.

As John Ludden says in his introduction, the new BGS strategy was collaboratively developed and extremely well received. It represents the culmination of a sustained process of revitalisation and renewal in our science and maps how we will take our data and exploitation activity forward. We see the BGS very much as a hub, virtual and tangible, at home and internationally. This is reflected in our plans for the Keyworth site. It was a great honour to welcome the Princess Royal, who opened the Mary Ward Teachers' Training College in 1970, back to Keyworth in July to declare our new state-of-the-art William Smith Building open. A major investment by our parent Research Council, the NERC, and our parent Department, for Business Innovation and Skills, it is not only designed for purpose, it is an affirmation of our joint commitment to continued excellence in geoscience, to Keyworth and to a new style of working.

My successor is being recruited by open competition, another mark of progress. There will be an announcement in due course and I hope to hand on in the New Year. Especial thanks are due to Professor Mike Petterson who did much, as Director of Science, to bring the BGS and universities closer together and played a hugely effective part, as Director of Resources, in stimulating and embedding a new BGS culture. Mike has set an example of the greater career mobility which he rightly advocated to broaden experience and deepen skills. We wish him every success as Professor of Applied and Environmental Geology at Leicester. Following completion of his task, the Resources Directorate has been merged with Business under David Ovadia.

I shall not be departing totally. I have agreed to serve on as Chairman of the Commercialisation, Marketing and Grants Committee, helping develop exploitation and external income. It has been an incomparable privilege working with BGS people, whose skills, resourcefulness and determination I first came to appreciate and respect when I had charge of oil and gas at the old Department of Energy. Their special qualities will, I know, be fully equal to the opportunities ahead.

The BGS Board 2008–09

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	Chairman (formerly of the DTI)
Mr P Bide	Department for Communities and Local Government (observer)
Mrs R Johnson-Sabine	Vice President of Exploration, Tethys Petroleum
Mr E Nickless	Executive Secretary, Geological Society of London
Dr S Paterson	Shell
Professor S Sparks	Director of Bristol Environmental Risk Research Centre, Bristol University
Professor P Styles	Head of the School of Earth Sciences and Geography, Keele University
Professor L Warren	Emeritus Professor Environmental Law, Aberystwyth University
Dr S Wilson	Strategy and Partnerships Director, NERC

Dr Paterson and Mr Nickless joined the Board on 1 June 2009 and Mrs Johnson-Sabine left the Board on the same date.

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.

Introduction

Executive Director
John N Ludden

The key achievement of the year was the preparation and launch of our new five-year strategy. This was a true team effort engaging people at all levels in the organisation, integrating feedback from our Board and the NERC and incorporating the views of the wider community. We launched the strategy at the Royal Society in March 2009 and this will be followed in 2009/10 by a comprehensive five-year Delivery Plan.

Another significant achievement was the completion of the new William Smith Building which accommodates about 200 staff and was opened by the Princess Royal in July 2009. This is the first NERC facility to receive a full 'excellent BREEAM' environmental assessment rating. A substantial second phase of development and regeneration of the Keyworth site has now been approved and includes provision for a second new office building, a new computer server facility and a major extension to the core store of the National Geoscience Data Centre.

At the heart of the science we deliver is an up-to-date digital framework for the geology of Great Britain and Northern Ireland. In 2008/09 we updated and published 31 maps, completed the Isle of Wight HiRES airborne survey, and undertook geochemical sampling for the London Earth project. This was complemented by pilot projects from government for a National Seabed Mapping Initiative and the creation of a new offshore consortium with the petroleum sector around the Faroes region. As part of our strategy for developing a 3D geological framework, more than 50 000 borehole records were scanned.

The need to make our data accessible to different user communities is the focus of initiatives such as OneGeology, GeoSeas and the EU INSPIRE directive. Our work as a public sector data provider resulted in us receiving a prize from Oracle and the GSNI's TELLUS project won the Association of Geographic Information award for Innovation and Best Practice in the central government category. Furthermore, data from the TELLUS project has helped to boost mineral exploration to unprecedented levels; in recognition of this, Northern Ireland won the Country award at the Mines and Money forum.

There is a synergy between our geosciences database and our network of observatories. We have continued our involvement on Montserrat volcano through a space radar deployment to penetrate eruption clouds and assess risks. Further development of automated geophysical technology (ALERT) for monitoring the impacts of weather and climate on slope stability may help us commercialise the technology. Earthquake monitoring and hazard assessment have improved through continued upgrade of the UK seismic network and we carried out ground acceleration assessments for the Market Rasen and Folkestone earthquakes. In addition, a joint initiative with the Proudman Oceanographic Laboratory, enabled us to undertake a study for DEFRA on earthquake-generated tsunami risks and early warning systems in the UK and the release on our newly redesigned website of the National Landslides Information Centre was very well received. The latter, along with the very successful Schools Seismology Project, is an example of how we make BGS science as available as possible. Indeed, much of our science is freely accessible through our website, which is now averaging more than 11 million hits per month.

This year we released some key products including:

- the first release of data on radon in Scotland;
- non-coal mining hazards;
- offshore Quaternary deposits;
- potentially harmful elements; and
- groundwater flooding susceptibility.

In addition, updated versions of the DiGMapGB-10, DiGMapGB-50, GeoSure, Geological Indicators of Flooding, Permeability, and Soil Parent Materials datasets were made available.

Our strategy highlights the 'zone of human interaction' of the Earth's crust. Study of this zone will define how humankind can live with a changing planet and has a key role for geology and geophysics. One area of our research aims to develop our understanding of the subsurface for geological storage. Activities last year included:

- an all-Ireland carbon capture and storage (CCS) study;
- transfer of CCS technology to China and India;
- formal establishment of the EC group CO2GeoNet; and
- the completion of the first phase of a CCS study of Scotland.

We gained five new industrial partners in the Edinburgh Anisotropy Project and have expanded the remit of this consortium to include CCS. We won a large EC contract

" The BGS's new strategy marks a fundamental change in the way we provide and deliver geoscientific knowledge and excellent research to academia, government and industry. Our science will be more collaborative and joined up to meet the challenges of energy and resource security and environmental change "

Denis Peach
Chief Scientist

on radioactive waste repository science (FORGE) and will enhance this through close association with DECC, NDA and other European radioactive waste management facilities. The development of the UK underground gas storage sites have also been the subject of BGS advice and public discussion. Communication with the public on the need for subsurface storage is a difficult challenge that we are pursuing through close engagement with the UK Committee on Radioactive Waste Management (CoRWM), with the EC Zero Emissions Panel (ZEP) and with the UK government through advice networks and participation on government panels.

At shallower levels, the zone of human interaction includes use of our geological data to model future impacts of population growth and suburban expansion on groundwater. In close association with other NERC centres and the Environment Agency we will develop an environmental modelling platform. We are further developing our links with government and, with the Department for Business, Innovation and Skills as lead, created the BGS Government Advisory Panel which will work closely with government on matching our deliverables to government Strategic Action Plans in urban development, energy resources, mineral resource sustainability and also environmental protection.

Our work contributes to research and training in higher education institutes. We are now deploying our digital field mapping technology in numerous undergraduate programmes and are enhancing our field mapping courses at home and overseas. Highlights of our research outputs and those for the NERC Isotopes Geosciences Laboratory (NIGL) for 2008/09 include:

- providing constraints on rapid climate change;
- new uses for isotopes in biogenic silica;
- new interpretations on ice survival throughout the Late Glacial Interstadial;
- pollution studies in the Clyde and Thames estuaries;
- forensic calibration of coastal environmental change;
- forward modelling of organic pollution in contaminated sites through the LINK Bioremediation consortium; and
- advancing our understanding of the paleo-environmental evolution of Madagascar and the East African continental margin.

This year marked the end of several large international development projects funded by the World Bank. A notable example was the Madagascar project, which delivered a 2000 page report and over ninety map sheets at a scale of 1:100k. The Afghanistan project funded by the Department for International Development also ended. We started a new World Bank project involving a national geochemical survey in Nigera and initiated the second phase of a project involving mapping and geophysics in the United Arab Emirates.

In what became a challenging year, especially in an economic context, we achieved our major objectives in 2008/09. We recruited about 40 new staff this year, although staff numbers are slowly declining in response to the implementation of the RCUK Shared Service Centre and a generally more strategic recruitment policy. We fell only slightly short of our external income target in a year that saw continued stagnation of the property market and thus significant downturn in demand for the information we provide to that sector. As the year closed, the effects of strategic changes in NERC funding and the economic downturn were becoming increasingly apparent and we have implemented strict policies on spending and recruitment.

" In the development and delivery of geoscientific data and systems the BGS continues to punch above its weight. Through our expertise we are well placed to contribute to a digital Britain and a digital world for the benefit of all society "

Ian Jackson
Chief of Operations

Active landsliding and toppling failures, Brighstone Bay, Isle of Wight

Science Programmes

The BGS Science Programme provides up-to-date knowledge on the three-dimensional geology, landscape and natural resources of the UK landmass and continental shelf, and carries out applied research to understand environmental processes and predict the impacts of natural hazards and climate change. We collaborate with national and international research partners, clients and sponsors, to combine the national geoscientific 'evidence base' with high-impact research to support policy and decision-making on sustainable use of land, energy and natural resources, and living with environmental change.

The primary objectives of the science programme during the year have been to consolidate our national capability in strategic priority areas and build partnerships in readiness for delivery of the new BGS strategy 'Applied Geoscience for our Changing Earth'.

Our strategy focuses on the development of regional and national scale observatories and models to understand properties and processes both on and below the Earth's surface, and we will share this knowledge with our environmental research partners to predict the impacts of environmental change and inform decisions on mitigation and adaptation strategies and the sustainable use of resources. Impacts of environmental change are likely to be greatest and most unpredictable at the confluence of cities, catchments and coasts, so we have initially chosen the Thames Basin, Clyde Basin and Belfast conurbation as hubs to develop collaborative environmental observatories and models, supported by funding from the NERC, DETI and a variety of other government and industry sources. In 2008/09, we accelerated our programmes to fill remaining gaps in the geological knowledge base in these areas by completing new 3D geological models of London and the Clyde Gateway, and the London Earth project completed a soil geochemical sampling of the northern half of the London conurbation. In Belfast, data acquisition and digital mapping was completed to prepare for the DETI-funded modelling project which will commence in 2009.

The challenge of securing future energy supplies while reducing carbon dioxide emissions continues to grow as a global priority. We assembled a new consortium of industry partners during the year to commence a major regional study of the geological structure and evolution of the Faeroes Continental Margin, which will guide further hydrocarbon exploration and production in this frontier region. Our contribution to the development and implementation of Carbon Capture and Storage technologies has continued to expand into a programme of truly international scope. A new web-based decision-support tool for carbon dioxide storage site assessment and monitoring was completed for the International Energy Agency, with projects in Europe, China and India focusing on best practice for carbon dioxide storage capacity assessment, reservoir integrity and methodologies for leakage detection. Closer to home, we contributed to major, integrated assessments of carbon dioxide storage potential for Scotland and the all-island of Ireland, and completed assessments of matching carbon dioxide storage capacity for coal-fired power stations in Yorkshire and Central Scotland. These studies will provide the evidence-base for future decisions and investment in this new technology as an essential contribution to the UK's targets for carbon dioxide emissions reduction.

The wet summer of 2007 was notorious for major floods, but did it also contribute to the increased landslide activity in the following autumn and winter? Landslides can cause considerable loss of life, damage and disruption to infrastructure, and may occur on natural slopes or in man-made excavations, embankments or spoil heaps. Although we can predict that a wetter climate will lead to greater ground instability, we cannot forecast the impact of individual weather events on landslide activity with accuracy in both space and time. To establish and understand links between climate, weather and ground stability, we broadened our network of global positioning system and ground resistivity sensors in 2008 to provide us with more real-time information on ground movement and groundwater saturation in a range of settings including natural landslides and engineered embankments. We have also established a new rapid response team to investigate and survey landslides as soon as possible after they occur, to gather information on local conditions and impacts that will help inform mitigation measures.

A new UK national seabed mapping programme will be essential to inform spatial planning and decision-making on deployment of new offshore infrastructure, for example for carbon dioxide transport and storage, offshore renewable energy and marine aggregate exploitation. This ambitious project will require many partners and will take many years to complete. Offshore survey projects during the year have enabled us to develop and demonstrate new survey capability for seabed geological mapping at resolutions of 1:50 000. A newly commissioned shallow water survey vessel will provide us with new capability for surveys in the nearshore zone, where new knowledge will be crucial to understand impacts of climate change and storms on coastal sediment fluxes and rates of erosion.

Science Programmes

Geology and Landscape

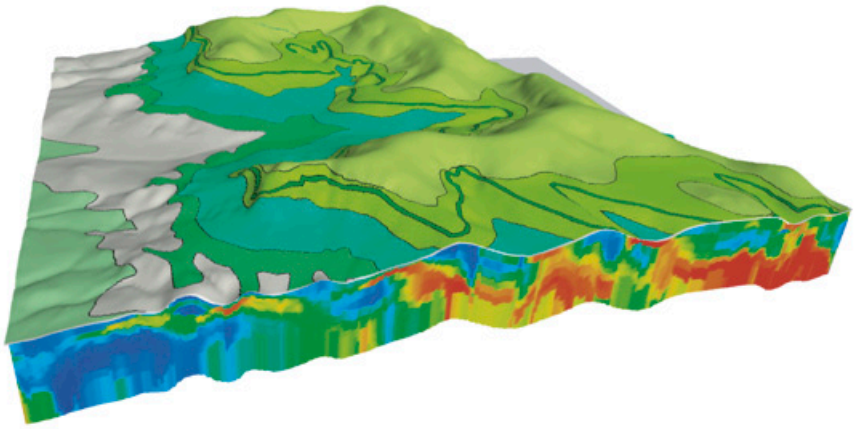
An understanding of the geology of the UK is essential for continued economic and social development. The BGS's multidisciplinary surveys provide baseline information for applied geological research, including the protection of the natural environment, the quality and character of the countryside, the built environment and existing communities. These surveys contribute to our understanding and protection of water, mineral and energy resources, agriculture, forestry, soils, and to studies of climate change. We publish geological maps, 3D models and other research outputs, that support our information products and underpin many aspects of our work. We have a unique dataset on the geology of the UK and offer the most extensive and broad-ranging knowledge on the subject. Our outputs contribute to the development of the UK, and provide a vital baseline for land-use planning, industry, the education sector, and tourism.

Sampling on Stork Ridge, Adelaide Island, West Antarctica, for cosmogenic nuclide analysis (see British ice sheet dynamics)

New insights into the structure and evolution of southern England

A new understanding of the structure of the Cretaceous and Palaeogene bedrock has emerged through 3D modelling of London, with the identification of previously unknown faulting and folding patterns beneath the capital. The recently completed 3D model of Greater London, covering 2400 square kilometres consists of geological surfaces down to the base of the Chalk Group at a resolution consistent with the geology shown on our published 1:50 000 scale maps of the area, and is proving to be of great utility for planning and development. The modelled area is currently being extended westwards into the Windsor–Reading and Newbury areas.

New interpretations of the Isle of Wight's geology have been made from high-resolution airborne geophysical datasets *(see page 20)* combined with multidisciplinary ground surveys of the island. The study, which will provide key baseline data on geo-environmental issues, is scheduled for completion in late 2009, followed by publication of new maps, a 3D model and an explanation of the geology.



Structure and evolution of southern England: the London 1:50 000 scale resolution 3D model covering an area of 60 by 40 km, viewed from the south-west (NEXTMap Britain™ elevation data from Intermap Technologies).

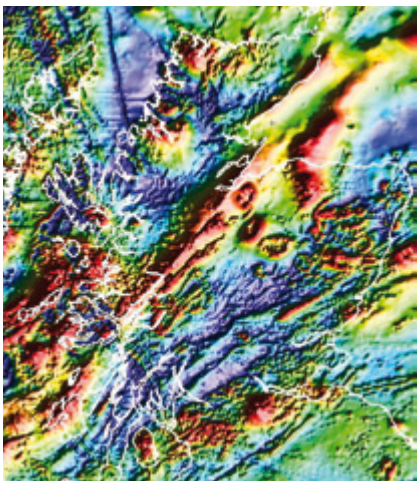
The Environment Agency and water utility companies have commissioned several 3D geological models to investigate water resources in nationally important aquifers in England, such as the Cretaceous Chalk in the south-east, the Permo-Triassic Sherwood Sandstone in the Midlands, and the Middle Jurassic limestones of the Cotswolds.

Ancient Carboniferous basins and sea-surface temperature variation

Our surveys of the Carboniferous basins in the UK are providing new insights into the 3D architecture of these sedimentary rocks that may have potential for energy resources including coal bed methane and shale gas. An associated pilot study has estimated seasonal temperature variation of 5–6°C in the shallow equatorial seas in which the Carboniferous (Mississippian) rocks of Great Britain were deposited. At this time, the region lay on the Laurussian continental margin, at a latitude of 2° south. The value obtained is 1 to 2°C higher than present-day variation in the equatorial region. A collaborative study with Milan University and the NERC Isotope Geosciences Laboratory obtained stable oxygen isotope compositions from a large, late Visean, productid brachiopod *Gigantoproductus* aff. *okensis*. The shell is from the Monsal Dale Limestone Formation of Derbyshire, a sequence of shallow-water, thickly bedded and bioturbated limestone. The shell has twenty annual growth bands, resulting from seasonal environmental changes during its lifespan. Periodic variations of 1.1% in $\delta^{18}O$ values are evident in the growth bands, indicating a high seasonal temperature variation. This may have been related both to strong monsoon circulation at a time of high insolation during the southern hemisphere summer and to the growth of ice sheets of limited extent in Gondwana. The study will help us understand the influence of climate on the deposition of these sedimentary rocks.

Regional syntheses — UK Geoscience Framework

The subsurface geological structure of Northern Scotland, based on the results of regional geophysical (gravity and magnetic) surveys, was released this year as the third of the BGS Geophysics CD series. Stratigraphical framework research reports for the Lower Cretaceous rocks of the UK, the Triassic Mercia Mudstone Group and igneous intrusive lithodemic units (such as granites), were published jointly with the Geological Society Stratigraphy Commission. These research reports underpin our baseline geological datasets for the UK and are available as free downloads from our website.



Regional syntheses: aeromagnetic image from the new BGS Northern Scotland Geophysics CD.

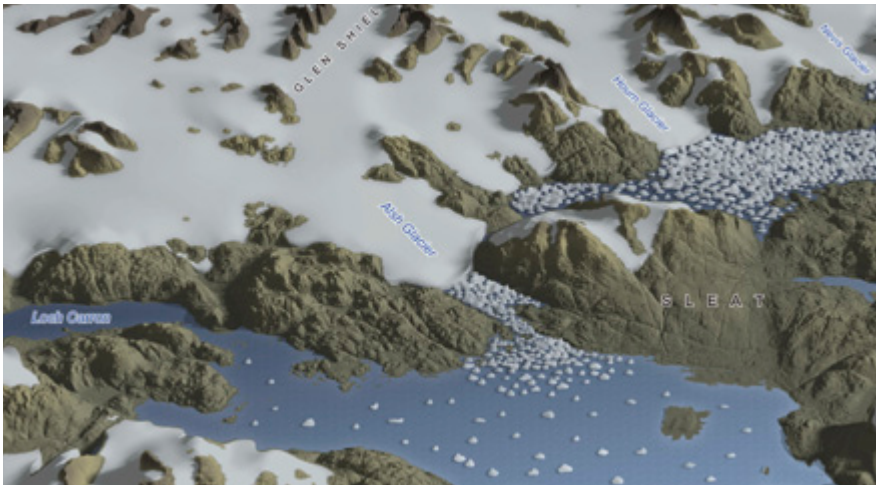
Clyde Basin

For the next 25 years, the Clyde Gateway, along with the Clyde Waterfront area will be the national regeneration priority for Scotland. We have continued to work closely with Glasgow City Council and other partners to develop collaborative research jointly with Abertay, Edinburgh, Glasgow and Strathclyde universities. With funding from the Clyde Gateway Developments Ltd and partners, a detailed 3D subsurface model of the soils, rocks and groundwater recharge and shallow flow was completed. Emphasis was placed on evaluating uncertainty in each layer, using our new confidence calculator, which combines measurements of data density and geological complexity. Modelling of the superficial deposits in 3D extended to the north-east of the Glasgow conurbation, where a large deep buried valley was modelled and has been interpreted to extend across the entire width of Scotland's Midland Valley. This laterally extensive feature hosts a major aquifer and large volumes of sand and gravel, and will be the subject of more detailed investigation.

British ice sheet dynamics

Quaternary specialists continued to investigate environmental change and its landscape legacy over the past 2 million to 3 million years. This year's highlight was the culmination of numerical ice-sheet modelling work that simulates the growth and decay of the last British Ice Sheet. This project, in collaboration with the University of Wales Aberystwyth, saw the detailed dynamic behaviour of an ice sheet revealed for the first time throughout an entire glacial cycle (about 40 000 years). Major ice streams and ice divides, proven from field evidence, were replicated in a model environment allowing their time-transgressive behaviour to be studied. Detailed modelling of the last glaciation (about 12 000 BP) of the Scottish Highlands has shed important new light on climate variation.

This modelling led to the discovery that the British Ice Sheet survived abrupt, rapid warming at the end of the last ice age. Around 14 500 years ago the climate of the North Atlantic region warmed by around 5°C in only a few decades, switching from fully glacial to warmer, wetter, interglacial-like conditions. Most researchers believed that glaciers completely disappeared from the British Isles during this 1500-year warm period. However, our new findings demonstrate that



British ice sheet dynamics: oblique aerial view of part of the north-west Scottish Highlands and Skye during the Younger Dryas glaciation (about 12 000 years ago). Image is generated from 3D optimum ice-sheet model output draped on NEXTMap Britain™ shaded relief DTM from Intermap Technologies.

Snowdonia's ancient volcanoes: spheroidal siliceous nodules developed in the Pitts Head Tuff Formation, North Wales.

the ice-sheet margin in north-west Scotland underwent numerous oscillations around 14 000 years ago, precisely when it is thought to have disappeared. This work implies that some ice sheets are robust enough to survive major shifts in climate, possibly because atmospheric circulation changes enhance winter snowfall during warmer periods, or marked changes in the geometry of the ice mass leave it less susceptible to melting.

BGS Quaternary scientists also joined a cruise to west Antarctica, with the British Antarctic Survey. Glacially transported boulders and bedrock were analysed by cosmogenic dating and lichenometry — using the size of lichens to estimate the minimum age of an exposed surface — to determine the historical rate of Antarctic ice sheet thinning and sea-level rise.

Highland Boundary Fault — no more?

In a fresh look at a long-standing controversy in Scottish geology, an international group attended the 2008 Highland Workshop in Edinburgh to consider the possibility that remnants of an Ocean–Continent Transition Zone are preserved at the Highland Border in Scotland. In the field, delegates reached the conclusion that the rocks of the Highland Border Ophiolite probably constitute a slice of exhumed, serpentinised, subcontinental mantle that once formed part of the floor of an extended basin on the margin of the ancient continent of Laurentia. The team then moved the debate to EGU2009, co-convening a session dedicated to 'Extension-related processes and rifting in ancient versus modern settings'.

Investigating the mechanisms of Snowdonia's ancient volcanoes

Recent surveys in the Nefyn district of North Wales provided new insight into the ancient volcanic processes that formed the rocks of the Snowdonia National Park. The Llwyd Mawr Ignimbrite is thought to have made up one of a series of eruptive centres that were active during Late Ordovician times (about 455 million years ago). At this time North Wales lay along the subducting margin of an ancient ocean, known as Iapetus, that once separated Africa, South America and Europe from North America. Detailed field mapping has shown that the approximately 350-metre-thick ignimbrite body preserves evidence of rapid lateral and vertical facies change, and depositional control by active faults. A preliminary interpretation of the data suggests that the ignimbrite formed by a process of caldera collapse, in which a thin crust founders into an underlying magma chamber, rapidly releasing large volumes of lava and volcanic gases. Ongoing fieldwork will seek to develop models illustrating how the physical process of collapse and deposition operated, while geochronology and geochemistry, carried out in partnership with the NERC Isotope Geosciences Laboratory and the University of Portsmouth, will seek to gain insights into the crustal-scale magmatic and tectonic processes that were fundamental in laying the foundations of present-day Wales.

A window on Cambrian biodiversity

The Cambrian was a critical period in the evolution of animal life and saw the appearance of most of the ancestral stock for present-day diversity. A collaborative study with partners at the University of Leicester is investigating the timing and nature of this event as recorded in the historically important Comley Limestones of Shropshire. These have yielded some of the world's oldest three-dimensionally preserved soft-bodied animals, including minute crustaceans with fossilised limbs, as well as examples of early biomineralising (shell-building) organisms. Excavations at a key location have provided valuable new material that will help tie biological events on the Avalonian palaeo-microcontinent during the Cambrian with those seen in comparable fossil assemblages from China and Scandinavia.

Cambrian biodiversity: scanning electron microscope image of the small shelly fossil Microdictyon *(about 1 mm long), recovered from an acid-digested limestone.*

Landscape and geodiversity — the underlying issue

Continued development pressure on land and resources demands a greater awareness and understanding of the dynamics of our planet in order to deliver a sustainable environment for the future. Geodiversity is an important environmental asset but is one of the least known and valued. It links people, place and ecology to landforms and landscape, from the past through the present to the future.

Geodiversity for planning in Scotland

We were commissioned by East Dunbartonshire and the City of Edinburgh councils to survey and record features of geodiversity value in their areas as part of their Greenspace strategies. The results of this work will assist their development and environmental planners in enhancing quality of life and protecting local environments through evaluation of Local Nature Conservation sites.

Enhancing quality of life in north-east England

We are advancing the scientific and amenity value of geodiversity in north-east England by completing a geodiversity audit and action plan for the Durham Magnesian Limestone Plateau on behalf of the Limestone Landscapes Partnership. The partnership, incorporating a broad range of public, voluntary and private sector organisations, aims to co-ordinate activities and resources in a long-term and purposeful way to significantly enhance quality of life, the environment of the plateau and the well-being of its communities. The Permian rocks of the area have possibly the widest textural variation of any in Britain and one of the more unusual proposals is to develop a sensory rock trail with interpretation to include the visually impaired.

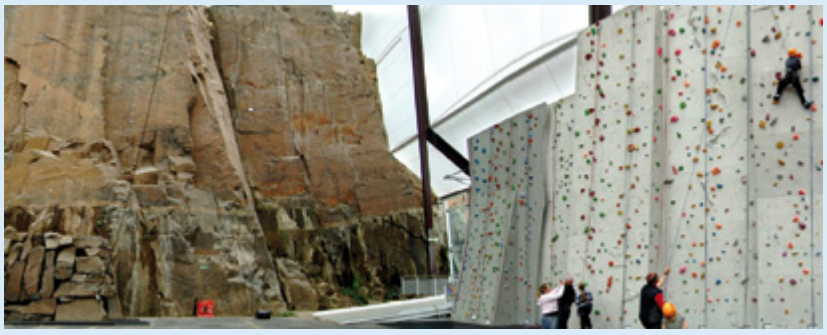
Examples of the wide range of diagenetic textures found in the Permian dolomitic limestones of County Durham.

We have actively supported the formation and expansion of geodiversity partnerships. All regions of England now have a partnership, with the East Midlands, South-West and South-East being the most recent. The BGS is a member of the core committee producing the geodiversity action plan for the UK (UKGAP) under the auspices of Natural England. We have contributed to several Local Geodiversity Action Plans (LGAPs) funded by the Aggregates Levy Sustainability Fund (ALSF). We have also produced a Geodiversity Action Plan for London, commissioned by the London Authority, and contributed to others for seven English counties.

South Wales RIGS

The South Wales RIGS project is a three-year study to identify Regionally Important Geodiversity Sites in south-east Wales, selected for their scientific, educational, historical and aesthetic values. The project draws together a wide range of organisations and individuals, from amateur and student geologists to professional and academic geoscientists, as well as the various statutory organisations in the region. Local people are encouraged to engage with their environment by developing their appreciation for geology and the associated industrial history of the area.

The first year has seen the establishment of strategy documentation and the identification of more than 2800 potential sites through a process of literature review. The desk study is still ongoing. A workshop has been designed and run to encourage volunteers of all geological abilities to get involved and gain the confidence to contribute to the project. The workshop also addresses consistent record-keeping, health and safety in the field, and provides some tuition in fieldwork techniques. Much of the fieldwork has been undertaken by volunteers drawn mainly from local geology groups such as the South Wales Geologists' Association and the Open University Geological Society. Other partners in this project include the National Museum of Wales, Countryside Council for Wales, Fforest Fawr Geopark, Brecon Beacons National Park, the Geological Society and Cardiff University with funding from the Welsh Assembly Government-administered Aggregates Levy Sustainability Fund.



Edinburgh International Climbing Arena, Ratho Quarry. Quarry walls show jointed intrusion of dolerite with zones of segregation separating artificial climbing walls.

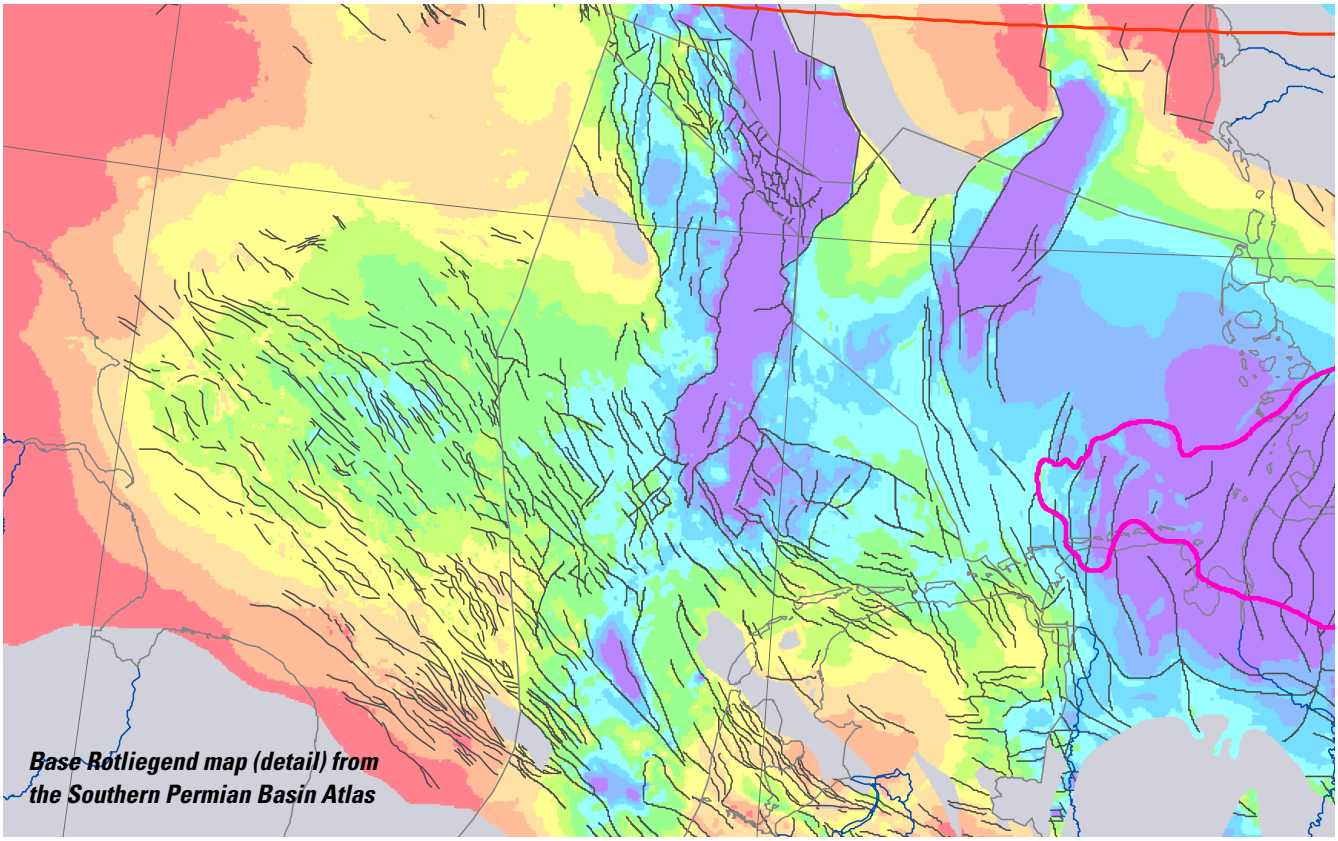
A field party examining Triassic strata on Sully Island, Vale of Glamorgan.

© A Kendall

Science Programmes

Marine Geoscience

Marine Geoscience surveys cover both the shallow geology (habitats, site investigation) and the deeper subsurface (petroleum geology and basin analysis). High-resolution seabed geology maps are vital to underpin marine spatial planning. Geohazards and the deglaciation dynamics of the last British Ice Sheet are key research topics. Industry co-funding supports our basin analysis work. BGS continues to lead the operational aspects of the European contribution to the Integrated Ocean Drilling Program.



Base Rotliegend map (detail) from the Southern Permian Basin Atlas

Regional hydrocarbon exploration

The collaboration between the BGS, other European geological surveys and the petroleum industry to produce a Petroleum Geological Atlas of the Southern Permian Basin Area, which began in 2003, is reaching its final phase. The atlas *(above)*, which will be available both in hard copy and digital versions, comprehensively summarises the hydrocarbon geology of the area based on more than 150 years of petroleum research and exploration undertaken in all of the contributing countries — the Netherlands, UK, Belgium, Denmark, Germany and Poland.

The atlas has been sponsored by partners in the petroleum industry which also provided access to their datasets. It includes contributions from more than a hundred geoscientists from national geological surveys, the academic world, the industry and national licensing bodies and its compilation and production was co-ordinated by TNO (the Netherlands geological survey organisation). The atlas synthesises the geological and structural history of the basin and chronicles its development as one of the major hydrocarbon provinces of the world.

We continue to advise the Department of Energy and Climate Change (DECC) on hydrocarbon exploration in the UK, and a new CD for promoting undeveloped oil and gas discoveries and key exploration opportunities in unlicensed UK offshore blocks ahead of the twenty-sixth UK Offshore Licensing Round was produced. The CD is used by DECC to attract additional investment from existing operators and potential new entrant companies in the UK petroleum industry. Another DECC initiative

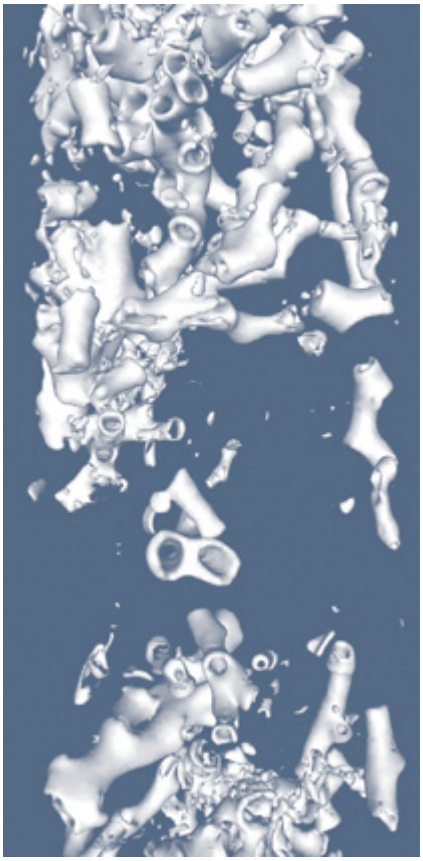


Image courtesy of D Sinclair at SAMS, to be published in Marine Ecology Progress Series (reproduced with permission of MEPS)

Marine habitats: computed tomography image of a section of a BGS core taken through the rubble adjacent to a cold-water coral reef near Mingulay.

led to the mapping of Lower Carboniferous Coal Measure source-rock basins beneath the Central North Sea with the aim of stimulating petroleum exploration across the sporadically explored western margin of the North Sea. A programme of seismic interpretation and gravity modelling has revealed a mosaic of Lower Carboniferous basins and intrabasinal basement blocks that has many features in common with the contemporary basin architecture of northern England and southern Scotland.

Marine geological mapping

Advances in marine geological mapping were focused on three Regional Environmental Characterisation projects supported by the Aggregate Levy Sustainability Fund through the Marine Environment Protection Fund in areas east of the Isle of Wight, offshore East Anglia and adjacent to the Humber. The East Anglian work builds on the first BGS digital map in a new Sea Bed Geology series produced in collaboration with the UK Hydrographic Office and SeaZone Solutions Ltd, which will provide much more detailed geological maps based on digital bathymetry.

We led a National Seabed Survey working group under the auspices of the Healthy and Biologically Diverse Seas Evidence Group which is part of the UK Marine Monitoring and Assessment Strategy. A summary of new data and techniques used to map the seabed was included in a feeder report for the next Charting Progress report on the state of the seas, due to be published in 2010. About 15% of the UK continental shelf is now covered by multibeam surveys.

Marine habitats

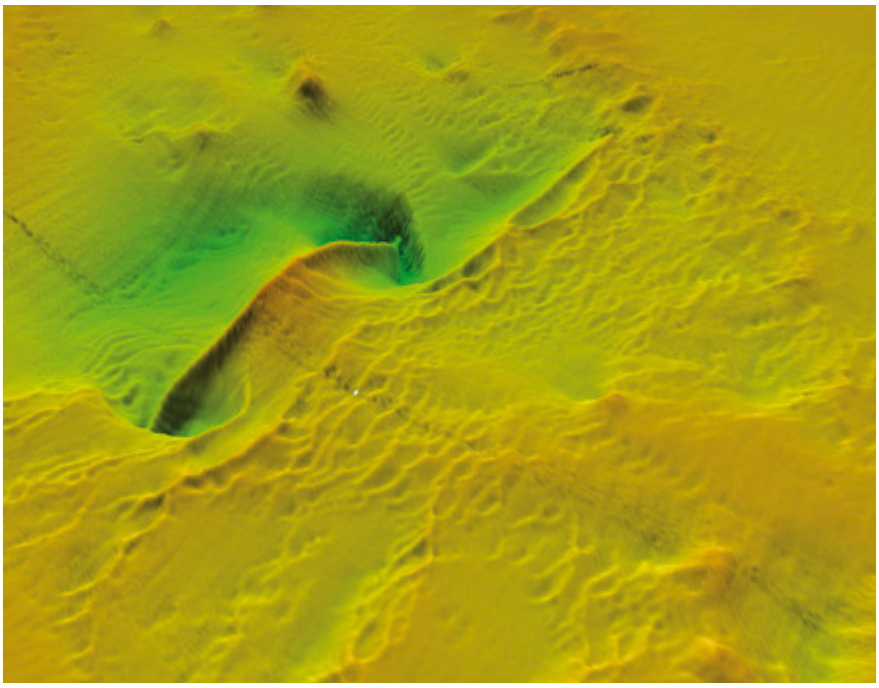
Cores collected by the BGS in 2007, from the Mingulay cold water coral reef, in the Minch, are being examined as part of a BGS University Funding Iniative *(see page 41)* award at the University of the Highlands and Islands. Computed tomography (CT) scanning undertaken by the Scottish Association for Marine Science (SAMS) has revealed that the distribution of coral fragments in a debris deposit down-current of the reef is not uniform. This scanning allows appropriate subsample planning before the cores are cut.

Integrated Ocean Drilling Program

Following the postponement of the New Jersey Shallow Shelf Expedition in 2008, the European Science Operator team has been heavily involved in planning for the 2009 field season. A contract has been agreed to implement the New Jersey Expedition in the May to July period and the Great Barrier Reef Expedition is now scheduled during the October to December weather window.

Beaufort's Dyke

Seismic profiling across Beaufort's Dyke between Northern Ireland and Scotland in collaboration with the Agri-Food and Biosciences Institute and the University of Ulster revealed a range of bedforms demonstrating the seabed to be sedimentologically active. This suggests that the strong currents known at the surface reach down to the base of the trough at over 300 metres of water depth. Similar symmetrical sediment waves occupying hollows within the strongly swept sea floor were identified in a survey in the centre of the Irish Sea conducted for the Joint Nature Conservancy Council *(see below)*. The hollows are eroded into a sea floor cemented by methane-derived authigenic carbonate. Methane gas from the underlying Carboniferous is oxidised just below the sea floor leading to the formation of calcium carbonate, thereby creating a hard substrate that provides an important habitat for benthic species in the area.



Data were acquired by CEFAS, BGS and University of Ulster on behalf of the JNCC. Data © JNCC

Multibeam image of steep-sided symmetrical sediment wave located in centre of a hollow eroded in cemented sea bed (mid Irish Sea). This feature is about 500 m in length.

Science Programmes

Environmental Geoscience Baselines

The Environmental Geoscience Baselines programme provides a knowledge base on the physical and chemical properties of the surface environment. This underpins environmental research and decision making for healthy and sustainable environments. Baseline mapping is a national capability activity in which the BGS can provide international leadership.

Sampling for G-BASE

G-BASE

The Geochemical Baseline Survey of the Environment (G-BASE) project continued to gather, analyse and interpret high resolution geochemical data from the UK as part of a national programme. A major new sub-project commenced with the aim of mapping the baseline soil chemistry of the Greater London area. During the first year of this project, known as London Earth, over 3100 soil samples were collected from London north of the Thames and were submitted for multi-element chemical analysis. London Earth will provide unique information showing the distribution of more than fifty chemical elements in the soils of London that will help us to identify the environmental impacts and changes related to human activities in Britain's most populous city. A successful programme of outreach was undertaken as part of London Earth and a number of new collaborations with universities and local government have been established.

Isle of Wight from above

A high-resolution resource and environmental airborne survey (HiRES) was performed across the Isle of Wight and part of the mainland. It was conducted alongside geological mapping and 3D modelling and took place in October 2008, supported by a programme of public outreach, including radio and television interviews. The aircraft flew along north–south lines at 200-metre intervals forming a 38 x 22 kilometre rectangle and the survey delivered 4385 line-kilometres of magnetic, radiometric and electromagnetic data. It was the first HiRES survey in the south of England and thus the first covering a major Tertiary sedimentary basin. The data are being interpreted alongside new field geological surveys and will contribute to new maps, 3D models and environmental assessments of the island. Interpretation is at an early stage but the distribution of conductive units within the Palaeogene in the north of the island together with ground-truthing

Survey aircraft over the Isle of Wight.

indicate the possibility of a significant reverse fault associated with the Sandown monoclinal structure. Elsewhere the results reflect strongly the geological grain of the island and will enhance the detailed model derived from the large-scale field geological survey.

Saline intrusion in the Mediterranean

The Joint Airborne Capability operated by the BGS and the Geological Survey of Finland performed an airborne survey under the EUFAR framework — which shares airborne survey capability among a consortium of European environmental survey organisations — around the coast of the Gulf of Lyons, in southern France. The survey campaign was conducted at very high resolution (a flight-line spacing of 100 metres) and at low altitude (50 metres) across the coastal zone of the Roussillon aquifer acquiring magnetic, radiometric (gamma-ray spectrometry) and electromagnetic datasets.

The main client for the survey was the French Bureau de Recherches Géologiques et Minières (BRGM). The data are being used for investigations into the degree of saline intrusion in the Quaternary aquifers of the Mediterranean coast and an evaluation of airborne geophysical data for use in coastal sedimentary studies.

Field orientation exercise, Minna area, Nigeria.

Geochemical mapping in Nigeria

This is a project funded by the World Bank to give technical assistance to the Nigerian Geological Survey Agency (NGSA) to carry out a national programme of geochemical mapping. The project commented in October 2008 and is due to last two years. The Nigerians wish to have national geochemical maps for resource exploration as well as addressing issues relating to the environment and health. The Global Reference Network (GRN) of cells for geochemical mapping has 44 cells in Nigeria and the project will complete two of these cells by collecting stream sediments in order to train the NGSA in techniques of geochemical mapping. Each cell covers an area of 25 600 square kilometres. The induction and training phase of the project is now complete, the highlight being a week-long workshop on 'Geochemical Mapping' held in Kaduna, Nigeria, in January 2009, at which more than fifty Nigerian geologists received training.

Europe-wide geochemical mapping of agricultural soils

We contributed to this EuroGeoSurveys project (GEMAS) by collecting samples of agricultural soils from 138 sites across the UK. Geological surveys in 34 countries across Europe provided samples from both arable land and permanent grassland, within cells of 50 x 50 km across their territory.

All samples will be prepared and chemically analysed under standardised, quality-assured conditions enabling variations in the chemistry of agricultural soil across Europe to be evaluated. The resulting data will provide support to policy makers and regulators and will have particular relevance to the REACH regulation (Registration, Evaluation and Authorisation of Chemicals) and the proposed future EU Soil Framework Directive. Research applications of the chemical data include investigations into the relationship between soil chemistry and agricultural productivity, and forensic food geochemistry. A sample archive to support future analyses will also result.

Geochemical mapping of agricultural soils: sampling for GEMAS.

Science Programmes

Geological Survey of Northern Ireland

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 upon expertise from within other parts of the BGS. GSNI also works for other Northern Ireland government departments and liaises closely with the Geological Survey of Ireland (GSI).

Slieve Rushen from Hawkswood Trail

Awards

The GSNI received two major awards during the year. To recognise the impact of the Tellus Project on business and investment, the international periodical Mining Journal presented its prestigious Country Award to Northern Ireland as 'the country that has shown the most improvement, in terms of attractiveness to mineral investors, during 2008-9'. The Association of Geographic Information awarded the GSNI first place in the 'Excellence in Innovation and Best Practice, Central Government category'.

Tellus

The geophysical and geochemical data acquired by the Tellus project continue to be widely licensed by industry, government and academia. To further reinforce the uptake of the data, and as part of the Regional Innovation Strategy for Northern Ireland, the DETI commissioned the GSNI to undertake a three-year programme of analysis and outreach. This includes the introduction of user-friendly methods of internet data delivery, the development of a range of 3D models and new facilities to display the 3D geological data.

Geology and landscape

Increased collaboration between the BGS, GSNI and GSI is resulting in the revision of the deep geology of the British Isles. This new information will underpin a wide range of future projects and will include new research generated through Northern Ireland-based Ph.D. studentships under the BGS University Funding Initiative. Projects under way include the Cenozoic tectonics of the north of Ireland (with University College Dublin) and the geochemistry of the Tyrone Igneous Complex (with the University of Southampton and the Natural History Museum).

The Cushendall Superficial and Bedrock 1:50 000 scale map was completed. As well as the 'Landscapes from Stone' geological description, the map includes an account of the rich mining heritage of the area. Northern Ireland will be the first UK region to complete digital geological mapping at

© Cavan County Council, Marble Arch Caves Global Geopark

Geology and landscape: view of Cuilcagh from Moneygashel.

the 10 000 scale. This will underpin natural resources and environmental projects.

Environment and hazards

The GSNI provided technical support to government regulators and developers demonstrating the continued relevance of geoscientific data in land planning and environmental decision making.

We assisted the Planning Service on policy matters including sustainable mineral development, the EU Mines Waste Directive and aggregates mapping. We also advised on development and control applications in geologically unstable areas and have helped develop planning protocols for assessing peat slide risk associated with wind farm construction. A new abandoned mines geographical information system was developed to alert the Planning Service to potential geohazards associated with old underground workings.

© GSNI/DETI

Energy and minerals: map of prospecting licences in Northern Ireland.

Collaboration and outreach

Under the auspices of the GSNI, GSI and the Royal Irish Academy (RIA) a forum was held in Parliament Buildings, Stormont, Belfast, on the role of geoscience in the twenty-first century. This resulted in a revised strategy document *'Geosciences: Building the Future'*.

Working with NI Environment Link and the RIA, the GSNI organised and contributed to a high-profile climate change conference in Belfast. Keynote speaker Professor Iain Stewart gave a series of public and schools lectures as part of this event.

The first published product of the GSNI–GSI–BGS Scientific Framework Agreement was a *'Climate through time'* poster. This educational resource was designed in close consultation with teachers' associations and has been widely distributed.

© GSNI/DETI

DETI Minister Arlene Foster and Professor Iain Stewart with schoolchildren.

GSNI contributed two articles and co-ordinated editing of the showcase UNESCO publication 'European Geoparks.' In September, the approval of the extension of the Marble Arch Caves Geopark in Fermanagh into Co. Cavan brought about the first international Geopark.

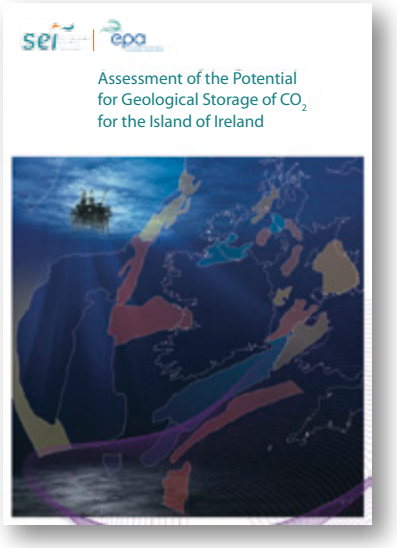
GSNI hydrogeologists assisted the Northern Ireland Environment Agency to meet EU Water Framework Directive compliance targets and also established groundwater study sites that will be monitored over the next twenty-five years. This information will support multi-disciplinary studies including eco-hydrology, surface water–groundwater interaction and the long term impact of climate change on the natural environment.

Energy and minerals

Through successful promotion of the geophysical and geochemical data acquired by the Tellus Project, the GSNI has helped natural resource companies to capitalise upon new exploration opportunities. Prospecting licences for both minerals and petroleum now cover 80% of Northern Ireland. The GSNI monitored and reported on exploration work programmes on behalf of the DETI.

The NI Innovation Fund enabled the GSNI to research the deep geothermal energy potential of Northern Ireland. New geophysical surveys and drilling will contribute to understanding the geological structure and geothermal energy potential of the Lough Neagh–Larne sedimentary basin and the Mournes granite complex. As a partner in the EU ALTENER-funded GeoThermal Regulations for Heating (GTR-H project), the GSNI helped to produce a draft template of geothermal energy regulations that can be adapted for use by member states.

The GSNI participated in an all-Ireland assessment of the potential for carbon capture and storage. We also facilitated the natural resources sector through the supply of geological information and advice regarding underground natural gas and compressed air energy storage.



Energy and minerals: all-Ireland CCS report.

Science Programmes

Earth Hazards and Systems

The BGS seismic and geomagnetic monitoring stations are part of global networks providing data on the solid Earth and its surrounding space environment. The data support research into natural hazards that threaten life, infrastructure and the environment. The knowledge gained is applied by decision makers to assess risk and develop mitigation strategies.

The aftermath of pyroclastic flows into Plymouth, Montserrat

Volcanic hazard

As the world's population grows and becomes increasingly dependent on global finance, communications and resource networks, more and more people are at risk from the sixty or so volcanic eruptions that happen in an average year. Most of the world's potentially active volcanoes are not well understood and are inadequately monitored. Lack of preparedness can lead to devastating consequences during even small eruptions (for instance, 23 000 people died at Nevado del Ruiz in 1985). The BGS Volcanology Team was established in April 2008 to carry out research that will enhance our knowledge and understanding of volcanic hazards and impacts worldwide. We aim to communicate our research results clearly to audiences ranging from high-level policy makers to members of the public to reduce volcanic risk.

Volcano monitoring

We are collaborating with colleagues in Italy in the European Space Agency funded 'Globvolcano' consortium, which is providing volcano observatories worldwide with high-resolution thermal infrared imagery. This helps to detect imminent eruptions, monitor ongoing eruptions and assess damage after eruptions. Results from the SeaCALIPSO seismic tomography experiment at Montserrat are improving our understanding of how magma is supplied to volcanoes. Significant publications this year included studies of seismic precursors to the world's largest documented lava dome collapse at the Soufrière Hills Volcano in 2003 and, in contrast, a study on how seismic eruption precursors at the volcano have declined in recent years making forecasts of volcanic activity more difficult. Research continues into lava dome growth, morphology and stability, and applications of seismic interferometry and multiple monitoring datasets.

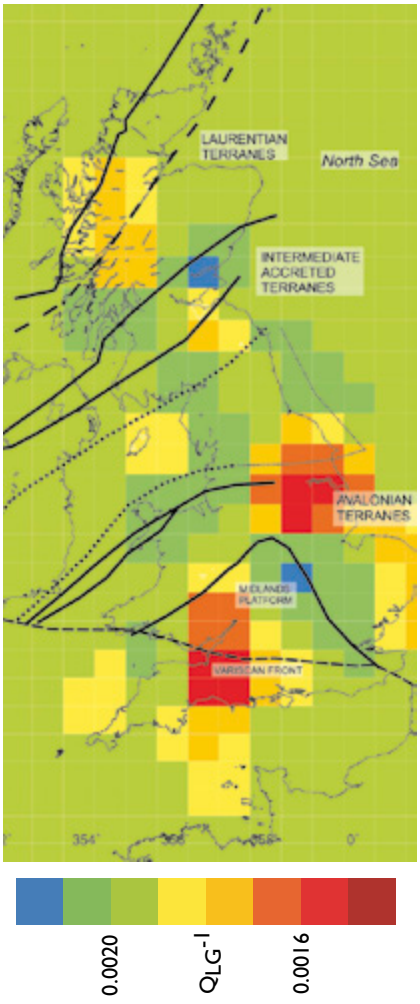
Geomagnetism research

Joint research with UK universities has progressed through three Ph.D. studentships,

and work on geomagnetic hazard, field modelling and on long-term trends in geomagnetic data has been published. We organised a UK/South Africa workshop, sponsored by the Royal Society, on the threat to electrical grid systems during geomagnetic disturbances. This was held near Cape Town in December 2008. A joint review paper, intended for both scientists and power engineers, has since been submitted for publication and a follow-up expanded workshop is being planned.

Automatic detection of potentially damaging earthquakes

BGS seismologists now receive alerts by SMS and email within minutes of potentially damaging earthquakes anywhere in the world. The alerts are sent by a real-time acquisition and analysis system, EarlyBird, developed at the US West Coast/Alaska Tsunami Warning Center, which we have installed, tuned and tested for possible future use in a tsunami warning system. EarlyBird automatically locates earthquakes and calculates their magnitudes and source mechanisms using near-real-time data from over 200 stations around the world.



Attenuation of seismic waves in the UK crust related to known crustal features. Areas of high attenuation are blue/green; areas of low attenuation are red/orange.

Attenuation of seismic waves

A paper published in Geophysical Journal International describes an investigation into seismic wave attenuation in the UK. Our aim was to use recordings of multiply-reflected shear waves to discover whether attenuation correlates with the crustal blocks making up the UK. From these measurements, physical properties of the Earth's crust can be inferred. Our results show there are regions of lower than average attenuation in north-western Scotland, eastern central England, and south-western England. South-eastern England, the East Irish Sea Basin region and an area of eastern Scotland between the Southern Uplands Fault and the Highland Boundary Fault have higher than average attenuation. These results will be used to understand seismic wave propagation in the UK and to estimate ground motion for future earthquakes.

Modelling ground motion from British earthquakes

Seismic hazard studies produce estimates of ground acceleration, but in areas of low seismicity, like the UK, there are few measurements of strong ground motion from earthquakes to base these estimates on. The recent Market Rasen, Lincolnshire and Folkestone earthquakes were the largest and most damaging to strike the UK in many years. However, the stress drop — the change in stress across a fault before and after an earthquake — was ten times larger for Market Rasen than for Folkestone and resulted in a much higher ground acceleration than predicted by empirical ground-motion relationships commonly used in seismic hazard studies. This suggests that seismic hazard models may be improved by including estimates of stress drop.

Magnetic observatories

The BGS operates magnetic observatories across the world: three in the UK and others at Ascension Island, Port Stanley (Falkland Islands), Sable Island (Canada) and northern Alaska. Scientific and commercial demand for rapid access to geomagnetic data products has increased dramatically over the past decade and improvements to data communications, computers, data processing software and quality control procedures were made in 2008 to maintain our position as an international leader in magnetic observatory practice. We developed back-up systems to cover potential points of failure in collecting and processing data, and in disseminating results. The improvements were such that in 2008, for directional drilling services to the oil industry, we achieved 99.5% data delivery within seven minutes of observation and a 100% data collection record from the UK observatories. We further developed our World Data Centre (wdc.bgs.ac.uk) and served nearly 40 000 requests through our Geomagnetism Information and Forecasting Service (geomag.bgs.ac.uk/on_line_gifs.html).

Navigation products are derived from detailed BGS geomagnetic data.

Understanding changes in the Earth's deep interior requires data from a global network of geomagnetic observatories. We are committed to supporting the global observatory network wherever we can. We lead the INDIGO project, working in partnership with the Institut Royal Météorologique de Belgique, to produce packages including renovated ex-NERC instrumentation, digitisers, software and training. By 2008 INDIGO had equipped seven institutes running magnetic observatories in developing nations, including Pakistan and Indonesia.

Science Programmes

Land Use and Development

Land Use and Development comprises four thematic research teams focusing on 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 contributes to the description of the physical properties of the UK landmass and provides underlying information and expertise to support decision making for government policy, responses to extreme events, and the sustainable development of cities and food supply.

Landslide at Cayton Bay near Scarborough. Several properties have had to be demolished and others are still under threat

Response to landslides

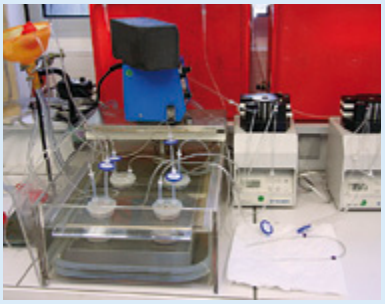
We responded to a number of landslide events this year including Lyme Regis in Dorset, Cayton Bay in North Yorkshire, Snake Pass in Derbyshire and Horncliffe in Northumberland. When information is received about a landslide, either through the media or as a direct report, we assess its significance in terms of threat to life, property and/or infrastructure and our Landslides Response Team is then deployed. We aim to be present at the landslide as soon as possible, to observe the event and collect factual data for the National Landslide Database. We then provide impartial advice to those affected and authorities dealing with the problems. Providing factual information to the media is an important role. The information is then made available on our new landslides web pages (www.bgs.ac.uk/landslides) as part of a growing number of landslide case studies keeping key stakeholders and the public fully up to date.

Monitoring and mapping coastal landslides

We are improving our geological maps and monitoring the changes of coastal landslides in several locations around the country. Using aerial photography, the entire coast of Great Britain is being assessed for the presence of landsliding. The data gathered by this work will improve the geological maps and refine the landslide component of our national ground stability GeoSure datasets, improving its

Understanding soil formation

We are working in conjunction with the University of Reading and Université Paul Sabatier in Toulouse, to investigate how changes in the minerals present in soils and the creation of surface area can influence soil formation. By studying soils of different ages in the laboratory, we are able to observe how these properties have affected the fertility of soils over time. These studies of past soil processes are invaluable in understanding current soil processes. Early analytical results suggest similar mineralogical trends in soil profiles developed above granites from the Cairngorms and Dartmoor. Profiles at both locations show decreasing feldspar, mica and hematite contents with increasing distance from the bedrock. However, while the greatest rate of mineralogical change appears to occur in the 'B' horizon of the Dartmoor profile, changes appear more gradual through the Cairngorm soil. Early data on dissolution rates from laboratory flow-through experiments suggest that the reactivity of both surface soils could be similar despite their underlying mineralogical differences.



Soil flow-through dissolution experiments.

accuracy in the changeable coastal zone. Complementing this work, a series of detailed surveys have been undertaken on selected coastal sections to determine the nature and rate of landsliding and erosion. This work forms part of an ongoing monitoring programme that has collected data over more than seven years using terrestrial laser scanning (LiDAR).

Climate change impact on Britain's earthworks

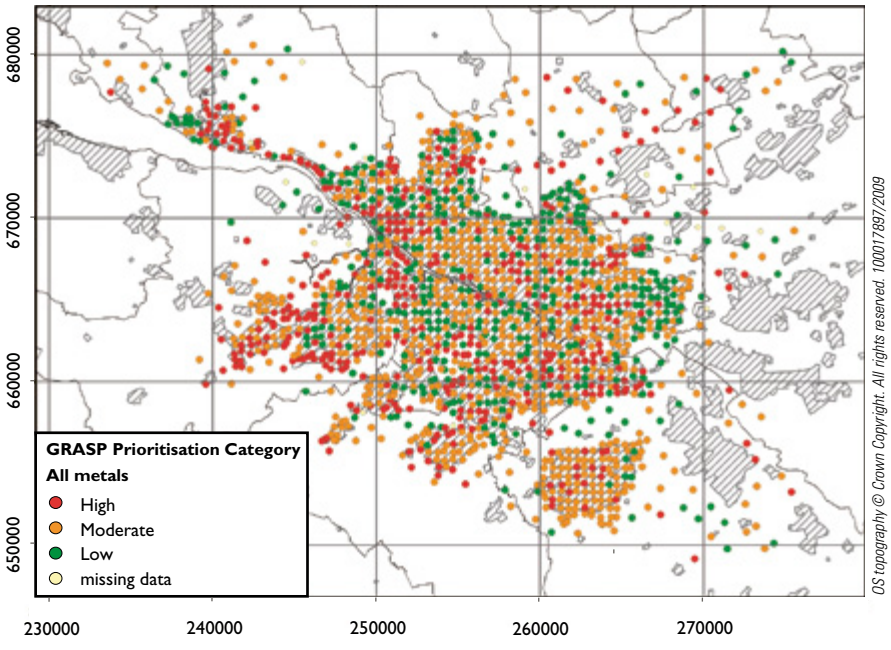
Many of the UK's strategic water and transportation assets are supported by earthworks that are Georgian and Victorian in age. Research investigating the current condition, ageing and climate-induced deterioration of these earthworks is vital if future built environments and transportation networks are to adapt and become resilient to climate change.

Climate change is often associated with changes in rainfall and associated surface and groundwater patterns. Using our expertise on physical properties and processes, we have found that the cyclic variation in water within earthworks controls the pervasive processes that lead to the loss of engineering performance and result in instability. Fabric removal via dissolution, fabric rupture via secondary mineralisation and cyclic shrinkage and heave have been identified as physical processes that affect the geotechnical properties and hence the engineering performance within earthworks.

A team from the BGS and the universities of Birmingham, Loughborough and Newcastle working with key stakeholders are leading research into understanding the 'whole failure' process of earthworks. We are providing a new holistic view of failure via a novel application of geophysical proxies to spatially and temporally model moisture variation and the resulting geotechnical properties at the BIONICS (Building Knowledge for Climate Change) and East Leake (Great Central Railway) observatories. Our goals at these observatories include developing improved modelling approaches to incorporate site-scale heterogeneity. These will help to underpin realistic 'life-cycle' diagnoses of earthworks performance.

Urban groundwater threats

Within the Clyde Urban Super Project (CUSP), a GIS-based prioritisation tool, GRASP (GRoundwater And Soil Pollutants), has been trialled to aid urban planning and sustainable development. GRASP has provided a broad-scale assessment of threats to groundwater quality across Glasgow, identifying areas where shallow groundwater quality is at greatest risk from the leaching and downward movement of potentially harmful metals in the soil. GRASP is innovative in combining an assessment of soil leaching potential with measured soil metal concentration data. It relies largely on input data from our G-BASE project *(see page 20)*. Soil parameters such as pH, clay content, organic matter and metal concentration are combined with assessments of climate, groundwater levels and the leaching potential of unsaturated Quaternary deposits, which are based on additional hydrogeological and climatic datasets.



Urban groundwater threats: GRASP output indicating all metal concentrations within the trial area in the Clyde conurbation.

Science Programmes

Environment and Health

Our Environment and Health programme investigates and monitors the impacts of contaminated land and groundwater on the environment and human health. Projects address the fate and transport of contaminants within the framework of the source–pathway–receptor model of risk assessment. Our work programme is built around a mix of site investigations and innovative laboratory studies that serve to inform national debates on the remediation of contaminated land and disposal of radioactive waste.

River water sampling in Rookhope burn

Environmental impact of historical metal mining

The catchment-scale study of the Rookhope Burn, a tributary of the River Wear, in the North Pennines has revealed diffuse discharges of mine water entering the river through the hyporheic zone (the interface zone between groundwater and surface water), characterised by elevated sulphate and zinc concentrations. This has a significant local impact on the in-stream zinc load and has implications for the potential to carry out remediation in the context of the Water Framework Directive. A study to evaluate the freshwater ecosystem health has been initiated in collaboration with Loughborough University. Further work is planned on the hyporheic zone to understand the processes controlling contaminant migration and natural attenuation. A vegetation and soil survey in the Rookhope catchment has highlighted high concentrations of lead in both soils and vegetation. Lead isotopes have been used to constrain the sources of lead that give rise to anomalously high environmental background concentrations, of an order that could pose a health risk to young children. This catchment is dominated by an anthropogenic component linked to past mining and smelting of lead. Additionally, a long-distance aerial deposition of petrol-type lead has been identified in high moorland and contributes up to 35% of the total lead load.

Medical geology

Medical geology is defined as the science dealing with the relationships between natural geological factors and health in man and animals, and understanding the influence of environmental factors on the geographical distribution of such health problems. Our medical geology team have completed a pilot study to produce a hazard map of the bioaccessibility of arsenic in soils from the Tamar Valley in the south-west of England. A novel methodology, which used a combination of total arsenic data obtained from geochemical mapping, non-destructive near infrared spectroscopy and a physiologically based extraction test, was used to model the potentially harmful portion of the arsenic content of the soils.

Mudstones as reservoirs for contaminants

Our groundwater pollution team has focused on the role of low permeability strata, such as mudstones, that form capillary barriers limiting the downward migration of dense non-aqueous phase liquids (DNAPLs). The Mercia Mudstone Group comprises silty clays, which contain gypsum, siltstone and very fine sandstone. The deposits are typically weathered near-surface, and often associated with overlying minor aquifers including river terrace sands and gravels. Where DNAPLs, such as chlorinated solvents, are present in these hydrogeological settings, the contaminant is distributed between the immiscible phase and high concentration dissolved-phase mass. The clean-up of these fluvial aquifers depletes the primary source of contaminants; however, the underlying mudstone may provide a significant secondary source of contaminant mass. This transfer may extend remediation times and increase costs. Core samples recovered from the Source Area Bioremediation (SABRE) research site indicate trichloroethene occurrence within the weathered, fractured mudstone to depths approaching two metres below the mudstone surface. Numerical simulations indicated that the mass flux entering the overlying aquifer would be degraded by enhanced bioremediation; however, the rate of flux at this boundary was highly dependent on the fracture spacing and aperture.

Recovering core samples of mudstone to determine contaminant distribution at an industrial site in the UK.

The BGS organised and hosted an international meeting on 'Practical applications of medical geology' at our Keyworth headquarters. The meeting provided a common platform for medical geology practitioners to present and highlight successful applications of interdisciplinary case studies. It facilitated professionals, from industry, regulatory authorities and academia, to discuss their findings and identify problems and scientific solutions to conducting such research. Over one hundred delegates attended and the breadth of topics covered by the oral and poster presentations demonstrated the importance of this discipline in contributing to improving human health outcomes through an understanding of geological context.

Geological disposal of radioactive waste

The BGS is co-ordinator of FORGE (Fate of Repository Gases), a European FP7 project, which started in February 2009. Understanding gas generation and migration is crucial in quantitatively assessing repositories for deep disposal of radioactive waste. This is the focus of this international, multidisciplinary project with twenty-four partners from twelve European countries including radioactive waste management organisations, regulators and academia. A Biological Flow Apparatus (BFA) is being developed in the BioTran project that examines the significance of biological processes on the movement of contaminants, such as radionuclides, through rocks. This work now forms part of the EU ReCoSy (Redox Phenomena Controlling Systems) consortium where the BGS is an Associate Group. BioTran is also linked to an EPSRC project which is evaluating biogeochemical effects on radionuclide migration and BGS will be co-supervising a Ph.D. student with the University of Birmingham. Low-temperature experiments have been conducted to study the growth and crystal morphology of calcite precipitated in synthetic groundwater of varying salinity and simulating groundwater chemistry in repository settings. They have shown that growth morphology is strongly influenced by salinity and the presence of magnesium. It is expected that this new understanding will enable observations of changes in crystal growth fabrics in natural groundwater systems to be used to elucidate the geochemical evolution of deep groundwater systems.

Geological disposal of radioactive waste: excavating a new gallery in Jurassic Callovian–Oxfordian clay at ANDRA's underground research laboratory near Bure, Haute Marne/Meuse, France.

Science Programmes

Climate Change

What are the sources and sinks for greenhouse gases? How stormy will it be in the near future? How sensitive are our environments to changes in climate? What will the world be like when mean global temperatures are 5 to 6 °C warmer? These are the priority questions that our Climate Change programme is tackling, adding to both the scientific evidence base and serving UK government and public needs. These are questions that the Earth science community is uniquely positioned to answer, as increasingly high-resolution records of palaeoclimate are able to resolve issues beyond the capability of traditional climate models, and new understanding of surface processes allows us to look holistically at the impact of climate on our environments.

A recently deglaciated valley adjacent to the Jostedalsbreen ice cap in central Norway. The British and Scandinavian ice-sheets have responded to climate change in similar ways

Ice-age Britain and connections to Europe

Over the past two and a half million years, northern Europe has been subjected to a series of rapidly varying climates, including periodic ice ages. Britain was at the cutting-edge of many of these glaciations and permafrost conditions were widespread. A fruitful collaboration with Royal Holloway University of London has painted an unprecedented picture of the impact of climate change on Britain's landscape and its earliest inhabitants. Further collaboration with the Geological Survey of the Netherlands and the University of Bergen (Norway) is showing that the long-term development and response of both the British and Scandinavian ice sheets to climate change is strikingly similar. These relatively young geological records provide an invaluable and unique potential to further calibrate global climate models and so improve the accuracy of future climate predictions.

Sea-level rise in the Thames

Changes in sea level at any particular site are not a simple reflection of the amount of ice locked in Greenland or the Antarctic. Global sea levels are complicated (principally) by the expansion of water due to its rise in temperature, by a rise

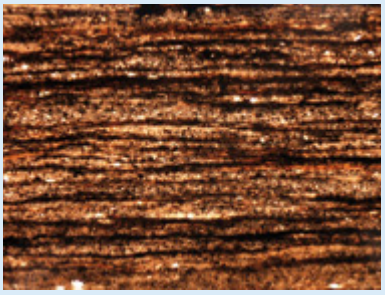
or fall in the level of land, and by relative changes in the storage of water in various parts of the hydrological cycle, and each of these has a lag-time associated with it. This makes it very difficult to predict local and regional sea-level rise, and it points to the importance of documenting sea-level changes for the recent past. The geological record provides a wealth of observational data, although teasing sea-level evidence from the record is a challenge. We have examined records from the Thames estuary, using novel techniques in biogeochemical molecular fingerprinting, and have uncovered evidence for a series of sea-level falls during the otherwise long-lasting rise in sea level during the past 10 000 years. These new findings include evidence for the sudden release of fresh water from glacial Lake Agassiz in North America at 8200 years BP.

Coastal erosion around the UK

Since 1961, sea levels have risen 50% faster than computer models have predicted. By 2100, UK sea levels may rise by more than a metre. Our coastline is the first and foremost guard against rising sea levels, but not all coasts are made the same. The processes of coastal change remain enigmatic, particularly when it comes to the role of geology. Our scientists have been examining various sections of the coastline to document rigorously the mechanisms and rates at which our coasts are currently retreating. Recent work performed for the Environment Agency has examined the role of geology in the breaching of Spurn Head by storm events. Spurn Head guards one of the busiest commercial ports in the UK and its evolution over time is tightly coupled to the frequency of storms and the wave climate that forces sediment transport along the shoreline.

Environmental instability in a time of rapid climate change

55 million years ago, at the end of the Paleocene, both the temperature and atmospheric carbon dioxide were rising as rapidly as they are today. Arctic waters were probably ice-free with water temperatures of 20°C. The Earth was undergoing runaway global warming. We learned this from the geological record long ago, but now new research at the BGS has uncovered the volatility of such a rapid climate change. New high-resolution records from sediment cores in the shallow ocean show that rapid and multiple changes in environmental conditions occurred over a time span of 5000 years after the initial rapid rise in temperature. Such instability is quantified by very large swings in the content of atmospheric carbon dioxide and most likely manifests itself as very large storms prior to an eventual new steady-state.



Regular laminations across about 2 mm within the core that crosses the Palaeocene–Eocene boundary. These may mark annual rhythms of sedimentation and record perhaps the highest resolution record of one of the most significant rapid climate changes in Earth's history.

Coastal erosion: aerial photograph of the 1849 breach in the Spurn Head peninsula. This part of the peninsula is now relatively wide (slightly less than 200 metres across) in response to engineered protection of this section. The partly-submerged sediment bar to the west (left) of the breach is a result of either the 1849 breach or an earlier one.

Science Programmes

Groundwater Resources

This programme carries out surveys of groundwater quantity and quality, and develops and applies innovative monitoring and modelling techniques to improve our understanding of groundwater processes and related resource issues. Understanding groundwater extreme events continues to grow in importance in relation to environmental change studies.

Pumping drinking water from a shallow groundwater source in Tanzania: what will climate change mean for this supply?

Helping African communities adapt to climate change

One of the major uncertainties surrounding climate change is how it will impact on water supplies across rural Africa, where many of the poorest and most vulnerable people in the world live. We have been involved in several initiatives during 2008 to begin to answer this question.

Research into the behaviour of groundwater and boreholes equipped with handpumps showed that catastrophic failure across the continent is unlikely, and increased use of groundwater may help to buffer the effects of a changing climate. We reported these findings at a conference in Uganda, the first international conference to address climate and groundwater in Africa. We have also been involved in publishing a series of thirty papers on groundwater resources in Africa, to help lay the foundations for future research.

There is clearly much more research to be carried out in this area. Groundwater may help communities to adapt to climate change. However, to be sustainable, wells and boreholes will need to be designed in a way appropriate to the hydrogeological environment, and mechanisms found to help local people effectively manage these resources in an uncertain future.

Sources of groundwater nitrate in Malta

The Maltese Islands have some of the highest concentrations of groundwater nitrate in Europe. The high population density and complex pattern of agriculture, animal husbandry and waste disposal make it difficult to determine the most important sources. This study aimed to provide the Maltese authorities with a scientific basis for implementing nitrate control measures to meet their obligations under the European Nitrate and Water Framework Directives. In collaboration with NERC Isotope Geosciences Laboratory *(see pages 42–43)*, we carried out a

Molybdenum in British drinking water

There is currently no statutory limit for molybdenum in British drinking water. However, the World Health Organisation (WHO) guideline value for molybdenum is 70 micrograms per litre and it can be anticipated that European drinking-water legislation will ultimately follow WHO guidance. Until recently, there had been little data on the distribution of molybdenum in British drinking water from which to assess the implications for the water industry of introducing such a limit. To address this lack of information we undertook a joint research project in collaboration with the Centre for Ecology and Hydrology during 2006–08, funded by DEFRA (Drinking Water Inspectorate). Archive data for British surface waters and groundwaters were collated and their distributions assessed. A new survey of drinking-water sources was also carried out from a small number of public-supply sources and some domestic taps from their supply areas. The ranges observed indicate that molybdenum concentrations in Britain are typically more than an order of magnitude smaller than the WHO guideline value. The highest concentrations were found in river samples from industrial areas of north-east England, though even here concentrations rarely exceeded 70 micrograms per litre. In the event that a new drinking-water limit comparable to the WHO guideline value is introduced in the coming years, our results suggest that molybdenum should not pose a significant problem for the water-supply industry.

Agden Reservoir, south Yorkshire: one of the major sources of drinking water for Sheffield and one of the source waters for our molybdenum survey.

comprehensive programme of sample collection and analysis from public and private groundwater supplies, together with potential nitrogen sources – animal wastes, synthetic fertilisers, sewage and agricultural soils. Nitrate stable isotopes indicated that the most likely source was leaching from agricultural soils followed by animal waste disposal, with other sources being ruled out. Other indicators provided little relationship with current land use. Evidence from groundwater tracers and coliform bacteria showed groundwater residence times to be much greater than anticipated for a karst aquifer and probably in the order of decades. These long residence times mean that nitrate concentrations in groundwater will continue to be a problem after control measures are introduced and other monitoring will be required to demonstrate nitrate leaching reduction at the surface.

Groundwater nitrate in Malta: small holdings below Dingli Cliff.

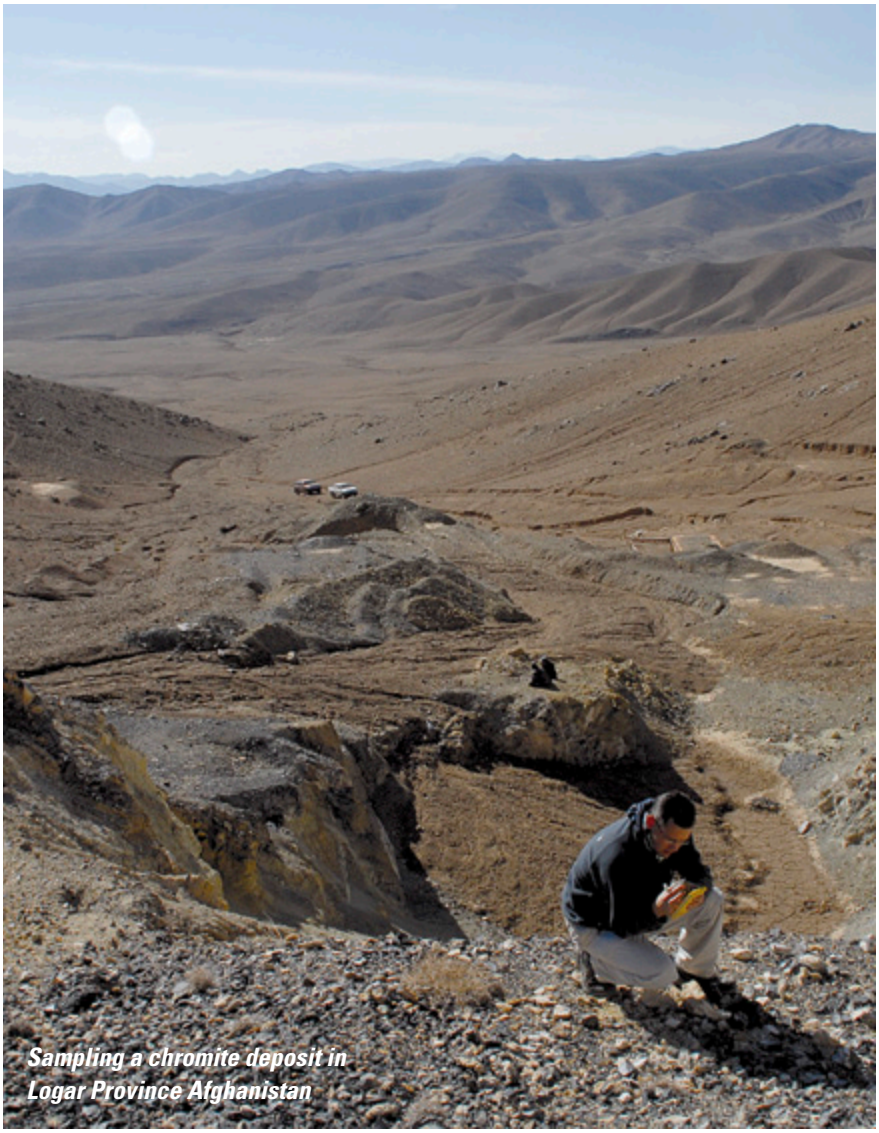
Modelling climate change impacts on UK groundwater resources

We have been investigating how the uncertainty associated with global climate model predictions of temperature and rainfall translates into predictions of impacts on groundwater resources and flows in ecologically important groundwater-fed rivers. Mathematical models have been used to simulate the infiltration of rainfall through the soil to the water table and the flow of groundwater through aquifers. From these models we have predicted changes in monthly groundwater levels and river flows. While the uncertainties associated with predicting climate change persist in the prognoses of groundwater resources, there is general confirmation from the modelling that the seasonal variation in the terrestrial water cycle will become more intense. It is likely that we will see longer drier summers during the twenty-first century and greater pressure on our groundwater resources.

Science Programmes

Minerals

Working with partners from government, academia and industry, our Minerals research portfolio includes metallogenesis, geomaterials, security of supply and policy issues. Much of this is underpinned by our internationally-respected mineral statistics database and our position as the major UK provider of national spatial and statistical minerals information via our MineralsUK.com web portal.



Sampling a chromite deposit in Logar Province Afghanistan

Chromite in Afghanistan

Following our recent technical assistance project in Afghanistan, research was carried out on chromite mineralisation formerly worked in the Logar ophiolite complex located approximately 30 kilometres south of Kabul. The Logar ophiolite, which crops out over about 2000 square kilometres, represents a remnant of Tethyan oceanic crust obducted during the Himalayan orogeny. The chromite occurs in massive lenses, comparable with podiform chromitite found in many ophiolites worldwide. Geochemical and mineralogical studies indicate that the chromite is of two types. One type, relatively rich in chromium, is interpreted to have been derived from a boninitic magma formed in a supra-subduction zone setting. Elsewhere the chromite is more aluminium-rich and was derived from a mid-ocean ridge environment. Although the platinum-group element contents of the chromitites are low, there is potential for small-scale commercial extraction of chromite for metallurgical and refractory applications in the Logar district.

New interpretations from old data

Between 1971 and 1990, our Industrial Minerals Assessment Unit (IMAU) undertook a major survey of sand and gravel resources in selected areas of England, Scotland and Wales. Funded by the then Department of the Environment, this comprehensive survey produced 149 maps and reports, backed up by a large digital dataset of consistent quality, including resource distribution and detailed borehole information. During the past year, we have revisited IMAU sand and gravel data to assess whether they can be used to enhance our knowledge and products to better meet the requirements of our user community. We have worked in collaboration with a team of experts at Deltares, the Dutch institute for delta environments, to produce a 3D visualisation of particle sizes within the Kesgrave Sand and Gravel in the Ipswich area. The results of this initial study have been extremely encouraging. Potential applications include local and regional spatial planning, as well as environmental and groundwater modelling.

Building stone resources: extracting a building stone block using compressed air technology (to avoid blasting) in the recently reopened Swinton sandstone quarry near Berwick-upon-Tweed.

Building stone resources for urban regeneration

In many parts of the UK, stone forms the essential fabric of towns and cities — buildings, street materials and paving, walls and bridges. Its use ranges from housing to iconic buildings and monuments. Much of the extensive Victorian architecture in urban centres is now in need of repair and restoration, and large sums of public money have been made available to bring new life to deprived areas. In the past most towns and cities were supplied by local building stone quarries, providing stone with local characteristics, yet today most of these quarries are closed and stone has to be imported from alternative sources. We are working with local authorities and government agencies (such as English Heritage, Historic Scotland) to identify former sources of stone, and, together with quarry operators and landowners, undertaking resource assessments to identify the potential for reopening of quarries. Key quarries are being identified which can supply appropriate stone in different regions of the UK to satisfy long-term needs for both conservation and new-build construction.

Safeguarding mineral resources for the future

In 2006, a requirement was introduced for Mineral Planning Authorities in England to define Mineral Safeguarding Areas (MSAs). This change in planning guidance seeks to protect mineral resources for future generations by obliging the authorities to take them into account when considering applications for other forms of development such as housing, retail or industry. By providing information on the distribution of mineral resources which underpins MSAs, we have an important role to play in this process. We have published a generic 'Guide to safeguarding minerals in England' to assist planners in delineating MSAs by highlighting key decisions and possible approaches. We have also assisted several planning authorities, including West Sussex, Shropshire and Warwickshire, in defining MSAs. This has established exemplar studies, using our mineral resource maps and geological expertise, and consultations with planners, industry and environmental organisations, to define effective MSAs in England.

Kaolin (china clay) extraction in Cornwall — planners in England must now safeguard resources of kaolin and other minerals against unnecessary sterilisation by other development.

Global information on materials for industry

A wide range of raw materials is required to maintain our economy and standard of living. Two additions have been made to the BGS Mineral Commodity Profile series which provides key information on economically important minerals and metals. New profiles on nickel and cobalt provide an overview of the global industry for each, reviewing resources, processing, uses, production, trade, prices, recycling and alternative materials. Nickel and cobalt are critical components of many alloys such as the superalloys used in jet engines, although nickel's main use is in stainless steel. Most cobalt is used in lithium-ion batteries — it is estimated that in 2007 about 15% of global mine production of cobalt went into batteries in mobile phones and laptop computers. Clearly, as demand for these metals grows, so secure and adequate supplies must remain available. To ensure this accurate and up-to-date knowledge of the global commodity marketplace is essential.

Global information: skutterudite, a cobalt–nickel arsenide, a mineral from which cobalt is derived.

Science Programmes

Energy

The aim of our Energy research programme is to foster national capability and undertake research to facilitate Britain's transition to a low-carbon and secure energy economy. Most of our work is conducted in collaboration with industry and government partners across the European Community, and facilitates transfer of low-carbon energy technologies to emerging world economies.

The 845 megawatt Huaneng coal-fired power station in Beijing. China builds one new power station a week but is considering the technology of carbon capture and storage to reduce its emissions

BGS takes a leading role in climate change reduction

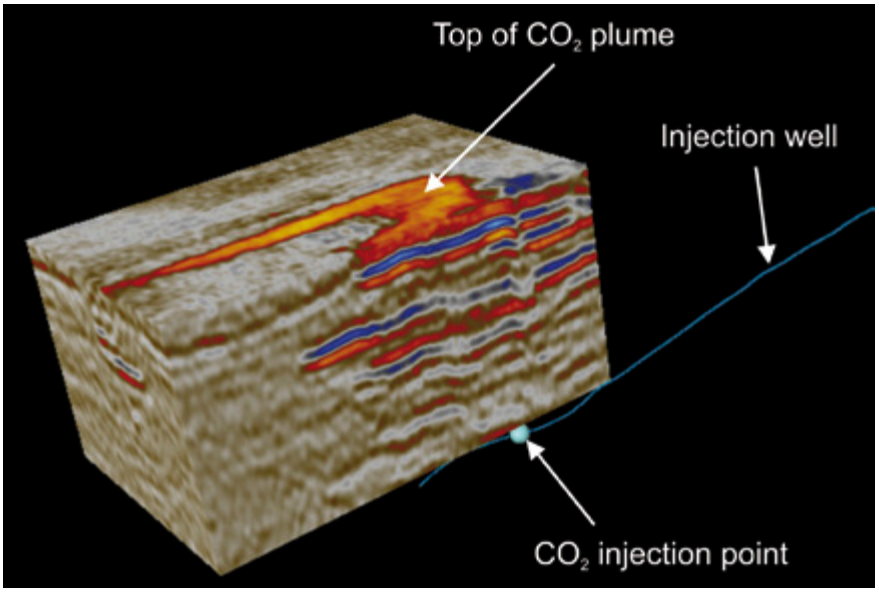
The UK Department of Energy and Climate Change (DECC) Carbon Capture and Storage (CCS) competition is one of the most important climate change abatement measures that the government is initiating the next few years. It is hoped that it will help to kick-start CCS in Britain and provide a beacon to developers and governments in other parts of the world including the new big carbon dioxide emitters, India and China. Our CCS team uniquely provides specialist geological advice to DECC on the competition and is thus at the heart of 'science to policy' in this new exciting area. We also provide advice on CCS to other governments, for example the Government of Western Australia.

CCS research goes from strength to strength

We are leading the geological part of a large project, funded by the Energy Technologies Institute (ETI) to derive a precise and defensible estimate for carbon dioxide storage capacity in part of the western North Sea. Meanwhile, in the Norwegian sector, we continue to develop high-resolution time-lapse seismic monitoring of the world's largest carbon dioxide injection project in the Sleipner gas field. Monitoring has recently shown that there is no detectable leakage of carbon dioxide and that time-lapse seismic can be used to trace exact directions and amounts of carbon dioxide flow, even 1000 metres below the seabed.

Promoting Carbon Capture and Storage

We hosted two important meetings which are likely to affect the course of international CCS research in the next few years. A conference in November discussed the results and directions of the 'Near Zero Emissions Coal project' (NZEC) and the 'Cooperation Action within CCS China–EU' (COACH) storage capacity projects in China, while an International Energy Authority (IEA) meeting discussed shallow leakage



3D seismic image of the Sleipner carbon dioxide storage site in the North Sea. The cube is approximately 2 km long, 1.5 km wide and 200 m high. Bright colours are carbon dioxide layers trapped beneath mudstone baffles. Inclined injection well shown by a light blue line, the injection point is shown by the light blue dot.

monitoring and environmental impacts of carbon dioxide storage.

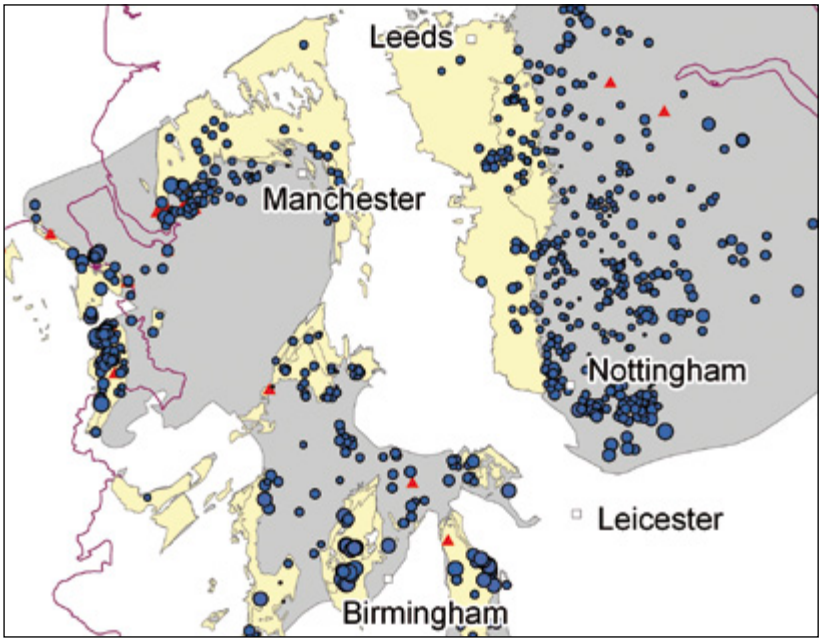
Improving Britain's energy supply security

Long-term increases in the price of fossil fuels, concerns about security of energy supply and commitments to reductions in the emissions of greenhouse gases have led the UK government to set a target of 15% of the UK's energy from renewables by 2020. Renewable heat will provide an important contribution to this target and we have continued to research the national resource base of geothermal heat. Scoping studies have explored the thermal capacity of flooded mine workings, especially close to urban centres, and reassessed the potential of geothermal power from the granite of Scotland. Promising results from new data collected over the past 20 years has indicated a number of targets worthy of further research. A project was completed in Northern Ireland to provide an online report service on site suitability for a ground source heat pumps.

In the future it is likely that the UK will start to develop its resources of methane from deep coal seams and shale. Even seams that are too deep to mine might yield useful energy in the form of methane. Shale may also contain gas, and can yield three to four times as much gas as a conventional sandstone gas reservoir. Both these sources of gas may become very important to the UK — they are potentially cheap as well as secure because they are sourced locally. However, exploiting them may be technically challenging. Our energy teams are establishing a geographical information system holding information on coal seam thickness, coal gas content and shale gas prospectivity for parts of onshore Britain, which we hope will encourage industrial exploration in shale gas and coal bed methane (CBM). We are also researching the primary palaeoecological and depositional controls on types and amounts of organic carbon in shale through a Ph.D. project with the University of Leicester. This work will bear on how much shale gas can be generated and the quality of the gas.

Extending the life of hydrocarbons reservoirs

The Edinburgh Anisotropy Project (EAP) develops innovative techniques for imaging and assessing hydrocarbon reservoirs by wave analysis and modelling of seismic survey data. This year, the project consortium showed that it is possible to distinguish between oil and water in a reservoir using seismic shear-wave data. This is a major development for industry since the remote discrimination of these fluids is usually only possible by expensive drilling. Also, theoretical studies now allow us to model variations in wave velocity and attenuation to differentiate between open and closed fractures in hydrocarbons reservoirs. This means that we can understand how oil and gas flows in hydrocarbon reservoirs even without drilling. These, and other novel methods for remotely determining reservoir structure and properties, were developed in collaboration with the international oil company sponsors who fund EAP activities.



Improving Britain's energy supply security: map of exposed (yellow) and concealed (grey) coalfields in central England and north Wales. Large circles are boreholes proving the greatest aggregate thickness of coal. A sequence of many, thick coals is one of the main targets for coalbed methane (CBM) exploration. Red triangles are CBM exploration wells.

Science Programmes

Spatial Geoscience Technologies

Our Spatial Geoscience Technologies programme develops satellite, airborne and ground-based observation technologies and 3D/4D geoscientific information systems. Our aim is to increase mapping and modelling efficiency and improve the information content, quality and consistency of maps and models delivered to stakeholders. This is underpinned by cutting edge standards and best practice guidance.

BGS•SIGMAmobile in use in the United Arab Emirates

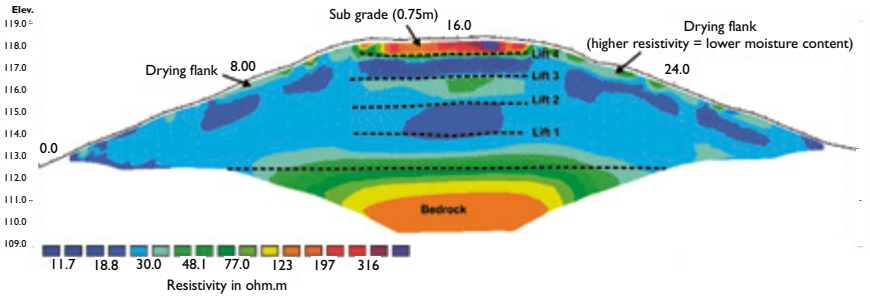
Digital field mapping

Our flagship digital field mapping system, BGS•SIGMA*mobile*, reached maturity, with widespread take-up by geologists working from the snow-bound Scottish Highlands to the deserts of the United Arab Emirates. A highlight was the announcement at the 33rd International Geological Congress in Oslo that BGS•SIGMA*mobile* will be made available as a free, open-source system for all users, in return for feedback and any code developed. This led to increasing enquiries through the year. Steps were taken to support its launch in 2009, including the development of license agreements and web-based delivery systems. As a result, collaborations have been developed with several universities.

Geophysical tomography

Roll-out of our world-leading, time-lapse geophysical monitoring technology, ALERT, saw the system installed on an embankment test site this year, in support of the EPSRC-funded research on impacts of climate change on built infrastructure. ALERT is being used to image moisture content changes within the embankment, both within the internal structure in three dimensions and through time. The results are automatically logged and returned to our databases using wireless telemetry. Other ALERT systems have been installed to remotely monitor the *in situ* remediation of contaminated land and to track an active landslip at Hollin Hill, Yorkshire. Our research has attracted sponsorship from industry and involves close collaboration with academia, including a BGS-funded Ph.D. studentship at Loughborough University.

Other developments in 2008/09 included a prototype interface from ALERT to other sensors, such as a weather station and a borehole logger, which will allow them to take advantage of ALERT's telemetry links to return their data from remote sites. But the landmark technology development in



Geophysical tomography: 2D electrical resistivity image of the EPSRC BIONICS research embankment to monitor time-lapse variations in moisture content and hence slope stability. Collaboration with the University of Newcastle and University of Loughborough.

Geophysical Tomography was the granting of a US Patent, after a four-year defence, for a geophysical mapping method based on Capacitive Resistivity Imaging.

3D Visualisation

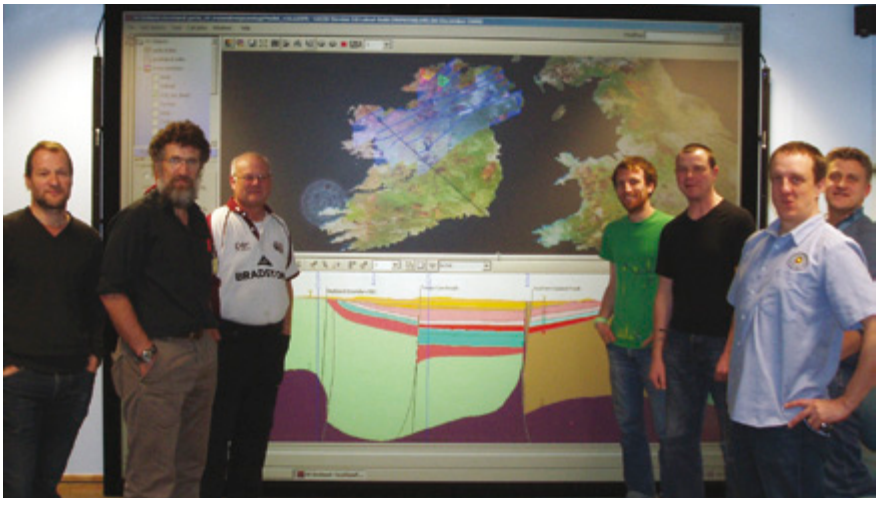
An upgraded version of GeoVisionary developed by our partners, Virtalis, was delivered to us in March 2009. This has a graphic interface which will be more familiar to users of geographical information systems (GIS) and enhanced functionality. The inclusion of common GIS tools and live links to other commercially available GIS software has seen the system move beyond visualisation to become a 3D GIS that is being deployed in many projects. These upgrades form the basis for a commercial release and a highlight of 2008/09 was the first sale of GeoVisionary to another European geological survey, with several more sales in advanced negotiations.

Earth Observation

A flagship application of Earth Observation came with activation of the International Charter on Space and Major Disasters by the Cabinet Office Civil Contingencies Secretariat, responding to the volcanic crisis on Montserrat. We were asked to manage the project, working in collaboration with the National Centre for Earth Observation. Imagery from the new TerraSAR-X satellite was instrumental in revealing the status of the lava dome through the eruption cloud cover. The report was well received and resulted in the Secretariat visiting Keyworth to find out more about our other disaster mitigation capabilities.

3D modelling systems

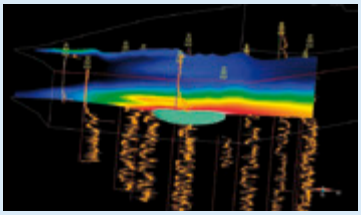
The take-up of BGS's GSI3D modelling system continued to grow, with around 35 BGS users across 20 projects during the year. A major achievement was the first successful modelling of complex, faulted and folded terrain in the Plynlimon area in Wales. A trial release has formed the basis for a 3D modelling collaboration with the Irish and Northern Irish Geological Surveys building a regional geological model of Ireland and Scotland.



3D modelling systems: a team of geologists from the geological surveys of Ireland (GSI), Northern Ireland (GSNI) and Britain (BGS) at a modelling session in the 3D Visualisation Facility.

Predicting underground conditions using 3D models

The rapid population of 3D models with meaningful geological properties remains a challenge. The PropBase project made a significant step forward by populating a model for the Weald Basin. This demonstrated that we can interrogate geophysical log data held in our databases to provide a 3D spatial interpolation of physical properties. This was underpinned by delivery of the PropBase QueryLayer which now allows access to all our property data in a single location and structure.



3D model of the Weald created to test predictions of physical properties in situ *underground.*

A biennial GSI3D Conference at BGS in September 2008 drew attendees from continental Europe and the United States and was written up in a conference abstract as well as in geoscience magazines. It saw the announcement of a trial, low-cost release for research users, which has since been taken up widely by the academic 3D geological modelling community and other geological surveys from around the world. The GSI3D methodology was also published in Computers and Geosciences.

We reviewed the Environment Agency's 3D geological modelling activities and advised on future system deployment. Recommendations for future projects and developments have been made. Free viewing software is now delivered alongside the models via a secure extranet site so that Agency staff can interrogate the models without loss of geological information.

Setting standards

Underpinning work on standards saw the completion of an upgrade to the Igneous Rock Classification Scheme, for publication early in the new financial year. A new volume on Discontinuities was taken to final draft, following external review.

One hundred and sixty years' worth of BGS archive magnetograms are being scanned and will be made available as a research resource

Science Resources

The role of the Science Resources Directorate is to ensure that the right human and other scientific resources are available to deliver the BGS programme.

Science and information staff are co-ordinated by Heads of Skills and Skills Leaders, who manage career development and training and allocate people to projects. 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-ordinate and deliver training to our staff, as well as to outsiders 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; also for publications, computer infrastructure and university co-operation.

At the end of the financial year 2008/09, the Science Resources Directorate was merged with the Business Development Directorate to form the new Resources and Business Directorate, from 1 April 2009.

The BGS University Funding Initiative

This initiative currently supports over 75 individual collaboration projects. These vary from small grants to help M.Sc./M.Geol. students with their research dissertation to support for major international research projects. However, our principal aim is to support science and research training at the doctoral level.

At present we have around 60 Ph.D. students on our books and these early-stage researchers are based at around 40 UK universities. Most are located in earth and environmental science or geography departments, but our collaboration also includes communications, chemical engineering and space science.

We currently spend around £400k per year supporting our university partners and the graduate students research a wide range of topics, reflecting the broad scope of our interests in the applied earth sciences. Subjects include topics such as climate change, carbon capture, space weather, seismology, palaeontology, igneous petrogenesis, mineral and petroleum exploration, earth hazards, glaciology plus geological aspects of human health.

We recently launched a website (www.bgs.ac.uk/research/bufi) where further information about our current activities can be found.

The BGS University Funding Initiative Ph.D. student field workshop 2009 on Milos island, Greece.

Science Resources

NERC Isotope Geosciences Laboratory

The NERC Isotope Geosciences Laboratory (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. NIGL serves many RAE grade 4 and 5 academic departments in the UK, and several NERC institutes, including the British Geological Survey. NIGL is one of the NERC facilities for isotope research and is funded till 2014.

Melting ice in the seas off Western Antarctica

Seasonal variability of freshwater around Western Antarctic

This study highlighted the seasonal variability of freshwater into bays off the Western Antarctica Peninsula over a two-year period. The research found that glacial meltwater accounts for up to five per cent of surface water in the summer months. This is an important benchmark for a region that is undergoing very rapid change due to retreating glaciers and increasing precipitation. As climate change continues we expect the freshwater contribution to increase, which will have potentially serious ecological consequences.

- Meredith, M.P.et al. 2008.

Isotopes in Biogenic Silica

This special issue of the Journal of Quaternary Science (Volume 23, Issue 4) comprises a selection of papers from the third meeting of a series on 'ISOtopes in PALaeoenvironmental reconstruction' (ISOPAL), themed around Isotopes and Biogenic silica (IBiS). The meeting was held at the NIGL in 2007 and consisted of a series of presentations giving methodological approaches to using isotopes in biogenic silica but also specific examples of the application. NIGL contributed to all 8 of the papers in the volume including first publication of the method.

- Leng, M.J. & Sloane, H.J. 2008.

© Sandra Ryan

Golyazi Bridge used to lie over Lake Uluabat until recent human abstraction.

Recent habitat degradation in a karstic lake, western Turkey

Lake Uluabat, western Turkey, is suffering from eutrophication, industrial pollution and water abstraction, and its naturally fluctuating water levels are now managed artificially. Researchers led by teams from Hull and NIGL combined monitoring and palaeolimnological techniques to investigate spatial and temporal limnological variability and ecosystem impact. Stable isotopes show a twentieth-century trend towards increased sediment accumulation rates and eutrophication which was probably initiated by deforestation and agriculture. A paper was published discussing the implications for lake restoration in the context of the EU Water Framework Directive.

- Reed, J. M. et al. 2008.

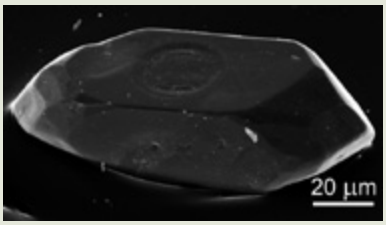
Depleted uranium contamination

Sample preparation and analytical techniques have been 'borrowed' from geochronology for a novel application in nuclear forensics. This paper demonstrates, for the first time, the application of high-precision isotope ratio LA-MC-ICP-MS analyses to a large population of individual uranium oxide grains from environmental samples. These data reveal details of the history of uranium processing in Colonie, NY, USA. The research is part of an environmental case study investigating the distribution of depleted uranium contamination surrounding a former munitions factory and was summarised as part of a wider investigation in health issues by Professor Randy Parrish, Head of NIGL, before the Committee on Science and Technology of the US Congress in March 2009.

- Lloyd, N.S. et al. 2009

Geochronology at the submicron scale

NIGL staff have developed a new method for analysing very thin rims that have grown on zircon crystals and other accessory minerals with inherited cores. In these crystals only the rims record the true crystallisation age of the host igneous rock. Whole crystals (with thin rims intact) are mounted on double-sided sticky tape and analysed by MC-ICP-MS using single pulses of a laser beam. Data acquisition relies on a low-volume ablation cell that facilitates rapid transfer of ablated material to the mass spectrometer and short sample washout times. Using reference zircons we can consistently measure $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ratios with external reproducibilities of 3% and 2.5% (2SD) respectively, using up to 90% less material than 'multi-second' static ablation protocols. The new method is therefore an ideal way to rapidly generate accurate and precise age information from complex accessory phase minerals at the submicron scale and it may permit depth profiling in materials with gradients in geochemical parameters.



SEM image of zircon after 10 pulses.

Strontium isotope analysis of archaeological materials

Analysis of strontium isotopes in tooth enamel, bones and other calcium phosphate (apatite) materials can be quickly performed using laser ablation ICP-MS techniques. However, ambiguous analytical difficulties have prevented the accurate determination of strontium isotope ratios in apatite-based materials. Researchers at NIGL and Bradford University have proved for the first time that the cause of these difficulties is due to a polyatomic (Ca–P–O) molecule with the same mass as the key radiogenic ^{87}Sr peak; procedures were developed to allow accurate values for the Sr isotope signature to be obtained.

- Horstwood, M.S.A. et al. 2008.

New analytical procedures allow accurate strontium signatures to be obtained.

The 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.

Science Resources

Publications

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 Geological Map of Great Britain (DiGMapGB), and the equivalent product covering Northern Ireland (DiGMapNI). We are also involved with developing our traditional products to take advantage of new digital technology, and have made great progress with eBooks and Digital Editions.

Cartographic GIS

We use geographical information systems (GIS) to capture geoscientific information to build digital map databases *(DiGMapGB, see Baseline Products, page 54)* and produce cartographically enhanced hardcopy.

We have added to the survey-scale map database (1:10 000 or 1:25 000 scale) to provide 16% coverage of Great Britain. 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 also print-on-demand maps.

We collaborated with another NERC research centre, the British Antarctic Survey, to produce a geological map of Antarctica under the OneGeology project *(page 52)*.

Skills in cartographic GIS and graphic design were applied to a wide variety of projects. A prestigious project culminated after a number of years with publication of a set of two maps at 1:625 000 scale and two guide books covering the geology of Great Britain. This fifth edition of the maps provided the most comprehensive interpretation of the rocks to date, in an innovative and attractive presentation.

Graphic Communications

Traditional printed products remain in demand, such as the Sheet Explanation that accompanies and provides a concise description of its partner 1:50 000 scale geological map. Increasingly, we provide books in digital format for web delivery, and

have been actively involved with developing digital editions with an attractive and user-friendly interface. The Annual Report 2007–08 was our first offering via this advanced interface.

Demand for multimedia products remains strong, particularly DVDs, and website design and production. The movie animation produced for OneGeology received much praise at the formal launch. Movies are powerful media to illustrate geological processes, and we applied these techniques successfully to describe submarine landslides. An animated presentation was made to illustrate the 3D Vale of York model.

We were pleased to be able to design and produce, together with our photographers, the BGS 2008 calendar.

Photographic Services

We were invited to photograph the six-kilometre long tunnel sections to the Glendoe Hydro Electric construction. The visit was invaluable to understanding the geological history, and the photographic images we obtained provided a significant resource which was used to enhance our 3D geological models.

The Geo-Imagebase underwent a major development into a digital asset management system, having many features expected in a modern image library. It was customised to better meet the needs of the internal photographic collections (some 192 000 images) and the public-facing National Archive of Geological Photographs (some 40 000).

There was an increase in demand for photographing material primarily for digital archival purposes. A two-year project commenced to capture approximately 500 000 magnetograms and another, on site in the Chatsworth House archive collection, to digitally scan 125 mine plans.

Output in 2008/09

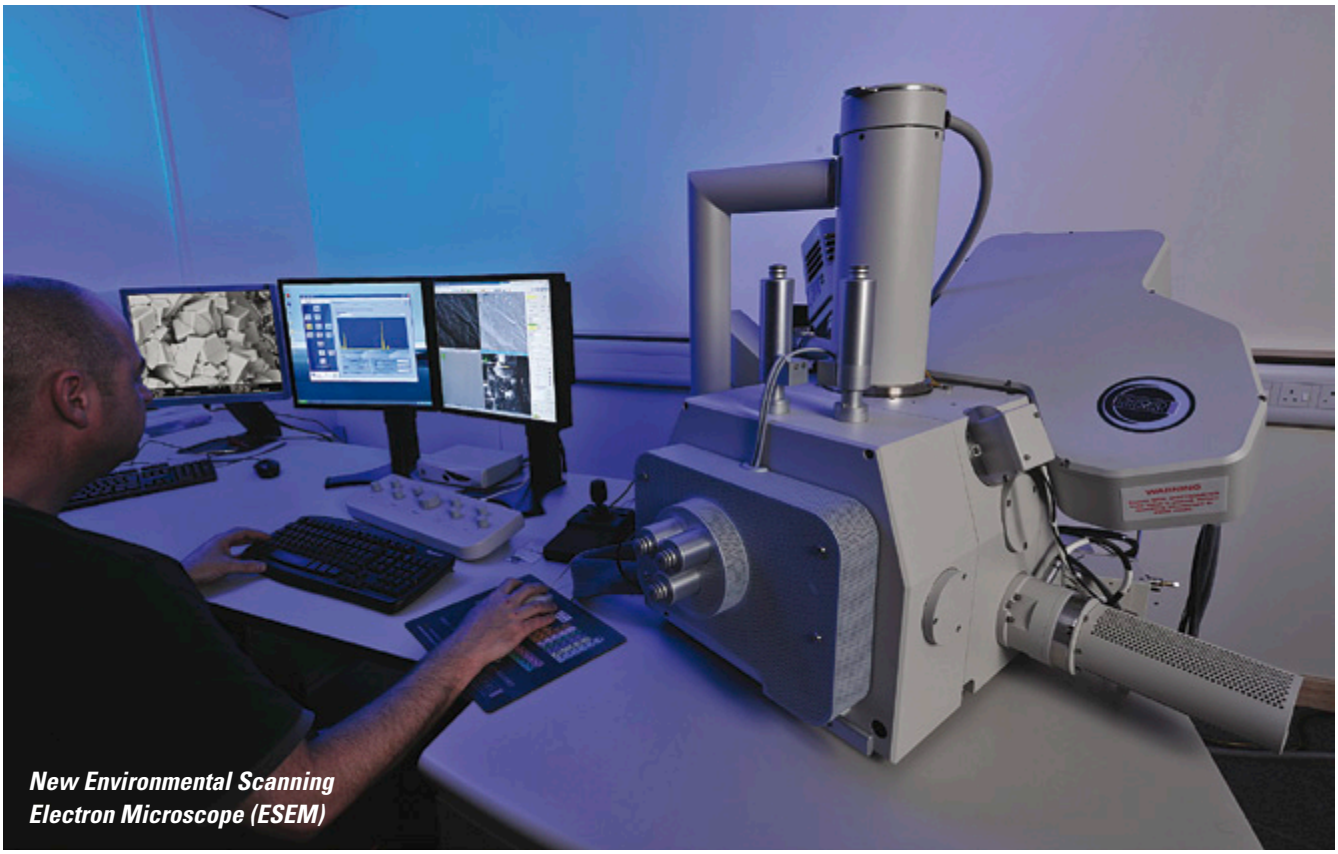
Digital map and book data and printed media included:

- over 300 5 x 5 kilometre tiles added to the 1:25 000 and 1:10 000 scale DiGMapGB database;
- over 200 of these were cartographically enhanced to enable print-on-demand reproduction;
- 23 new litho-printed maps were published for established series;
- 24 were published as folded editions;
- 4 special maps;
- 6 Sheet explanations;
- 14 Annuals;
- 46 multimedia projects;
- 7 computer animation projects;
- 192 000 images migrated into the new digital asset management system.

Graphic Communications produced digital editions of the Annual Report and BGS Science Strategy.

Science Resources

Laboratory Operations and Development of Capability



New Environmental Scanning Electron Microscope (ESEM)

Laboratory Operations

The Laboratory Operations programme is responsible for the strategic management of all of our wide range of laboratory facilities, ensuring that they provide a high quality, cost-effective and scientifically well-aligned input to our core strategic and commissioned programmes. During 2008/09, a major review of our laboratories was completed. A new laboratory leadership structure was established that will increase the visibility, impact and strategic alignment of our laboratories with our science strategy. Four Facility Leaders were appointed to lead newly formed laboratory facilities in analytical geochemistry; mineralogy, petrology and biostratigraphy; physical properties; and fluid processes research.

New environmental scanning electron microscope

In March 2009, the Mineralogy, Petrology and Biostratigraphy Facility was enhanced by the installation of a new 'state-of-the-art' FEI Quanta 600 Environmental Scanning Electron Microscope (ESEM). The ESEM is fully equipped with integrated, fully-quantitative spectrometers to provide major and trace element geochemical analysis, and a cryogenic on-column sample preparation chamber and cold-stage. The ESEM is being used to examine a wide variety of geological, environmental and biological samples under variable atmospheres of carbon dioxide, water vapour and other gases. This enables researchers to preserve and directly observe water-sensitive hydrous materials, frozen and wet samples, such as ices and gas hydrate-bearing sediments.

In collaboration with our Transport Properties Research Laboratory, the ESEM has already been used to image nanoparticulates as possible pathway tracers for fluid movement through low permeability geological materials. During 2009/10 the equipment will be fully-commissioned and applied to research into geological radioactive waste management, carbon dioxide sequestration, micropalaeontology, sediment diagenesis, energy resources and other environmental projects.

Underground storage of carbon dioxide

The deep underground storage of carbon dioxide requires high-quality engineered borehole seals as well as those offered by the natural caprock. As part of our contribution to the EC-funded CO_2GeoNet

network of excellence, researchers within the Hydrothermal Laboratory have led a work package investigating likely reactions between carbon dioxide stored underground and the cement used to seal deep boreholes. With support from the Analytical Geochemistry and Mineralogy, Petrology and Biostratigraphy Facilities, analysis of reaction products from short-term laboratory tests reveals the rapid formation of a well-defined carbonated zone on the outside of the cement. There is evidence that the reaction front is associated with solid volume changes that lead to micro-cracking. Work is continuing to understand if this carbonation will continue or slow down over time, and the impact it might have on the sealing properties of the borehole cement.

Low-level quantification of carbonate species: samples in platinum crucibles awaiting thermal analysis.

Maintenance and Development of Capability

The Maintenance and Development of Capability programme comprises many small- to medium-scale initiatives that underpin our core strategic and commissioned programme. The main objective of the programme is to assimilate new scientific ideas and technological developments across a wide range of our present and future activities. The programme is used to maintain our cutting-edge capability by introducing new methodologies, enhancing existing capabilities and obtaining formal accreditation of our scientific services.

Low-level quantification of carbonate species

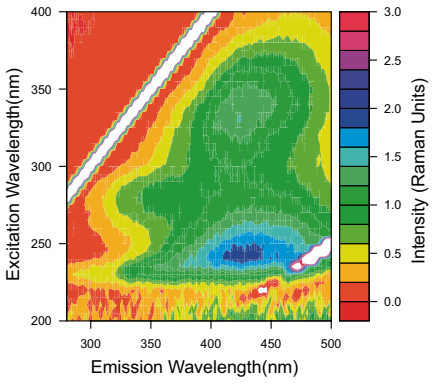
The Mineralogy, Petrology and Biostratigraphy Facility is the premier UK institution for geoscientific thermal analysis, a suite of analytical techniques for monitoring the reaction of rocks and soils to controlled heating programmes. Recent investment and research has been targeted at the low-level detection of carbonate species, particularly the most commonly occurring minerals calcite, dolomite, ankerite and siderite. The rapid, low-level detection and quantification of carbonate species provides critical data to a wide range of our research projects, but is particularly important in studies related to carbon dioxide storage from analogue and demonstration sites. Reactions between carbon-dioxide-rich porewaters and carbonate cements in reservoirs or cap rocks are relatively fast. Therefore the detection and characterisation of carbonate minerals is fundamental to understanding long-term storage processes. Initial studies suggest that levels as low as 60 ppm calcite are measurable, offering significantly lower detection than other mineralogical techniques.

Sewage tracers

Sewage contamination is a major cause of decreasing water and sediment quality in rivers and lakes within the UK and throughout the world. Untreated sewage can, under specific conditions, provide a growth medium for bacterial and viral pathogens that, if ingested by humans, leads to diseases such as salmonella, cholera, diarrhoea, typhoid, gastroenteritis and hepatitis A. Our organic geochemists have successfully developed a method to assess sewage accumulation and distinguish animal from human sources as well as determine the degree of treatment using specific groups of molecules called faecal sterols. The new methodology was used to track changes in sediment cores from three shallow lakes (former gravel pits) with varying histories of connectivity to a polluted river. Specific sterol ratios suggested that the shallow lake closest to the river was the most polluted with human-derived sewage and that the lakes had periodically received additional inputs from animal manure and slurry.

Tracing sources of organic carbon and groundwater flow

The sandstone aquifers of the UK are nationally important sources of public water supply. Dissolved organic carbon is known to have a range of important functions in the aquatic environment, both as a source of energy for micro-organisms, and in its role in the transport of metals and organic contaminants. BGS researchers have used fluorescence analysis to rapidly assess different types of dissolved organic carbon and their relative abundances within these aquifers. This technique has been useful in fingerprinting different sources of organic carbon, distinguishing the groundwater organic signature of agricultural sources from those of urban sources. It has also been a useful technique in identifying regions of contrasting flow within the shallow groundwater system. This work was carried out in conjunction with the Groundwater Resources programme *(see page 32)*.



Excitation–emission fluorescence plot of a groundwater sample showing fulvic-like centre (Emission 440 nm) and protein-like centres (Emission 340 nm); ratios of these two centres can be used to distinguish between different sources of organic carbon.

Science Resources

Staff Development and IT Infrastructure

We support staff learning and development by providing a training programme aligned with corporate strategy and business needs. The Systems and Network Support group provides ongoing IT support to our staff and has also been very active in the development and support of the NERC's IT Strategy.

Analysing the origin of glacial deposits in a section at Clava, east of Inverness on the Highland Quaternary Geology training course

Training and staff development

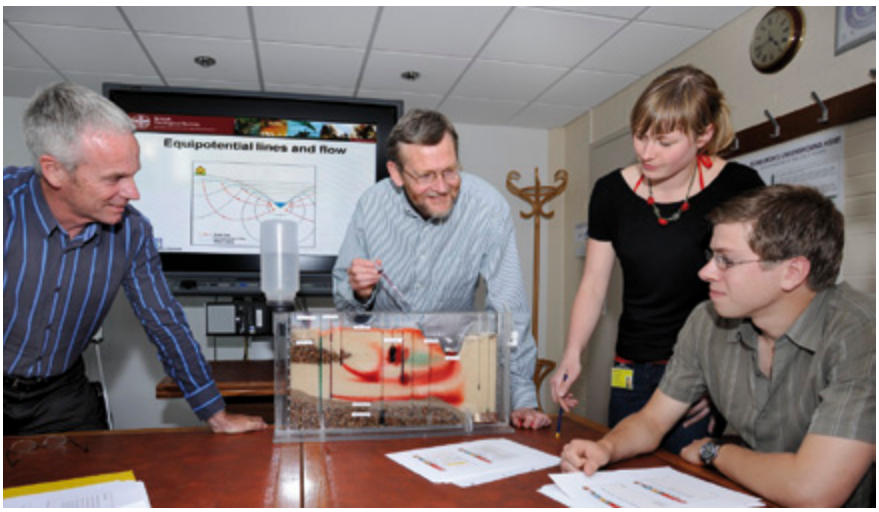
Training was provided in a number of specialist IT areas, including network administration and security, geographical information systems (GIS) development and Oracle database applications. Our training programme included courses in web technologies, digital data capture and processing workflow and the use of applications software for graphic design. Geological modelling and 3D visualisation software was supported through GOCAD and GSi3D training, and we ran in-house courses in the corporate software applications used widely by staff.

Scientific and technical training included courses in hydrogeology, multibeam sonar, statistics, climate change modelling, ground source heating, geotechnical testing, geomagnetism, radar interferometry and coupled transport modelling. Laboratory operations were supported with training in the operation of a variety of specialist analytical equipment. Field-based courses in extensional tectonics, the mapping of geological features and deformed terranes, and Highland and Lowland Quaternary geology were run in conjunction with the School of Field Geology and were attended both by BGS staff and university postgraduate students.

Health and safety training included standard topics such as fire awareness, manual handling, off-road and minibus driving, stress management and first aid as well as more specialist areas including drilling-rig operation, mast climbing, trailer towing, mobile crane operation, high pressure systems, quarry safety and sea survival.

Personal development training covered a range of management, communication and workplace skills and senior staff attended a series of NERC-organised leadership events under the Leadership for NERC (L4N) programme. Training events covering grant proposal and scientific publication writing, communicating science to the media and change management were prioritised and a number of workshops were run to support staff with Team Leader roles.

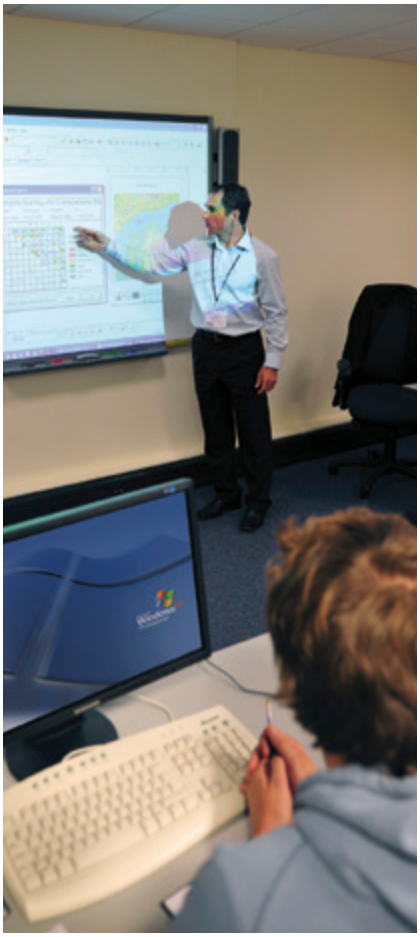
The BGS mentoring scheme continued, focusing on helping mentees to identify



Demonstrating flow paths using coloured dyes and a groundwater model for a training course in hydrogeology.

and achieve career development goals and realise their full potential.

On-the-job training for new recruits and those needing to learn new skills and/or undertake major job changes continued to receive funding, and support was provided for 31 staff working towards Further Education qualifications. Nine staff successfully obtained further education qualifications (1 Ph.D., 3 Master's degrees, 1 NVQ, 4 diplomas and certificates) during the year with BGS sponsorship.



New electronic whiteboard systems installed to improve training facilities.

IT Infrastructure

Systems and Network Support (SNS) provides day-to-day IT support to BGS staff as well as support for some of the NERC's corporate IT systems. It has been a very busy year for the team with a lot of effort put into supporting the NERC corporate Microsoft Exchange and Blackberry systems and migrating users to this email service. Good progress has been made with server virtualisation and we now have 33 virtual servers which has helped the NERC achieve its server reduction target of 50 for 2008/09. A number of new electronic whiteboards have been purchased as well as high-definition video-conferencing systems that should help to reduce the amount of travelling that staff need to do. Personal video-conference systems are supported and staff are encouraged to use these. New wireless LAN systems have been installed and a WLAN management system has been purchased that will help manage our growing number of WLANs. A new web proxy appliance has been bought for the Keyworth site that should help to manage web accesses and ensure better performance. As a means of enabling better support for desktop computers, SNS has been evaluating Zen Configuration Manager.

IT security continues to require a considerable level of resources and an IT Risk Register is used to indicate the highest risks. The IT Security Officer has a programme of external vulnerability tests and new externally facing systems are also externally tested before they can go live.

The new NERC corporate email kit.

A growing amount of effort is being put into the support for the NERC's corporate IT initiatives. In addition to corporate email, SNS also supports the NERC corporate directory service (using Microsoft Active Directory) which will be developed significantly as more parts of the NERC require it to manage their file and print services.

For the future, SNS expects more of the NERC's corporate IT systems to be based at Keyworth and this will require enhanced support facilities. There will be ongoing support for NERC initiatives and SNS staff will be expected to work more closely with other NERC IT staff and to adopt the 'NERC One IT Team' approach. Corporate data storage facilities will be reviewed to ensure that they remain fit for purpose and that requests for storage of new datasets can be adequately met.

Soil parent materials model

Information and Knowledge Exchange

The management of digital and analogue geoscientific data and information, the creation of national geospatial datasets and the delivery and exploitation of BGS science in the community is the responsibility of the Information and Knowledge Exchange Directorate.

The collections of the National Geoscience Data Centre (NGDC) have grown considerably in recent years, and are now held at seven sites across Great Britain from Hartland Point in Devon to Edinburgh in Scotland. In May 2008 the BGS convened a thematic meeting at the Geological Society, London entitled 'Exploiting Geoscience Collections'. Later in 2008 an independent, external review of the current NGDC facilities was commissioned with a remit to consult extensively with stakeholders and develop alternative solutions that might reduce overall operating costs. It is expected that additional capital expenditure funding will be available during 2009 to address some of the key issues raised in the report.

Digital national geoscience datasets are used extensively by our stakeholders and the research community. The programme has progressed considerably with the release for the first time this year of datasets covering:

- natural radon hazard potential for Scotland;
- groundwater flooding susceptibility;
- non-coal mining hazards; and
- offshore Quaternary deposits.

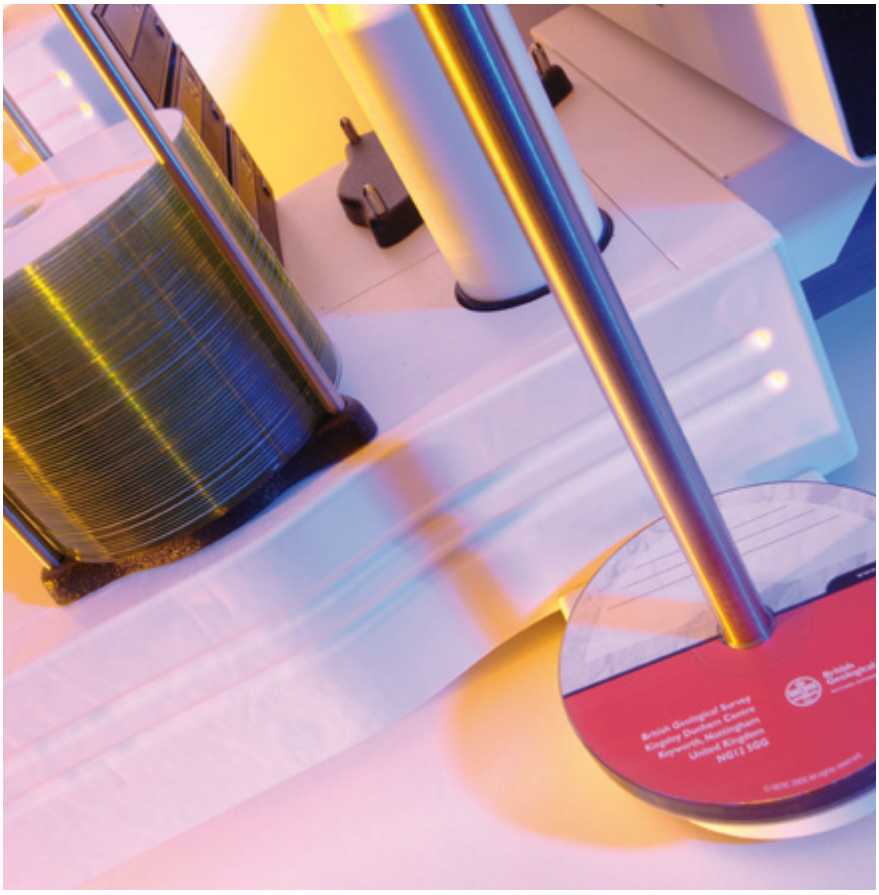
Upgrade of existing datasets continued with the release of:

- DiGMapGB-50 Version 5;
- DiGMapGB-10 Version 2;
- GeoSure Version 5;
- Geological Indicators of Flooding Version 5; and
- Permeability Version 5.

The Soil Parent Materials dataset (Version 4 released this year) is an excellent example of a geospatial dataset with significant research and commercial applications.

The new BGS website, launched in May 2008, has many new features including free availability of some national geoscience datasets through application programming interfaces for mashing, use of new media such as video, and GeoRSS feeds. With new, high-quality content and downloads being added on a regular basis the popularity of the website continues to grow rapidly, with hits increasing threefold over the year to an all-time high of 11 million per month.

Through the year the BGS played a leading role in the project to restructure library service provision across the four wholly owned NERC research centres. From 2011 it is planned that NERC library services will be delivered through a 'hub and spoke' system, the hub being located at Keyworth. Towards the end of the year internal restructuring led to the transfer of 'Systems and Network Support' and 'Publications' to Information and Knowledge Exchange.



Information and Knowledge Exchange

Information Management

The Information Management programme is responsible for all records, digital data and material collections within the BGS. This includes all digital databases and collections such as paper records, maps, plans, images, archives, rocks, minerals, fossils, and borehole core. The aim is to manage the information in a coherent and integrated manner for the benefit of the citizen, government, industry, academia and environmental science community.

The Core Store at Keyworth, an important repository of the national collections

Multilingual geoscience thesaurus

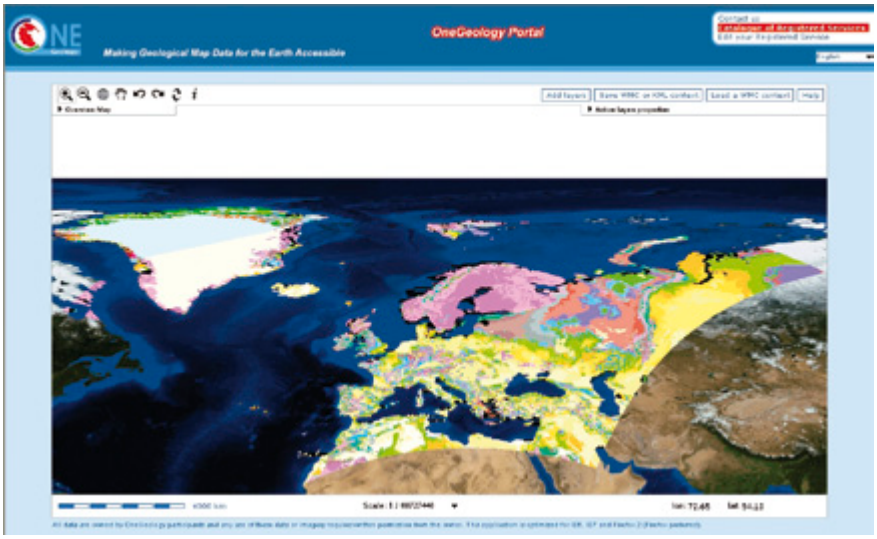
Cutting-edge work in the field of geoscientific informatics and, in particular, on improving discovery, accessibility and interoperability of data is a priority. The Multilingual Thesaurus of Geosciences (MulTG) project is an initiative of the IUGS Commission for Management and Application of Geoscience Information (CGI) in which we work with participants from eight other international institutions to create a multilingual thesaurus of geoscientific terms that will enable global discovery and exchange of information. The first release is planned for 2010 and will include most European languages. It will enable us to make our resources available to non-English speakers, and our scientists to find and utilise resources written in other languages.

In 2008 we launched an online software tool to aid distributed editing of the thesaurus by the working group members. Later releases will add depth to the thesaurus by adding more detailed concepts. Extension to non-European languages is a longer-term aim. The tool will enable interoperability of datasets within the EU and aid compliance with the INSPIRE directive.

A significant amount of geoscientific information consists of coded or textual information such as rock unit names, rock type, or geological age. Richly described vocabularies and ontologies that enable a shared understanding of this semantic content across language boundaries are essential in allowing reuse and interoperability of data. We are working with the CGI's GeoSciML Interoperability Working Group (IWC) to create a standard set of multilingual vocabularies that can provide the content for the GeoSciML geology exchange language. Improving the linkage between the IWC and the MulTG development will be an objective during 2009.

OneGeology

OneGeology has continued to grow in membership, amount of data served, and profile. Its web map portal was the centrepiece of the International Geological Congress in Oslo, a launch which received massive global media coverage — over 750 articles within a month. The web portal received over 29 million visits during the same period. The number of participating nations has reached 106, with 40 of these serving over 100 national map datasets. The governance of OneGeology has also progressed; with a global steering group of geological survey directors now in place, its sustainability is significantly more secure. Within Europe the component EC-supported OneGeology-Europe project had a productive first six months following its launch in Rome in September 2008. All work packages have progressed their development and deliverables. Good progress has been made overall and excellent momentum has been



The OneGeology web map portal.

established. The project has received the very firm support of the European Geological Surveys. Excellent global interest has resulted from this European initiative and the continent is seen as leading the world with respect to integration and presentation of geological data and its contribution to spatial data infrastructures.

Oracle award

Martin Nayembil and Keith Adlam received the Oracle 'Best Public Sector Paper of the Year' award for their paper titled 'Oracle Spatial in the British Geological Survey', presented at the Oracle Spatial Special Interest Group (SIG) seminar in 2008. The event was attended by over 70 industry participants. The presentation highlighted how we are using Oracle spatial technology to store, manage, analyse, interpret, mine and integrate spatial datasets with non-spatial datasets. The presentation also described the BGS's journey in working with GIS and relational databases, example methodologies of spatially enabling datasets and the road map for the immediate and distant future.

Martin Nayembil receiving the Oracle award.

National Geoscience Data Centre accredited as MEDIN Data Centre

The National Geoscience Data Centre (NGDC) has been accredited as a Marine Geoscience Data Archive Centre (DAC) for the UK by the Marine Environmental Data and Information Network (MEDIN). DACs work to agreed best-practice standards to provide secure long-term storage for an expanding range of marine datasets.

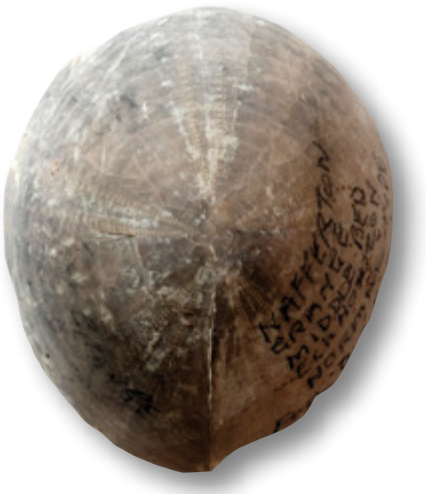
MEDIN is an open partnership and its partners represent government departments, research institutions and private companies. It is funded by a consortium of fifteen sponsoring organisations, including the NERC, and reports directly to the Marine Science Coordination Committee (previously the Inter Agency Committee on Marine Science and Technology). Marine data are expensive to collect and unique in relation to time and geographical location. There are wide benefits to be gained from working together to share and properly manage these data. The network will provide the capability to upload and retrieve data — which will always be available to the data owners.

National Geoscience Data Centre and the public

The NGDC is used on a daily basis by commercial and academic researchers as well as our own staff. The number of universities who use the NGDC to support their teaching is growing. This year Imperial College organised a core workshop as part of Petroleum Geoscience M.Sc. course. Students studied cores from the Triassic Sherwood Sandstone reservoir of the Wytch Farm Field, as the first step in a multidisciplinary project to characterise and model the reservoir. In addition the NGDC takes part in the annual Archives Awareness Campaign. In 2008 the theme was 'Communities, Industry and Earth History — how the past influences our environment'. Over 300 people joined tours following a geological timeline through the Library, Museum, the National Geological Records Centre, and the vast material collections, followed by demonstrations of the 3D visualisation suite and a BGS drilling rig.

Important collections added to the National Geoscience Data Centre

We have recently received a nationally important collection of more than 4000 Cretaceous fossils from the Chalk of Lincolnshire and Yorkshire. The material represents a lifetime of work by the donor, Dr Felix Whitham, who is the author of major publications on Cretaceous geology. A collection of this calibre, with such comprehensive geographical and geological documentation, is an important national scientific resource. It can be used to study the detailed pattern of evolutionary change in fossil groups. On a more practical level, it can also act as a geological 'reference tool' for understanding how different kinds of fossils can be used to characterise particular intervals of rock — valuable for both geological mapping and modelling. The Whitham Collection has been professionally curated by our staff, with geographical and geological metadata now within accessible databases allowing rapid geographical, geological and biological overview of the material.



The fossil sea urchin Echinocorys, *a specimen from the Felix Whitham collection.*

Information and Knowledge Exchange

Information Products

National digital datasets are used in both internal and external geographical information and reporting systems for environmental and ground stability assessments. Geology and soils, natural and mining hazards, flooding and radon information are all available to our wide stakeholder community, including the public, research community and commerce. During 2008 we have updated our geology, flooding and geohazard datasets, and have been working on new datasets that identify areas of past (non-coal) mining activity and where soil chemistry exceeds recommended soil guideline values.

The opencast mine at Parys Mountain, Anglesey

Data capture and best practice

We work with users to identify requirements for data capture that underpin the development of new baseline and derived datasets. Our activities include digitising analogue data for inclusion in our databases, pilot datasets and enhancements to our data holdings in terms of coverage and interpretative detail. Examples include offshore thickness modelling and mineral resource data holdings. An important element of this work is in developing geographical information systems (GIS) and spatial data best-practice methodologies to ensure our national datasets are delivered effectively and efficiently. We are continuing to work on product development, production workflows, quality control and providing information about the level of confidence that can be placed on the data.

During 2008/09 work began on the digital capture and 3D modelling of information held in Coal Board atlases dating from the 1950s. Information captured so far has included geological outcrop and subsurface data in South Wales together with allied coal quality information including coal rank, which is important for resource evaluation studies. We also developed a methodology for creating a national sulphate and chloride layer based on a pilot area. This methodology will be applied nationwide following a validation programme. We also enhanced the Industrial Minerals Assessment Unit (IMAU) database and developed a GIS front end. This has provided access to a previously under-used but valuable resource.

Baseline Products

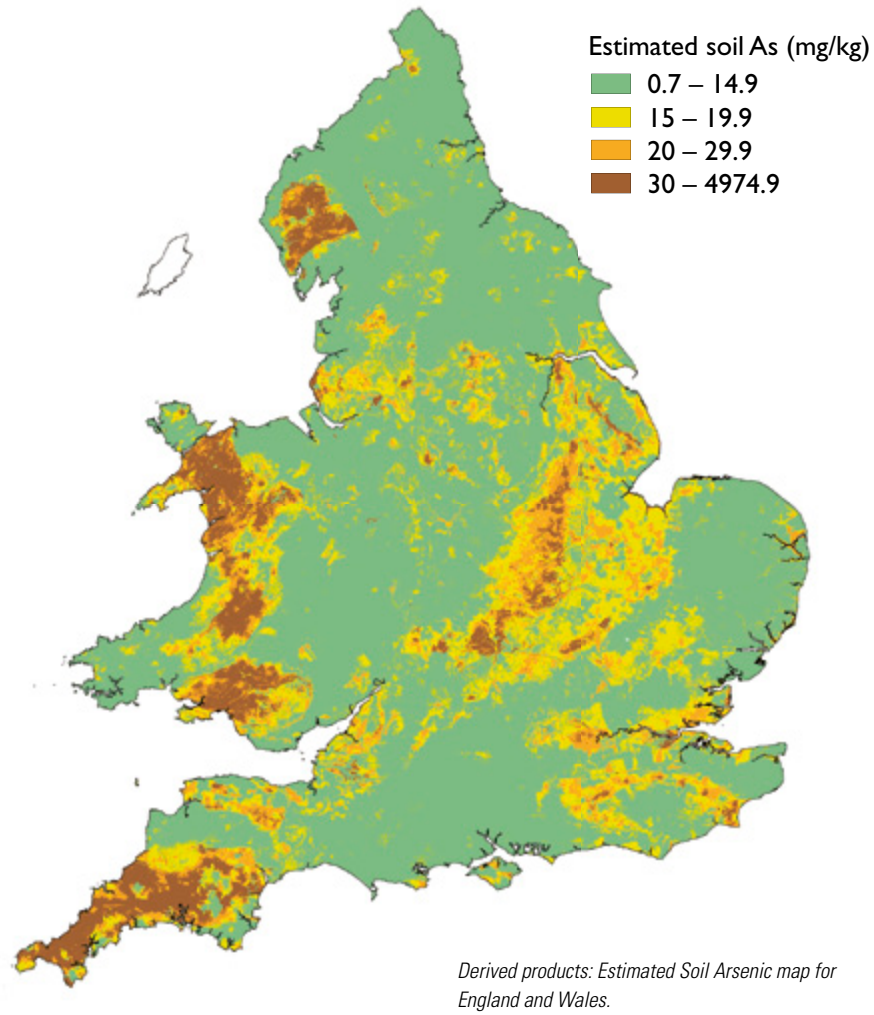
Baseline Products are core datasets that underpin geoscientific research and form the basis of many of our derived data products.

Demolition of houses following subsidence caused by shallow limestone workings in Edinburgh.

There have been significant developments in digital datasets this year, particularly in the geological map of Great Britain, DiGMapGB. The release of DiGMapGB-625 as a free digital download for personal, teaching, academic and non-commercial purposes provides a valuable introduction to digital geology for a spectrum of new users, encouraging wider and innovative use of our national geological information. In addition to the annual release of the latest version of DiGMapGB-50 (version 5), the higher resolution DiGMapGB-10 dataset has been improved with extensive new coverage and now comprises some 1400 map tiles (equivalent to 29 000 square kilometres), predominantly in urban and peri-urban areas.

Other updates include Geological Indicators of Flooding and Superficial Deposits thickness models. Derived from DiGMapGB-50, these products incorporate extensive data and knowledge captured from the growing digital borehole and geological cross-section archives. A new publication this year is the Soil Parent Material dataset

Subsidence-affected building in Ripon, compressible ground in a subsidence feature caused by soluble rocks.



Derived products: Estimated Soil Arsenic map for England and Wales.

(see page 50). Aimed at the expanding environmental research sector, this developing dataset provides insights into how geology influences our soils, landscape and environment and will contribute to research into how our soils form and how we manage their sustainable use. Much effort has been put into improving our offshore geology datasets known as DiGSBS-250 (seabed sediments) and DiGRock-250 (offshore bedrock) to satisfy increasing interest in data for offshore wind farm installations, undersea cabling and pipelines.

Derived Products

Derived Products are national datasets that deliver geological and geo-environmental data, interpretations and knowledge for the shallow subsurface or 'zone of human interaction' within the UK, in a form which is both relevant and accessible. Themes include geochemical hazards (such as radon gas, and potentially harmful elements such as arsenic and lead), natural hazards (including landslides and flooding), underground asset management (pipeline and concrete corrosion), and the impacts upon these of changing climatic conditions.

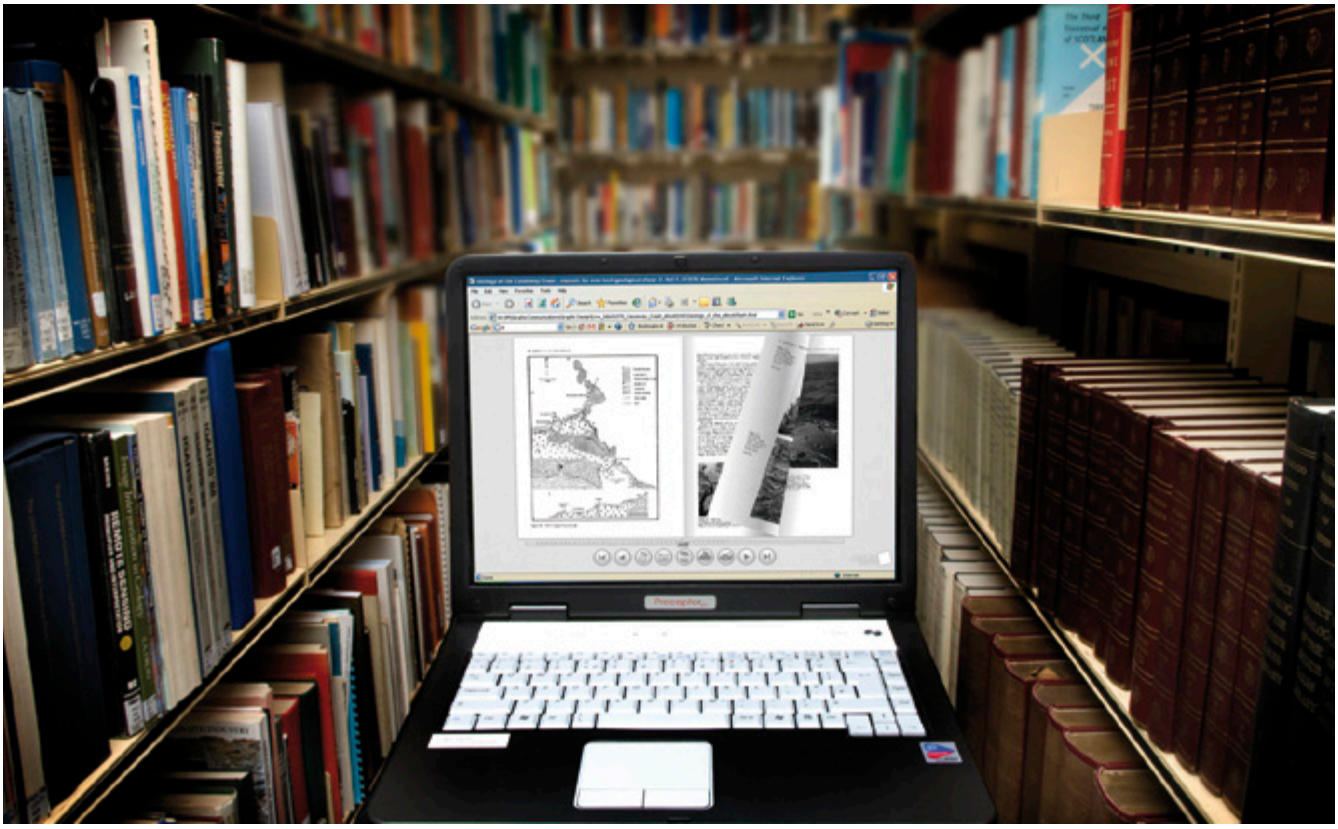
Historically a wide range of minerals has been mined in the UK including metalliferous minerals (mainly cross-cutting veins), and strata-bound resources (including sedimentary iron ores, building materials, evaporate minerals, and clays). A new scheme has been developed that predicts the likelihood of hazards associated with former or current underground mining (not including coal) for any given location in the UK.

The 'BGS Estimated Soil Arsenic' dataset for England and Wales is derived from national, high-resolution geochemical data from the BGS Geochemical Baseline Survey of the Environment (G-BASE) and Imperial College Wolfson surveys, in combination with maps of soil parent material derived from DiGMapGB-50 digital geological data. The team has developed a new methodology for estimating soil arsenic concentrations through combining the various datasets and establishing statistical relationships.

Information and Knowledge Exchange

Information Delivery

Our Information Delivery programme links BGS science and information to the wider community, through a range of information services including the corporate website and online services, licensing of digital data, media and outreach activities, and sales, enquiry and library services.

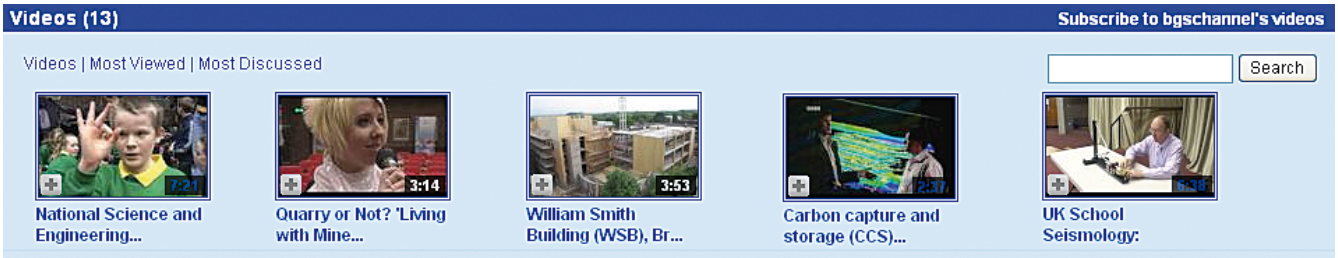


Research Knowledge Services

Research Knowledge Services manages the BGS libraries and online research information services. Planning for the switch from paper to desktop delivery of research information continued with increased training by Research Knowledge Services staff for BGS scientists in new online services. The NERC Open Research Archive Repository (NORA) continued to develop through the year, with BGS entries passing the 1000 mark.

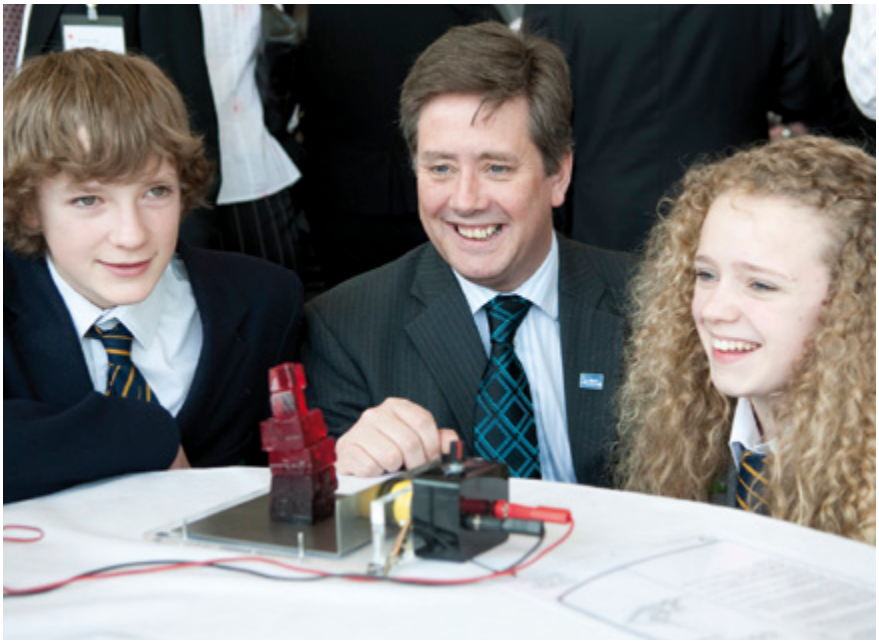
Web Systems

The Web Systems team builds and maintains all of the BGS websites and online services, and also runs the BGS intranet for staff. Following the launch of the new BGS website in May 2008, web hits continued to increase rapidly, with total monthly hits reaching 11 million, three times those of the previous year. Use of new online media for delivery of BGS information increased significantly in the year, including the use



Reaching new audiences for BGS science: the youtube.com/bgschannel was launched in August 2008.

of RSS feeds, online video and eBook technologies. Excellent progress was made on improving BGS web capabilities and infrastructure, including virtualisation of web servers, and on enhancing web-based working practices for BGS staff, including use of wiki and blogging facilities. A major highlight was the release of web services through the website for free delivery of spatial data and vocabularies, in open, interoperable formats enabling easy reuse, for example in mash-ups. This included the release of the 1:625 000 scale digital map of the UK and the BGS Lexicon of Named Rock Units, available free of charge for non-commercial use. A new version of the popular BGS GeoIndex system was also released, providing even easier access to index data on the National Geoscience Data Centre collections.



Communications: the Schools Seismology Project launch in Scotland was attended by Keith Brown, MSP, Minister for Schools & Skills, and pupils from Dundee High School.

Communications

Media interest in BGS science continued at a very high level in the year, with 32 press releases and 2358 online media article citations. The BGS YouTube channel was launched and has received much interest, including over 35 000 hits on the OneGeology project video. The UK Schools Seismology Project went from strength to strength, including its launch in April 2009 in Scotland at Our Dynamic Earth in Edinburgh. Partnerships in the UK, in particular with universities, and overseas continued to increase. Further sponsorship also enhanced the project, including from the Petroleum Exploration Society of Great Britain and the Scottish Oil Club. Another highlight was the nomination for an Outstanding Contribution for the BGS participation in the National Science & Engineering Week. The BGS *Seconds from Catastrophe?* activity was described as being 'inspirational' in the Science Directory for Schools published by the Department for Children, Schools and Families.

Information Services: the Climate through time *poster, a high-profile popular publication, produced in collaboration with the geological surveys of Northern Ireland (GSNI) and Ireland (GSI).*

Information Services

The Information Services team operates four services for providing data, information and advice:

- The Sales Service supplies books, maps and popular publications through online, mail order and retail routes. A highlight in the year was the publication of the *Climate through time* poster.
- The Intellectual Property Rights Service advises staff and external parties on the terms and conditions relating to the use of BGS materials. Five new value-added resellers were signed up in the year and interest from the academic community in use of BGS material grew significantly. Licensing of 3D subsurface models also began in earnest.
- The Enquiry Service helps researchers, business and the public by answering geological interest questions, providing copies of records and producing reports on ground conditions for sites in the UK. Turnover was affected in the year by the downturn in the housing market but, overall, enquiries still exceeded 13 000.
- The Business Solutions Service delivers BGS licensed digital information to businesses, researchers and many other users. A key launch in the year was the new GeoScholar DVD package as a free-of-charge aid for university teaching, including digital maps and other digital information for classic geological areas in the UK.

Wind ripples, western desert, United Arab Emirates

Business Development

Until the end of March 2009, the Business Development Directorate was responsible for corporate marketing, co-ordination of grant applications, supporting the BGS Board and the Senior Leadership Team, maintaining links with clients and stakeholders in the UK and internationally and managing large, multidisciplinary overseas projects. At the end of the financial year 2008/09, the Business Development Directorate merged with the Science Resources Directorate to form the new Resources and Business Directorate.

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, with 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. Several large overseas projects were successfully completed during 2008/09, including those in Madagascar, Ghana, Niger, Mali and Montserrat.

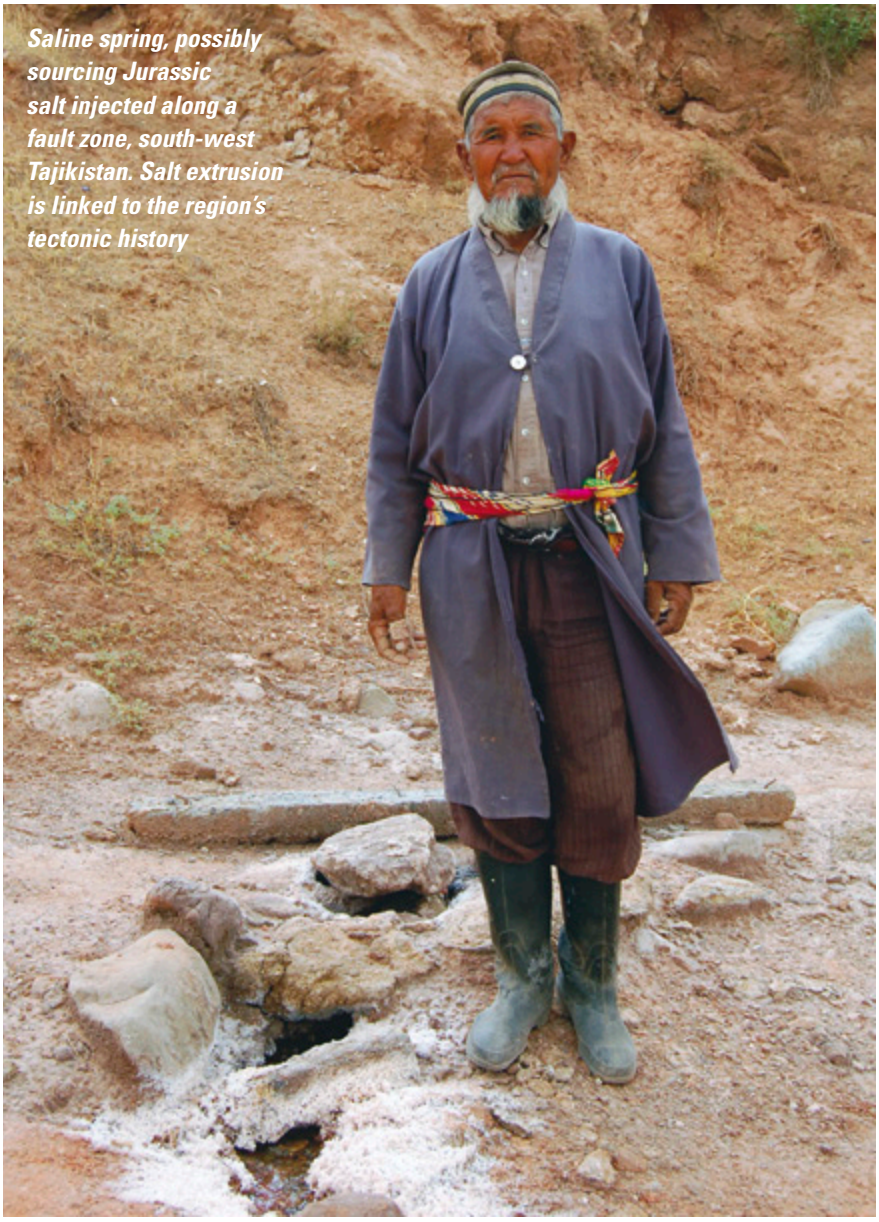
The newly created "Grantsmanship" team is responsible for co-ordinating the Survey's activities in Europe and, in particular, helping to win EU-Framework 7 grants. It also prepared the ground for the BGS to bid into future NERC calls for Research Projects. This involved extensive classification of current 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.

BGS and Ghanaian geologists examine an occurrence of baryte in limestone during field mapping and training, Volta Basin, Ghana.

Business Development

International

This year was one of reduced activity following the completion of projects in Madagascar and Ghana and the delivery of final products to clients. A geothematic project in Papua New Guinea successfully completed the mapping of the eastern half of the project area. Unfortunately an EU-funded project in Niger had to be abandoned because of security problems in the field area. A new project began, training geoscientists at the Nigeria Geological Survey Agency in geochemical exploration techniques *(see page 21);* and in the UAE, continued mapping and geophysical surveys are progressing well. A minerals promotion project funded by the UK Department for International Development (DFID) was undertaken in Malawi and the products presented at the African Mining Indaba in February 2009.



Saline spring, possibly sourcing Jurassic salt injected along a fault zone, south-west Tajikistan. Salt extrusion is linked to the region's tectonic history

Minerals promotion package for Malawi

Malawi has a wide variety of mineral resources, although at present only coal, limestone, gemstones, ornamental stone and construction materials are worked on a significant scale. To this list can now be added uranium, which has just started production at the Kayelekera Mine in the far north of the country. There is significant potential for further deposits of these minerals to be discovered and exploited, along with bauxite, rare earth metals, niobium, tantalum, titanium and monazite sands, gold, platinum group minerals, base metals such as nickel and copper, phosphate, vermiculite, graphite and gypsum. However, much of the available information on known mineral occurrences is out of date in terms of its format (hard-copy analogue rather than digital data) and interpretation. In this form the data are not attractive to mineral exploration and mining companies, who require modern digital data in order to reduce the high costs associated with grass-roots exploration.

As a result of discussions with the Malawi Ministry of Energy and Mines the UK Department for International Development (DFID) commissioned us in October 2008 to produce a series of promotional mineral potential brochures, together with a reinterpreted national geological and mineral occurrence map of Malawi (at a scale of 1:1 million). Existing satellite remote sensing and airborne

geophysical data were also procured, interpreted and organised into a 3D visualisation package for presentation at the February 2009 Mining 'Indaba' in Cape Town, South Africa. The package was launched by the Hon. Ted Kalebe, Minister for Energy and Mines Malawi, and was well received by private sector mining and mineral exploration companies, international funding agencies such as the World Bank, and representatives of other African Geological Surveys and their ministries. All products (including Landsat and magnetic anomaly maps) are available on a CD-ROM from the Geological Survey Department at Zomba — the brochures can also be downloaded from our website.

3D visualisation as an aid to oil and gas exploration, Tajikistan

In 2008 we were commissioned by Tethys Petroleum Limited to produce a 3D interpretation and visualisation model of a part of the Tajik–Afghan Basin in south-west Tajikistan. This basin is an extension of a much larger structure stretching westward into Uzbekistan and Turkmenistan where it has yielded some of the largest gas fields in the world. The Tajik sector of the basin is currently under-explored but has significant potential for gas, gas condensate and oil. The aim of the project was to verify remote sensing interpretations, assess the level of confidence that can be applied to existing geological maps and sections, undertake field reconnaissance, and thus build a 3D digital model of the geological structure of the basin. We created a geological model using Landsat imagery and DTM (digital terrain model) data. ASTER imagery was also acquired, processed and interpreted in order to enhance the geological model. Cross-sections were constructed using borehole and seismic data where available. A field visit was undertaken to test the quality of the remote sensing interpretation and to identify target areas for potential hydrocarbon traps.

An abandoned oil drilling rig in south-west Tajikistan dating from an earlier phase of hydrocarbon exploration during the Soviet regime.

Ripple-like impressions, thought to be microbial mats, from the late Precambrian Bimbila Formation near Yendi, north-east Ghana. Note the segmental impression of an Ediacaran-type animal in the lower right of the picture.

The results of the project were co-presented with Tethys Petroleum in the 3D visualisation theatre at the November 2008 PETEX conference and exhibition in London. The 3D model was created using the GeoVisionary software we developed in conjunction with Virtalis, one of the world's leading virtual reality and advanced visualisation companies. The ability to visualise the geological model of the Tajik Basin in this way means that geologists from Tethys are now able to plan their field campaigns and seismic acquisition programme with much greater rapidity and effectiveness.

Airborne geophysics for mineral exploration in Ghana

In March 2009 we completed an EU-funded project with Fugro Airborne Surveys Limited to combine newly acquired airborne geophysical and satellite image data with enhanced geological mapping for the Volta River and Keta Basins of Ghana, an area comprising 98 000 square kilometres. The project was part of a larger Mining Sector Support Programme whose objective is to sustain the sector's economic performance, alleviate poverty by increasing employment, and mitigate the negative environmental impacts of mining. An important aspect of the project was to provide training in modern geological mapping technology to Ghanaian geologists at the Geological Survey Department.

Particular attention was focused on the potential for locating deposits of gold, uranium, phosphate and diamonds, and mineral prospectivity maps have been produced for each of these commodities using fuzzy logic modelling. Outputs from the project include geological and topographical maps, processed satellite imagery, training manuals, a differential GPS survey, a fully attributed GIS, a series of abstracts and an excursion guide published in the Voltaian Basin Workshop Proceedings (Geological Survey of Denmark, 2008), and a final report. These products are now being used by exploration and mining companies with a view to undertaking more detailed assessment of the region's mineral potential.

Administration and Finance

Finance

During the financial year 2008/09 we received £26.74 million from the NERC to provide for both the funding of our core strategic science programme (CSP) and a contribution to our infrastructure. This accounted for approximately 53% of our non-capital funding.

The NERC also provided capital funding and capitalised repairs including £9.6 million (over the life of the project) towards the construction of the William Smith Building; which will provide new open-plan office accommodation.

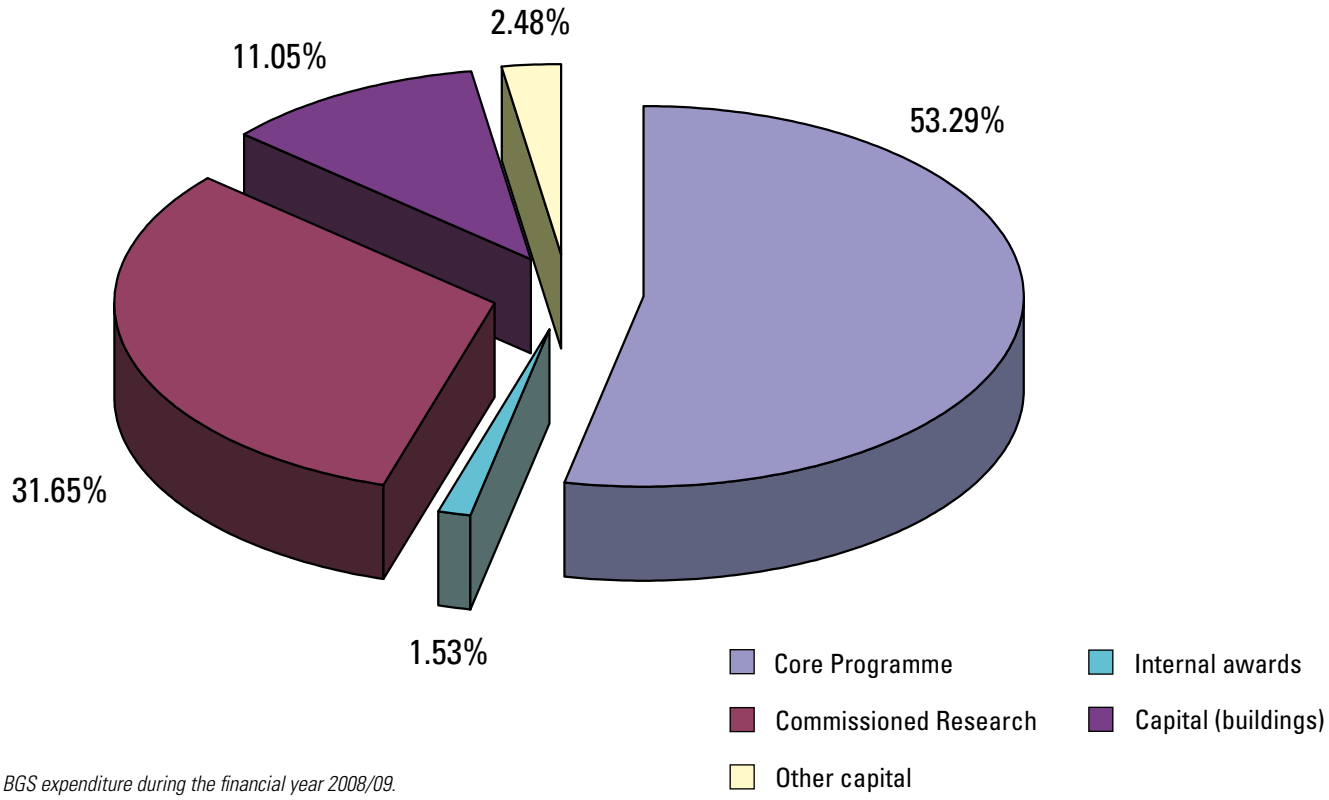
We earn approximately 47% of our non-capital budget from external sources. This is from research commissioned by external partners and customers and from chargeable services, products and data licensing. Externally funded projects accounted for £16.9 million of the £20.9 million external income. These projects enhance the CSP through funding, ideas, data and review as well as making a vital contribution to our infrastructure. In 2008/09 this income included revenue from varied sources including over £1.7 million from the United Arab Emirates project, and other income related to, for example, projects in Madagascar and Nigeria.

The income receivable from Value Added Resellers was lower by nearly £1 million in 2008/09 as it is directly related to the housing market.

Developments

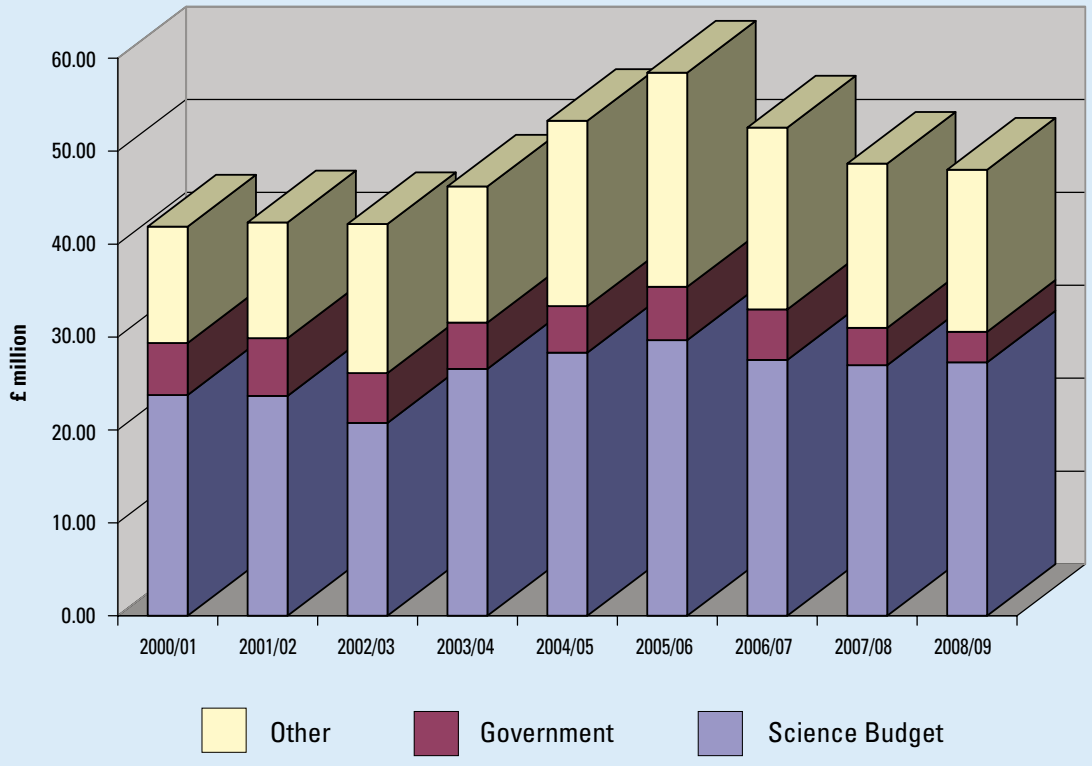
There are significant changes proposed to the NERC funding and commissioning procedures (Funding Allocation and Budgeting, or FAB) from April 2009 and our activities funded through the Science Budget in 2008/09 have been mapped to show the split between the National Capability and Research programmes (86%:14%). FAB will involve increasing use of the Joint Electronic Submissions system within the Research Councils UK more generally, and our finance team has facilitated the use of this throughout the year.

The introduction of a Shared Services Centre, which will undertake many operational finance tasks, has now slipped to 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.



BGS expenditure during the financial year 2008/09.

Summary of income and expenditure 2008/09 (excluding the NERC Isotope Geosciences Laboratory)	**£ million**
Income	
NERC Resource Allocation (Science Budget)	26.738
NERC Capital Allocation	7.673
Other Income	21.264
Total Income	**55.675**
Expenditure	
Salaries	30.762
Capital	7.562
Other Expenditure	17.525
Total Expenditure	**55.849**
Balance	**-0.174**



Sources of income from 2000/01 to 2008/09 (at 2008/09 prices).

Administration and Finance

Estates and Health & Safety

Estates

The major BGS project of the year was the William Smith Building (WSB) at Keyworth. The project was managed by a combination of BGS and NERC staff and consultants; the principal contractor of this Design and Build project is ROKSOL.

The WSB was officially handed over by ROKSOL in March 2009, after which there were two months to complete the fitting out of the building. The furniture will be supplied by Senator, who also provided the furniture for other areas on site which have recently been refurbished and turned into open-plan office accommodation. The WSB can accommodate 200 members of staff and will be occupied from May 2009. The building has met the indicators for the Building Research Establishment Environmental Assessment Method and been awarded its highest rating of 'Excellent'. The sustainable features include a structural timber frame, TermoDeck Heating system and ethylene tetrafluoroethylene atrium window panels.

Phase two of the project works includes all the landscaping around the WSB and the demolition of D block, which are scheduled to be completed early in the new financial year.

The Estates team has also been involved in a number of other projects funded by the NERC backlog maintenance budget. At the Keyworth site, the ground-floor corridor of J Block has been refurbished providing staff with modern office accommodation, which incorporates a number of energy-saving features. The refurbishing of the laboratories in U and K Blocks has also commenced and contracts placed for a number of other projects such as the insulation of K and P Blocks. At Eskdalemuir replacement high-efficiency boilers have been installed to improve the energy efficiency of the site; in addition a project to replace the roofs of the three main buildings has been completed.

A strategic review of the Keyworth site was undertaken during 2008 and the process of planning future development is under way. The first stage of the process, to employ architects and other consultants, will commence early in the 2009/10 financial year. Proposals for the Keyworth site include a new computer room; an extension to the National Geological Records Centre (NGRC); a new purpose-built office accommodation block; and the possible provision of a new conference facility.

Health and Safety

Our health and safety systems are implemented in accordance with NERC policies and guidelines and ensure that the requirements of current legislation and best practice are fully adopted. We have continued to work closely with the NERC health and safety management team and played an active role in the development and review of these policies and guidelines. Our safety support arrangements have been continually reviewed to reflect organisational changes and business needs, in particular, the arrangements for overseas and fieldwork projects.

Staff are encouraged to actively participate in all aspects of the management process; their input has yielded benefits demonstrated by improvements to the equipment and processes within the G-BASE and Dando drill teams and in the clothing and equipment available for overseas and field workers.

We have dedicated Local Safety Advisors (LSAs) at each site who fulfil a key role in assisting staff with local health and safety issues, supporting staff at all levels and monitoring standards and procedures. Wider issues are addressed by the Senior Leadership Team who discuss them with the BGS and NERC Executive Teams.

Team workshops have been held to forge stronger communication links between LSAs, to develop common procedures and implementation strategies, and as a forum for discussion and professional development.

The William Smith Building project started in December 2007 and was opened by Her Royal Highness The Princess Royal on 25 June 2009.

Environmental management

Energy

Energy costs rose sharply in 2008/09. In April gas prices were increased by 38% while electricity prices doubled in October 2008. Although there has been no discernible increase in the amount of electricity used within BGS, Keyworth's monthly electricity bills now average approximately £50 000 and Edinburgh's £13 500. Steps are being taken to reduce these energy costs:

- A Buildings Management System (BMS) is being installed in Keyworth and gas consumption fell by 10.81% in 2008 compared to 2007 as a result of the installation. When fully operational, the BMS is expected to improve energy monitoring and allow more efficient control of energy use in buildings and plant on the site.
- All the gas boilers on the Keyworth site have been fitted with 'optimum start' technology. Optimum start ensures buildings are at a suitable temperature for occupation at the beginning of the working day by starting the plant according to prevailing external conditions.
- Three new condensing gas boilers with low NO_2 emissions are being purchased for installation in M Block boiler house.
- Energy-efficient light fittings purchased out of NERC's 'Green fund' have been installed in the Keyworth Library and will be installed in the NGRC during 2009/10.
- The supplier of the wind turbine on the Keyworth site has agreed to provide a higher tower to improve its performance, which has been disappointing to date.
- A 'green' roof has been installed on the Keyworth's K Block boiler house and a section of the main roof of K block, both of which have been seeded with a wild flower and grass mix. Green-roof systems help to improve the thermal insulation of buildings and can also moderate surface-water run-off by as much as 50%, as well as providing habitat for wildlife.

Travel

Ten new vehicles were purchased for our fleet, including 2 Mitsubishi Outlanders, which emit 183g/km carbon dioxide, the smallest 'carbon footprint' of any vehicles in their class.

To encourage the wider use of video conferencing and reduce travel, more Polycom software licences are being bought to enable individuals to conduct video conference sessions via their PCs.

A 'Bike to Work' scheme was launched across NERC, which entitles staff to a 20–25% discount off the price of new bicycles. Following requests from the Keyworth Bicycle Users' Group, the local Council installed a new cycle lane and traffic lights for cyclists on the A606 at Tollerton.

There are now about two acres of wildflower meadows on the Keyworth site.

Waste management

The majority of Keyworth's waste is recycled rather than land filled: in 2008/09, for example, 16 tonnes of wood, 50 tonnes of paper and cardboard, and 4 tonnes of IT equipment were sent to be recycled. A bid for an electronic composter to treat all the canteen waste from our Keyworth site has been successful.

Biodiversity

The annual survey of the Keyworth grounds uncovered more than 200 bee orchids and spotted orchids, the highest number recorded to date and remarkable in view of the large areas of site affected by building work. Nottinghamshire Wildlife Trust staff carried out a survey of all the 300 trees on the Keyworth site and the results of this and a botanical survey are to be published on our intranet wildlife database.

Our open policy and proactive approach to promoting a positive safety culture is a key contributor to raising our standards and strengthening our market profile. Health and safety makes good business sense and achieving the highest safety standards remains a key business objective for the BGS.

Occupational Health

External Occupational Health providers continue to support our staff on a wide range of health issues and provide expert advice, drop-in sessions, medicals for overseas trips and specialist clinics. Our investment in promoting a healthier lifestyle, through well-being, sports and relaxation sessions, has been welcomed with many staff reaping the benefits of these.

Accidents and Incidents

Staff are reminded periodically of their obligation to report all accidents and, in particular, to report near-miss incidents as a key contributory factor in accident prevention. Accidents, significant near-misses and occupational ill-health incidents are investigated and reported monthly to the Senior Leadership Team and the BGS and NERC Executive Boards. We maintain a focus on the Health and Safety Commission's target of reducing accidents and the number of days lost through ill-health in the workplace, as outlined in their Strategy for Revitalising Health and Safety (HSG65). This is one of the indicators for measuring the success of our Safety Management Systems and a factor of maintaining a robust risk management strategy and safe working practices.

Health and Safety Training

Appropriate training is arranged for all staff to improve their skills base and competency levels and to enable them to carry out their work safely and efficiently, whether in the office or out in the field. The health and safety training modules are currently under review to ensure the content and style of delivery are appropriate and relevant to the delegates. Each Research Centre is responsible for producing a course programme suitable for their needs.

Audit and Review

The BGS will continue to follow our formal H&S audit and inspection schedules in order to monitor progress and focus on areas for improvement.

Administration and Finance

Human Resources

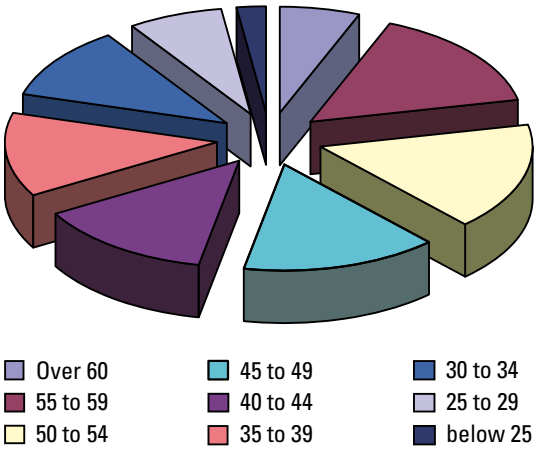
The Survey has been through another year of review and change. Following the decision to merge two existing directorates into the new Resource and Business Directorate and completion of the review of laboratory resources, the area was reorganised to bring the function in line with the Science and Information areas. New positions were created for both Skills Leaders and Facility Leaders and internal recruitment to fill these posts was completed by the end of the year. The Skills Leaders will work closely with HR to deliver the people element of the BGS strategy and will produce an implementation plan to deliver that strategy.

The Research Councils UK Shared Service Centre (SSC) project has continued to have a major impact on morale and staff numbers in the affected areas of HR, finance, operations and procurement. Increased staff turnover has resulted in continued training of new staff appointed on short-term contracts until the roles are transferred to the SSC in Swindon. The delays in implementation have resulted in staff having to spend considerable time working on the design of new systems and processes while maintaining business as usual within the BGS. Following a job-matching exercise, staff have now been appointed to posts in the retained functions. Once the SSC goes live there are a number of staff who will leave the organisation voluntarily but there have unfortunately also been three unavoidable compulsory redundancies — this number is however less than originally expected because of workforce planning over the extended transition period.

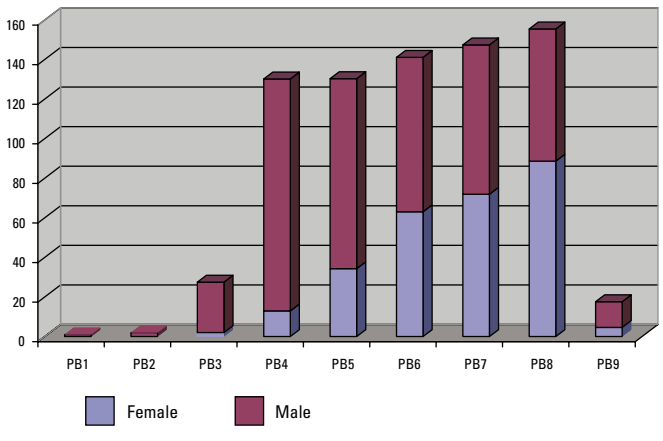
Work has continued on raising awareness of staff stress as part of managing the ongoing organisational changes. Following a presentation by HR, senior staff debated the issue at their annual group meeting. Further awareness sessions have been given to the Team Leaders and one-day awareness training will shortly commence again for all staff. As part of a research project funded by CIPD and the Health and Safety Executive, a number of managers have been appraised by their staff on the impact their behaviour has had on stress levels within their teams. The managers then attended a one-day follow up course to consider any required action plans.

Following the introduction of pension flexibilities in April 2008, a number of staff have applied for partial retirement, thereby reducing the number of their working days. There are benefits to both the Survey and the employee: the organisation is able to retain the skills that it needs while the individual has a phased period leading to full retirement that enables them to avoid the 'cliff edge' that they had faced previously. In the first year, 12 staff had been granted partial retirement with others being discussed. We currently have 8% of staff over the age of 60 and this number will increase as another 15% of our staff will reach 60 within the next five years.

Various factors have resulted in an overall reduction in staff numbers. These include the loss of permanent staff during the SSC transition, the move of staff towards partial retirement and a number of staff reaching age retirement. A number of recruitments were undertaken to fill skills gaps, but this was restricted to immediate business needs. Staff numbers at 31 March for the past four years have declined from 800 in 2006 to 756 in 2009.



Age profile of staff at 31 March 2009.



Staff numbers (full-time equivalents) by pay band and gender at 31 March 2009.

Administration and Finance

Business Support

The new Business Support team commenced operations in 2008/09. The group is responsible for support and guidance relating to operational activities around project management, staff resource allocations and time recording as well as governance relevant to quality assurance, project risk management and business performance.

Governance and quality management

Further progress has been made in ensuring the management systems we employ are both relevant and transparent in their application within the organisation. Review and audit undertaken during the year by the British Standards Institute (BSI) has resulted in ongoing accreditation to the ISO 9001:2000 quality management standard. Continuing UKAS accreditation for our laboratory operations has also been achieved. In addition to our external accreditation a series of internal audits have been carried out to benchmark performance against external and internal standards. A formal link between our internal audit team and our Quality Audit Committee has been established with the objective of ensuring our management systems continue to complement and enhance our science effectively. Procedures relevant to business continuity, incident response and a formal standards policy are all examples of new initiatives undertaken during the past year, demonstrating our continuing commitment to improving and enhancing the governance and management systems we employ.

Project management systems

Our current project management system supports the management of projects from bid stage through elements of project delivery and on to project closure. The principles of the system are vested in PRINCE2 methodology. Ongoing maintenance and new procedures for system control have been introduced to ensure these principles are adhered to. During the past year, analysis and process review ahead of migration to the corporate NERC Resource and Project Management System (RMS) has been completed. The RMS will replace all current systems for resource management, project management and time records and will go live in BGS during August 2009. Previous development work undertaken to improve our in-house project management methodology has been taken forward into the process review relevant to the new system. The RMS will provide increased functionality for risk and opportunity assessment and also early warnings of 'expressions of interest' for tenders. This additional functionality is being considered across the NERC and it is envisaged that these functional improvements will contribute to establishing a common NERC-wide process for project management. One of the primary drivers in moving to a NERC-wide solution for project management is to provide a single interface with the business support functions of the Research Councils UK Shared Services Centre (SSC) and provide functionality across the NERC Research Centres to enhance collaborative working.

The delay in moving to the RCUK Shared Service Centre has delayed the release of those staff required to provide the planned business support function. This position will continue until such time as the Shared Services Initiative is implemented.

Staff have received training on the new Resource and Project Management System (RMS).

A selection of BGS science published externally in 2008*

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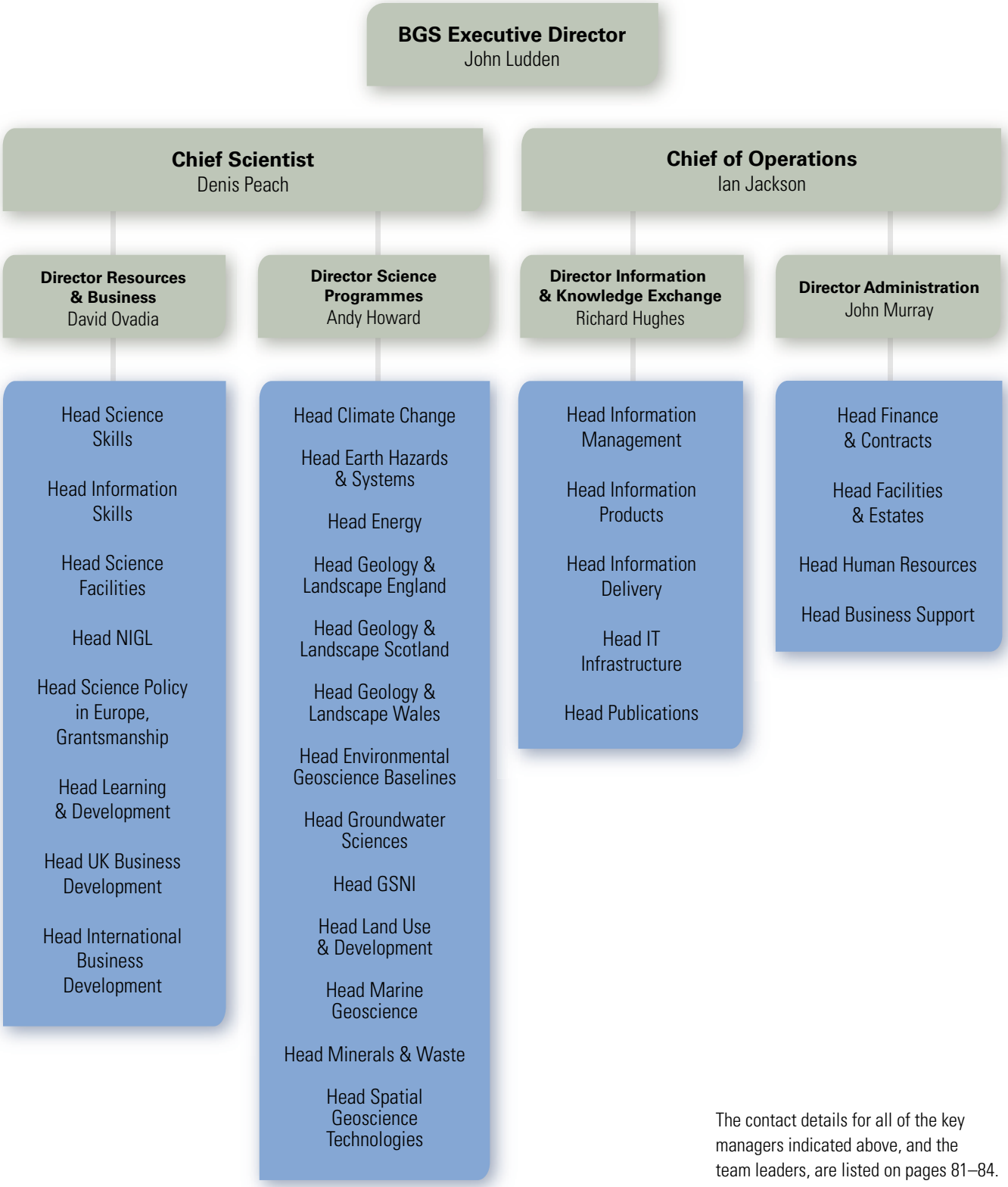
BGS structure from April 2009



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