British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

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2006–07 Annual Report

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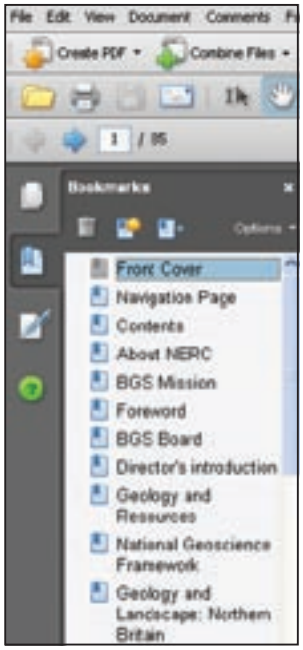

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British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey

Annual Report 2006–07

NATURAL ENVIRONMENT RESEARCH COUNCIL

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Proudman Oceanographic Laboratory
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About NERC

The British Geological Survey is a component body of the Natural Environment Research Council (NERC). The NERC uses a budget of around £375 million a year to fund independent environmental research in the UK. The priorities agreed by the NERC drive the marine, polar, atmospheric, earth, terrestrial and freshwater science communities.

The NERC trains and supports a world-class community of environmental scientists and runs the UK's fleet of research ships and scientific aircraft. It has bases in some of the world's most hostile environments and invests in satellite technology to monitor environmental change on a global scale.

The NERC brings these disciplines together and works with national and international partners towards a common goal: to provide knowledge and solutions to the twenty-first century's most pressing environmental challenges.

Wholly owned research centres

- British Antarctic Survey (BAS)
- British Geological Survey (BGS)
- Centre for Ecology & Hydrology (CEH)
- Proudman Oceanographic Laboratory (POL)

Collaborative centres 2006/07

- Centre for Population Biology
- National Centre for Atmospheric Science
- National Centre for Earth Observation
  - Centre for Observation of Air–Sea Interactions and Fluxes
  - Centre for Polar Observation and Modelling
  - Centre for Terrestrial Carbon Dynamics
  - Centre for the Observation and Modelling of Earthquakes and Tectonics
  - Climate and Land-Surface Systems Interaction Centre
  - Data Assimilation Research Centre
  - Environmental Systems Science Centre
- National Institute of Environmental eScience
- National Oceanography Centre, Southampton
- Plymouth Marine Laboratory
- Scottish Association for Marine Science
- Sea Mammal Research Unit
- Tyndall Centre for Climate Change Research

A large proportion of the NERC budget funds research in universities throughout the UK. The NERC's many facilities and data centres support NERC staff and grant-holders.

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

BGS Mission

The British Geological Survey — geoscience for decision making

The British Geological Survey (BGS), a part of the Natural Environment Research Council (NERC), is the nation's principal supplier of objective, impartial and up-to-date geological expertise and information for decision making for governmental, commercial and individual users. The BGS carries out research in strategically important areas including energy and natural resources, vulnerability to environmental change and hazards, and earth system science, often in collaboration with the national and international scientific academic community. In this way the BGS maintains and develops understanding of earth sciences to improve policy making, enhance national wealth and reduce risk.

This annual report describes research highlights from 1 April 2006 to 31 March 2007. It is available at www.bgs.ac.uk, where you can find information about many other BGS publications, or call 0115 936 3241.

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Mr Derek Davis
Chairman of the BGS Board

Foreword

The financial year 2006/07 has been a year of continuing BGS achievement, ranging from the success of the global OneGeology initiative to ongoing work whose significance is suddenly highlighted by events, like Thames flooding. It has also been a year of stocktaking and preparation for changes in the way BGS science is funded and in the way we earn our income.

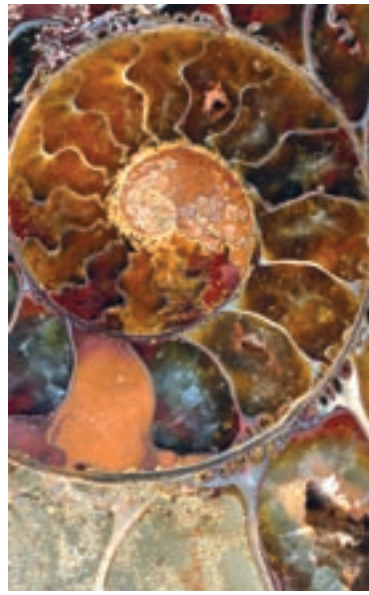
The direction of NERC strategy is underlining the challenge to which I drew attention last year, of combining BGS strengths with those of the research community in support of the best innovative science. This embraces not only the earth sciences but their interface with other disciplines where the BGS is, with its broad involvement in applications, a natural and well informed interlocutor. The new organisation outlined in John Ludden's introduction (*see page 8*), which is now being put in place, is designed to help us address this purposefully over the next period. Both science and the BGS stand to gain.

The survey and business sides of the BGS face at least equal challenge. We are working with Government to establish a more formal mechanism for reviewing and focusing our work for the public good. We are also preparing to build on the already considerable BGS contribution to exploiting geoscience and are developing an appropriate framework for this. Some of the potential lies in or close to traditional BGS areas. There is economic benefit to be tapped too, in partnership with others and through ventures capable of finding and making their own way in the world. Efforts here not only respond to Government calls to maximise economic advantage from the cumulative public investment in science. They will strengthen and enhance the BGS.

The process of change is never easy or comfortable. The new organisational structure has required time and care and BGS staff have shown commendable patience at all stages. The BGS Board has, I believe, also been a source of strength. Particular thanks are due to Professor Roger Scrutton who stands down after two terms but continues to contribute to the Geoscience Modelling and Framework Steering Committee. Professor Stephen Sparks and Professor Denis Peach are welcome new members.

Derek Davis

The BGS Board during 2006–07



The BGS Board was established by the NERC to support the management and strategic direction of the Survey. Board members are appointed by the NERC Chief Executive and approved by Council. Membership comprises the NERC Chief Executive or his nominee, up to ten non-executive members from a broad cross-section of the BGS user community and the BGS Executive Committee.

Board members: non-executive

Mr Derek Davis	(Chairman), formerly of the DTI
Mrs R Johnson-Sabine	Vice President, Maersk Oil UK Ltd
Mr J Smith	Managing Partner, Wardell Armstrong
Professor P Styles	Director of Research Institute for the Environment, Physical Sciences and Applied Mathematics, University of Keele
Professor L Warren	Zoologist and Emeritus Professor of Environmental Law at the University of Wales
Dr S Wilson	Director, Science and Innovation, NERC
Mr P Bide	Office of the Deputy Prime Minister (Observer)

BGS Executive Committee

Professor J Ludden	Executive Director
Mrs K Grant	Director, Administration and Operations Support
Professor M Culshaw	Director, Environment and Hazards
Mr I Jackson	Director, Information
Dr M Lee	Director, Geology and Resources
Mr D Ovadia	Director, Business Development and Strategy
Professor M Petterson	Director, Geoscientific Skills and Facilities

Secretariat

Mrs Rhonda Newsham, BGS

From top:

Professor Martin Culshaw joined the BGS Board during 2006/07.
Professor Denis Peach, BGS Chief Scientist and Stephen Sparks, FRS, Chaning Wills Professor of Geology, University of Bristol joined the Board in June 2007.

John N Ludden, Ph.D.
Executive Director

Director's introduction

The BGS is a highly successful geological survey and is widely considered to be a model for such organisations worldwide. Over the past year the BGS has been reviewing its mission, governance and organisational structure in the light of the new NERC strategy, the government review on research centres' governance (Costigan 2006), the vision of a new director, and the evolving needs of the stakeholders.

The BGS is relatively unique among geological surveys in that it belongs to a research council. As such the BGS must balance both its distinct public good remit as part of the wider NERC mission and the need to align its science to meet the NERC's strategic objectives.

The BGS constantly seeks the optimal fit within the NERC and is mindful of its role in delivering the NERC science strategy while recognising better the essential public-good role of the BGS. The option of moving the BGS fully out as a trading fund is rejected as not being best for either the NERC or the BGS.

Approximately half of the BGS's income (£52.5 million in 2006/7) is provided by the NERC of which about 90% is National Capability (NC) and 10% Research Programmes (RP). NC and RP are defined in simple terms as functions that are primarily focused on national need and scientific infrastructure (NC) and functions that are more cutting-edge scientific research (RP). The new NERC strategy will require the BGS to be more involved in RP and a more appropriate proportion for RP might be about 20% for the BGS to be delivering science as part of the NERC. The BGS needs structural changes, which will allow it to bid into the new NERC RP funding programme. Restructuring and focusing on improvements in the range and quality of our science are required to create a BGS that will have consolidated and enhanced its position as a world-leading geological survey, increased its science outputs and developed its scientific profile.

The way in which the BGS develops strategy will change and three new strategy committees will be created. These are: Science; Information and Knowledge Exchange; Commercialisation, Marketing and Grants.

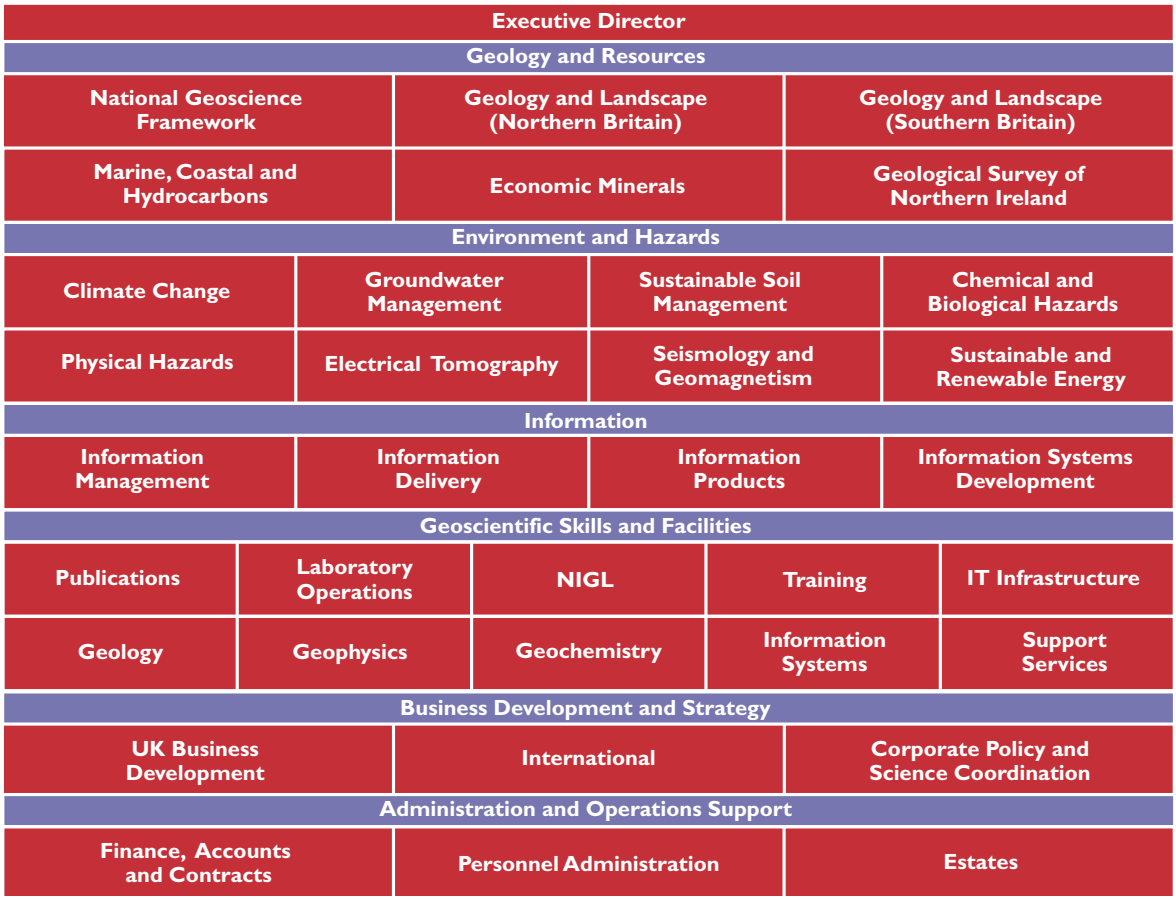
The Executive positions and responsibilities have been modified and a Chief Scientist appointed. The operational structure for delivery of science and information will change and new Heads of Science will be appointed in 2007/08 who will lead new science themes with a more outward-looking focus. Development of science strategy will be directly linked to funding allocation at an increased granularity (60 science and information team areas) that will allow the flexibility required in the future. The Keyworth science campus will be developed as a world-class centre for environmental geosciences.

The BGS has updated its mission statement and developed a new model for internal governance. The BGS work programme has been redefined in the context of the new NERC strategy and implementation of FAB (the NERC funding process designed to implement its new science strategy). The BGS will review and change the way it interacts with central government, especially in relation to the NC element of the mission. With the NERC and the BGS Board, it will be actively reviewing commercial options of all types in the future.

Collaboration with the university sector, other Research Councils and international surveys will broaden and deepen. BGS sites and their science and management will be reviewed and redefined.

The BGS mission is re-defined, as follows:

The British Geological Survey (BGS), a part of the Natural Environment Research Council (NERC), is the nation's principal supplier of objective, impartial and up-to-date geological expertise and information for decision making for



governmental, commercial and individual users. The BGS carries out research in strategically important areas including energy and natural resources, vulnerability to environmental change and hazards, and earth system science, often in collaboration with the national and international scientific academic community. In this way the BGS maintains and develops understanding of earth sciences to improve policy making, enhance national wealth and reduce risk.

'The British Geological Survey — geoscience for decision making'.

As shown by the breadth and quality of science described in this report, the BGS is a strong geological survey producing public-good science results and environmental research that influence the way we live. Such research can only become more important as the planet and people adapt to global change. The BGS within the NERC will have a fundamental role in delivering the science in Next Generation NERC.

Professor John Ludden

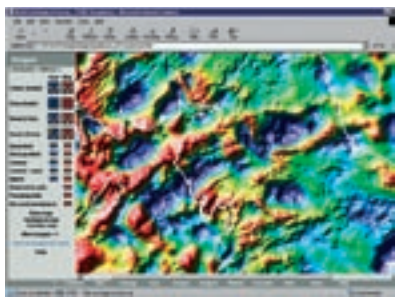
In 2006/07 the BGS's work programme was organised around three Programme Directorates: Geology and Resources; Environment and Hazards; and Information (*above*). These programmes managed and delivered the operational science programmes (coherent packages of related projects).

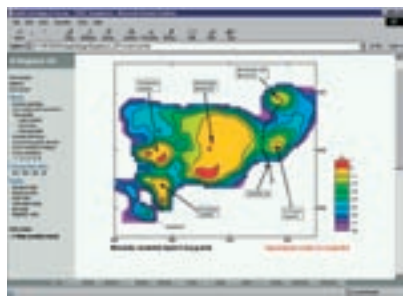
The resources (staff, facilities and infrastructure) necessary for this work programme to be carried out were managed by a fourth Directorate, Geoscientific Skills and Facilities.

Essential cross-directorate support was provided by the Business Development and Strategy Directorate and the Administration and Operations Support Directorate.

Costigan, G. 2006. Research Council institutes, centres, surveys and units: a review of governance issues. London: Department for Business Enterprise and Regulatory Reform, 56p
Ref URN 06/1139
www.berr.gov.uk/files/file27331.pdf

Geology and Resources





Above: geologists examining an outcrop in the North West Highlands of Scotland.

Left: two images from the new Regional Geophysics CD-ROMs (*see opposite*).

The core 'UK national interest' programme is carried out by the Geology and Resources Directorate enhanced by external funding from government departments, agencies and industry. We also have a strong portfolio of collaborative research projects and commissioned contracts worldwide. The programme directly underpins that of the Environment and Hazards Directorate and generates many of the publications and digital products delivered through the Information Directorate.

Geology and Resources

The Geology and Resources Directorate (GRD) operates through six multidisciplinary programmes designed to provide information on the three-dimensional geology, environmental characteristics and natural resources of the UK landmass and continental shelf. The objective is to provide a sound geoscientific 'evidence-base' to underpin decisions on the use and protection of the land, coast and seabed, and the sustainable development of the nation's energy and mineral resources.

Above: two interactive CD-ROMs have been published in the new 'Regional Geophysics' series. One covers southern Scotland and northern England, the other south-east England. They can be viewed using a standard web browser. Each provides a comprehensive account of the regional gravity and magnetic data with interactive links to detailed interpretations and discussion of individual structures and anomalies.

During the past year the implementation of digital field mapping methodologies and the delivery of '3D geology' have both gathered pace. The digital mapping system was used successfully on several projects during the 2006 field season and further development was undertaken during the winter in preparation for roll-out to the majority of teams in 2007. The system, based on a ruggedised tablet PC with full GIS capability, is beginning to attract substantial interest from universities and others outside the BGS. Development of an enhanced 3D bedrock modelling capability commenced in December 2006 (in collaboration with an external supplier) and 3D modelling and visualisation techniques are being used on an increasingly wide range of projects.

A major highlight was the completion, on time and on budget, of the Tellus geochemical and airborne geophysical surveys of Northern Ireland. Both surveys have produced spectacular data that will be used to underpin sustainable management of the environment, responsible exploitation of resources and geo-environmental research for many years to come. The Tellus airborne survey was part of a very successful year for the BGS-GTK Joint Airborne-geoscience Capability (JAC) that also included surveys in the Republic of Ireland, Finland, Sweden and the first part of a national survey of Kosovo.

The minerals sector was boosted by the launch of 'MineralsUK: Centre for Sustainable Mineral Development'. The new Centre has consolidated the BGS's position as a key advisor on the development of a national regulatory framework for minerals and is already helping to promote research in mineral planning and geo-materials conservation. A new CD-ROM (Explore Quarry Restoration) incorporating a 'time machine' function was also successfully launched to promote awareness of quarrying issues.

Spectacular images of the seabed off northern Scotland have provided new information on the extent and evolution of the British ice sheets. Multibeam and video data on the Atlantic margin have also provided new insights into the geology and ecosystems of the area. Activity remained strong in the hydrocarbons sector with projects on the UK Atlantic Margin and the Southern Permian Basin (in collaboration with industry and European geological survey organisations) and well as the long-standing contracts with DTI and the Falklands Islands Government.

Public awareness of geology has been raised significantly by publication of Harvey's British Mountain Maps of the Lake District, Snowdonia and the Peak District that include geological images from the BGS on the reverse side. A popular book on Hadrian's Wall (Ancient Frontiers) and a major UNESCO Geoparks conference in Belfast, with over 340 delegates from 40 countries, have also helped to raise the profile of geology.

UK stratigraphy: newly published research reports include one decribing the Triassic Mercia Mudstone Group of England and Wales, seen here at the classic exposure of St Audrie's Bay, Somerset.

Geology and Resources

National Geoscience Framework

This programme delivers integrated, regional-scale knowledge about the 3D geology and geophysics of the onshore UK, and co-ordinates the population of the national 3D geoscientific evidence base across our other programmes. The applications range from investigation of environmental resources, constraints and hazards in the shallow subsurface to strategic management of energy resources, groundwater and wastes at greater depths. The programme also develops new methods and best practices to keep us up to date with leading-edge technologies for geoscientific surveying and modelling, and manages the scientific standards that assure the quality of scientific output across the BGS.

Taking stock of UK stratigraphy

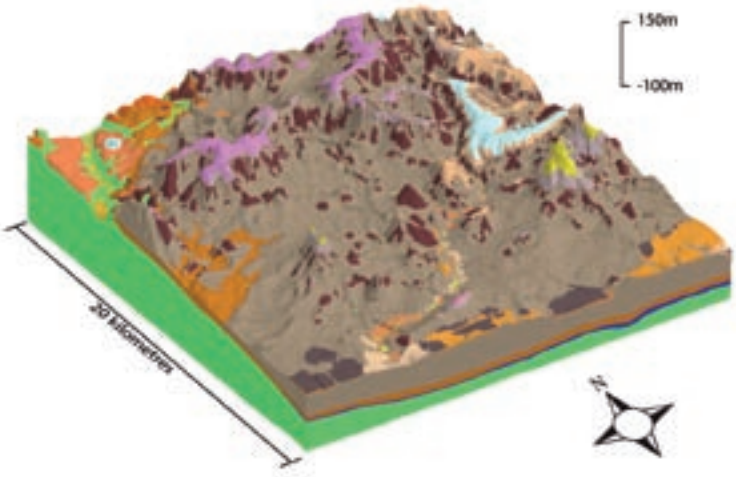
Understanding stratigraphy — the age and order of succession of rock formations — is essential for building 'LithoFrames', three-dimensional (3D) geological models of the subsurface. It is also a fundamental starting point for understanding and correlating key events and environmental changes in 'deep' geological time. We have completed, in collaboration with the Stratigraphy Commission of the Geological Society of London, a major stock-take of the current state of knowledge of the UK's stratigraphy, to be published as two wall-charts covering UK North and South and including offshore areas. Each chart will show, region by region, the name and age of all rock formations mapped in the UK, together with information on the geological environment in which each was formed. The charts will initially be released in printed form but a second phase of the project will develop the charts in online format for our website, where they will form a dynamic key and interface to our other digital products and information such as LithoFrames, DiGMapGB and the Lexicon of Named Rock Units.

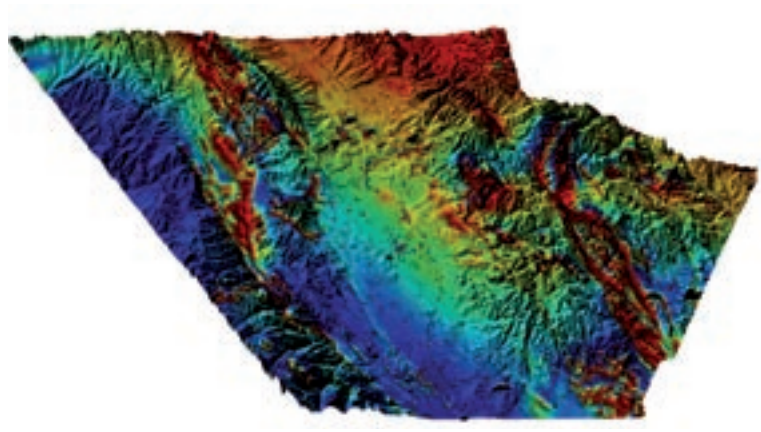
Airborne environmental surveys

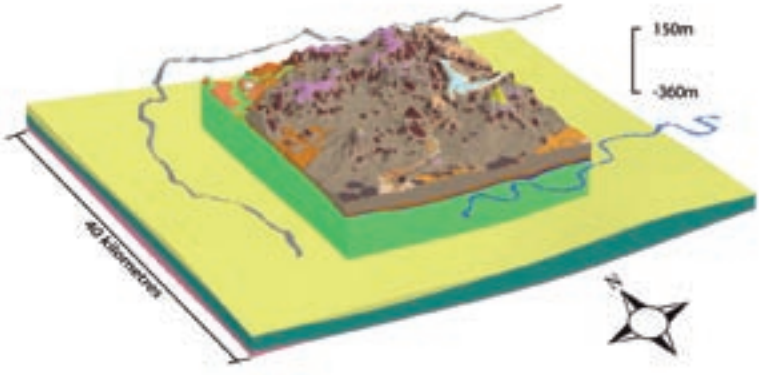
Airborne geophysical surveys were carried out in several countries by the Joint Airborne-geoscience Capability (JAC), using the specially equipped BGS de Havilland Twin Otter aircraft, and involving our partners at the Geological Survey of Finland. The new four-frequency electromagnetic system developed specifically for JAC saw its first operational use in 2006. This system, together with the magnetic and radiometric spectral survey equipment, provides a unique capability on a fixed-wing aircraft. Survey projects were conducted in Northern Ireland (Tellus), the Republic of Ireland, Sweden, Finland and Kosovo. Trial surveys of three test areas in the Republic of Ireland were commissioned by the Geological Survey of Ireland (GSI). The data are being evaluated by GSI for application to groundwater protection, environmental radon countermeasures and for base-metal mine rehabilitation. In Kosovo, we completed the first phase of a two-year programme to provide national-scale, high-resolution geophysical maps of the country for the client, the Independent Commission for Mines and Minerals in Pristina. The surveys were logistically complex, involving collaboration with the NATO Kosovo Force, and the JAC operated at the limits of fixed-wing low-altitude survey capability in mountainous terrain. The survey continues in 2007 and the results will be used initially to attract inward investment in the minerals sector.

London underground

Multidisciplinary 3D surveys are building a new picture of the subsurface geology and environment







Airborne environmental surveys (*above*): magnetic data obtained in 2006 across the central part of Kosovo draped on a digital terrain model also obtained by the airborne survey. The main NNW–SSE trending structures, reflected in the magnetic variations, follow the trend of the Carpatho-Balkans arc and the main Vardar Fault zone in the east of the country. Image courtesy of ICMM

London underground (*left*): multi-resolution 3D LithoFrame model of north-west London. The stratigraphical and structural interpretation is consistent to formation level throughout the model; additional detail is added at shallow depths, reflecting the greater density and reliability of data. (M25 road shown to north-west and River Thames to south-east).

of the London region, to support major development initiatives and growing requirements for new or upgraded subsurface infrastructure. The project pulls together contributions from several BGS programmes to develop a multi-resolution 3D 'LithoFrame' model that is consistent with a range of subsurface information, including deep boreholes, seismic surveys and site investigation data. The model will enhance our knowledge of the structural and stratigraphical evolution of the region, and in 2007 will be extended to the Kent and English Channel areas to understand the geological structural controls on the Folkestone earthquake of 28 April 2007. The multiple resolutions of the model will serve a range of applications including development planning, environmental protection and regional water resource management, and will be a key tool to model the impacts of sea-level rise associated with global warming and ground subsidence in the region.

3D bedrock modelling software

Implementation of the 3D National Geoscience Framework requires effective but easy-to-use modelling software that can be deployed to every geologist in the Survey, enabling them to construct 3D models as an integral part of a geological survey project. Whereas software and methods are readily available for rapid production of models in shallow and simple geology, the additional structural complexities in the bedrock environment currently require more specialised and expensive software. This development project is extending the simple and intuitive capabilities of the existing GSI3D software to build models in all types of bedrock terrain. The prototype is being used in geological environments with differing geological complexity, including London, Plynlimon (mid Wales), Lichfield, the Vale of York, Glasgow and Assynt. Regular feedback from these test areas, combined with an agile programming approach will ensure the software and methodology are fit for purpose. A simplified version of GSI3D, called the LithoFrame Viewer, will be developed for delivery of geological models to customers.

Streamlining digital surveying

Our in-house digital mapping workflow system, developed in partnership with the BGS Information Systems Development programme is being used in over ten active mapping projects both in the UK and overseas. Rugged Tablet PCs (purchased with the aid of the Research Councils Infrastructure Fund) with inbuilt Global Positioning Systems are being used in place of paper maps and notebooks to record the full range of geoscientific data. Geologists use a stylus to enter data via a BGS bespoke interface that has been designed specifically for geoscientific requirements. Complex programming, data models and dictionaries lie behind the system, but users are presented with a simple interface that promotes efficient and structured mapping. Additional benefits over conventional paper-based mapping include the ability to view a broad range of prior information in the field, including historical geological maps, terrain models and aerial photography. It also allows the user to predict outcrop positions from structural measurements.

Ice sheet reconstruction: sampling glacial erratic boulders in the Scottish Highlands for cosmogenic-isotope analysis.

Geology and Resources

Geology and Landscape: Northern Britain

This programme is responsible for providing strategic geological and rock-mass information for northern England and Scotland. These data are used to inform decision making and cost-effective development by land-use planners, mineral developers and organisations involved in conservation, the environment and education. Surveys were progressed in the Glen Oykel, Crianlarich, Killin, Aviemore, Montrose, Loch Doon, Ettrick, Hexham and Kirkby Lonsdale districts. Several maps and books were published, along with a large number of peer-reviewed papers. Collaborative research has been increased, and five studentships are attached to the strategic mapping programme.

Our National Parks — BGS input

We continued to collaborate with and support a number of UK National Parks, focusing on planning issues and geodiversity. The Northumberland National Park contains significant geological diversity including features of both regional and national importance. The BGS and the Northumberland National Park Authority have recently completed a project, funded from the Aggregates Levy Sustainability Fund via the Minerals Industry Research Organisation, to deliver a comprehensive Geodiversity Audit and Action Plan for the Park — the first of its kind for a National Park in Britain. The Geodiversity Audit emphasises the links between the underlying geology and the landscape, ecology, archaeology, economic and cultural history of the region. Notably, Northumberland produces high quality building stone, which imparts a distinctive character to the local built environment. The Action Plan highlights the enormous potential of geodiversity for conservation, education and enhanced enjoyment of the National Park. It also identifies measures, such as the possible reopening of 'craft quarries' to provide locally distinctive stone for building projects, that can contribute directly to the employment and economy of the park, while maintaining its special qualities.

GSI3D — building models that matter

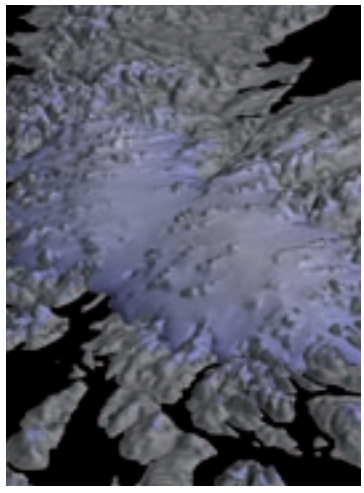
GSI3D modelling software is being used in several areas of northern Britain to produce three-dimensional (3D) geological models of the shallow subsurface. The digital models include artificial ground, natural superficial deposits and simple bedrock geology, and address various geo-information needs, as described below.

City of Glasgow

The Scottish Executive has identified the Clyde Corridor as Scotland's regeneration priority. The area is beset by problems arising from its industrial past, such as ground pollution, water pollution and mining-related subsidence. The BGS, in partnership with Glasgow City Council and other organisations, is assisting the planning and redevelopment process by providing reliable and up-to-date 3D shallow subsurface models. The models are the end-products of a complex process of borehole and other data capture, integration and interpretation. A trial 3D geological model of part of Glasgow, including superficial deposits and key coal seams, has already been supplied in the LithoFrame Viewer to Glasgow City Council. Importantly, the viewer has the capability of being able to generate synthetic boreholes and cross-sections within the model. Refinement and substantial expansion of the model are planned.

Limestone aquifers of north-east England

In implementing the EU Water Framework Directive, there is increasing recognition by both water companies and the regulator that 3D geological models have an important role in determining the geological setting of



Clockwise from left:

Ice sheet: computer modelling of the last ice caps in Scotland.

National Parks: Whittingham village, just outside the Northumberland National Park.

Montrose volcanic rocks: intimate intercalation of basaltic rock and fine sandstone, with geopetal and domed laminae (*inset*).

the aquifer and understanding surface–groundwater interactions. Our work in north-east England is helping the Environment Agency to develop a conceptual model, and improved understanding, of the hydrogeology of the regionally important Magnesian Limestone aquifer. Geological fence diagrams, derived from intersecting GSI3D geological cross-sections, have been combined with borehole data and processed in ArcGIS® to generate hydrogeological domain maps. These will enable improved management of the groundwater resource in this heavily industrial and densely populated area.

Ice sheet reconstruction

The new British Ice Sheet project is using a multi-faceted approach to investigate the extent and dynamics of the last ice sheet in Scotland, and the associated sea-level and climate changes. Exciting new datasets and state-of-the-art computer modelling have led to a major reinterpretation of the maximum extent and demise of the last British Ice Sheet. Extensive echo-sounder data from the continental shelf around the northern United Kingdom have revealed striking geomorphic evidence, in the form of tunnel valleys and moraines, relating to the former British and Fennoscandian ice sheets. The pattern of seabed landforms suggests that, at its maximum extent, a large coalescent ice sheet flowed from south-east to north-west across the northern North Sea, terminating at the continental shelf edge. A high-resolution coupled climate–ice-sheet model, developed in collaboration with Edinburgh and Aberystwyth universities, is furthering understanding of the dynamics of this ice sheet on a range of temporal and spatial scales. Field mapping across Scotland has provided essential baseline data for glaciological reconstruction and has identified sites for further investigation. In close collaboration with the universities of Glasgow and Edinburgh, cosmogenic dating methods (that measure the action of cosmic rays on exposed rock surfaces) have been employed in key areas to determine when the glaciers retreated and formed the landscape we see today. Field data and chronological information from the western Highlands illustrate details of the way that glaciers readvanced during the Younger Dryas, the most recent episode of rapid climate change. These models enable inferences to be made concerning the nature of the climate during this period.

Montrose volcanic rocks

Rigorous digital mapping and GSI3D modelling of bedrock and superficial deposits in the Midland Valley of Scotland are providing a new framework for scientific understanding and interpretation of detailed field observations. Digital mapping and modelling of cross-cutting relationships within basaltic rocks on the Angus coast, originally interpreted as lavas, presented contradictory evidence of both extrusive and intrusive origin. A follow-up field workshop, which brought together a diverse group of experts to examine the textures within these igneous rocks, demonstrated that the succession includes intercalations of both lavas and contemporaneous near-surface intrusions. This has led to a new appreciation of the timing and nature of ancient volcanism in the region and a revised stratigraphical classification of the succession.

Mendips: the 'De la Beche unconformity' at Vallis Vale, near Frome, Somerset. Here the horizontal pale yellow Inferior Oolite of Mid Jurassic age rests unconformably on the steeply dipping grey Carboniferous Limestone at the eastern end of the Mendips.

Geology and Resources

Geology and Landscape: Southern Britain

This programme provides the geological framework for Southern Britain and underpins research and development in other BGS programmes. Its work covers the interaction of physical landscape, geology and people in terms of geo-diversity and geoheritage. It maintains detailed knowledge and understanding of the geology of Southern Britain, enabling comprehensive and authoritative geological advice to be provided to stakeholders. During the year, surveys were completed in the Glossop, Chesterfield, Aylsham, Coalville, Llanidloes, Swansea, Bath, Andover, Tiverton and Newquay districts. Development of three-dimensional LithoFrame models was undertaken in Nottinghamshire and South Yorkshire, north of Birmingham around Lichfield, and in the London area.

Thames Through Time

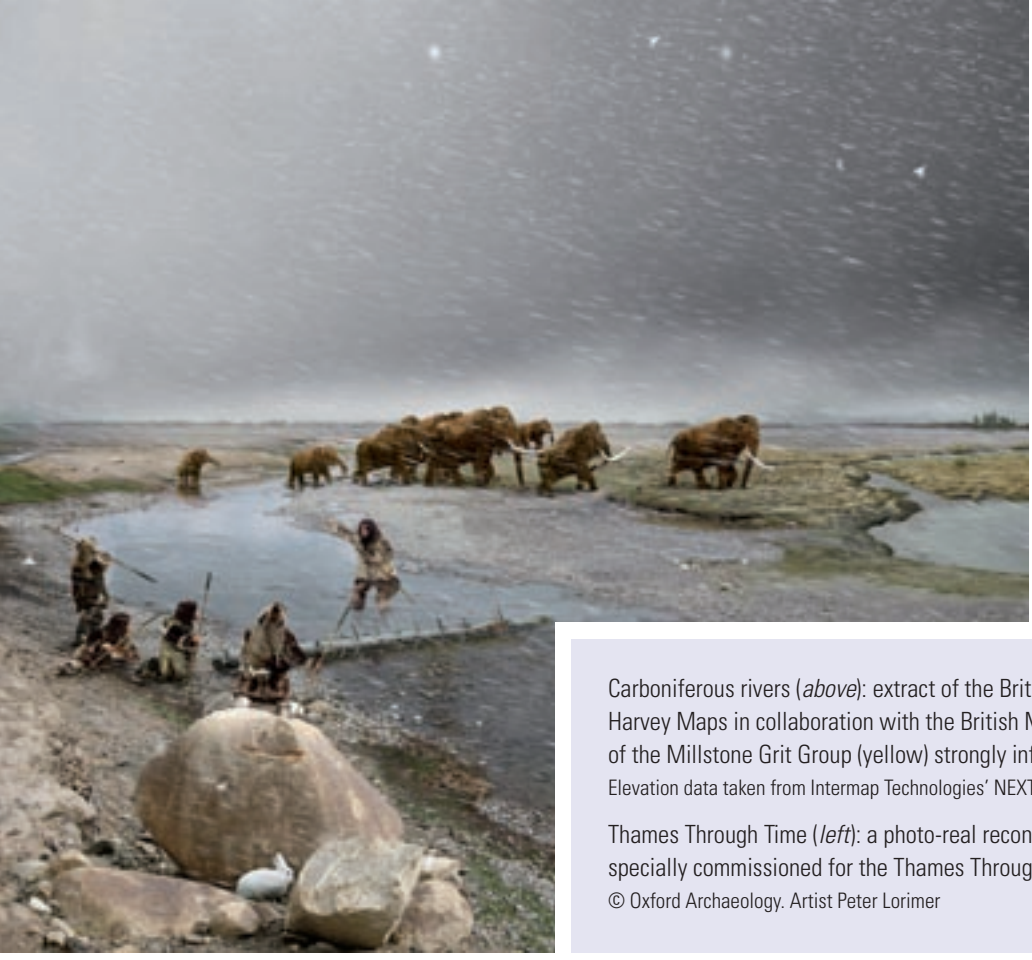
The river terrace deposits of the Upper and Middle Thames preserve one of the richest archives of Palaeolithic artefacts and Pleistocene fossils anywhere in the UK. The Thames terrace sequence is also one of the best known in Europe as recent advances in mapping and the application of biostratigraphy have provided a detailed record of environmental change throughout the various glacial and interglacials of the Middle and Late Pleistocene. Oxford Archaeology has been commissioned by English Heritage to produce an innovative three-volume account of the archaeology of the river terraces of the Thames from earliest times — some two million years ago — to the late Saxon Period: the 'Thames Through Time' project. The work has been supported by a grant under the Aggregates Levy Sustainability Fund. We have been collaborating with Oxford Archaeology and colleagues from Royal Holloway University of London and Durham University to write the first of these volumes covering the formation and changing environment of the Thames Valley and early human occupation. There have been other histories of the river but this is the first that integrates geology, palaeontology and archaeology to recreate the human interaction with the river against a background of rapidly changing environments and climate.

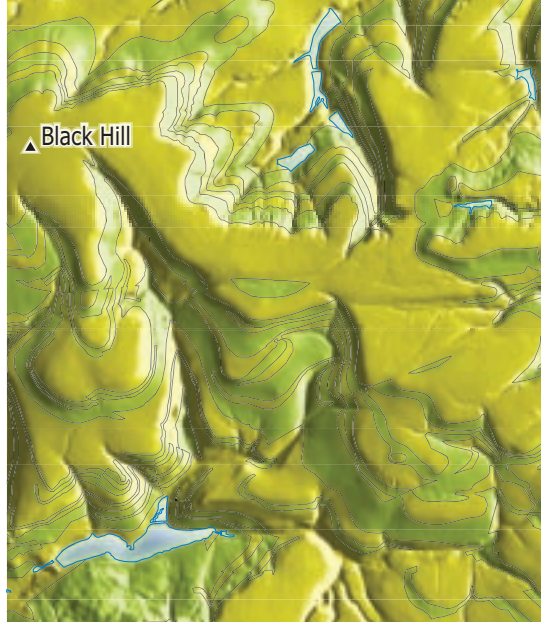
Sustainable communities: planning for the future

We have collaborated with the National Stone Centre and C G Down Planning Consultants in a three-year study, assessing aggregate supply and demand in the Milton Keynes and South Midlands Growth Zone. Adequate supply of aggregate is vital for development, but resources are finite and irregularly distributed. The study not only considered the geology of the area and the location of resources, focusing on sand and gravel, but also past and present patterns of aggregate supply and demand, environmental factors, transport links and planning issues. The study utilised a geographical information system to analyse the data and identify resources requiring further investigation, leading to a targeted drilling programme in summer 2006. The project was funded by the Aggregates Levy Sustainability Fund through the Minerals Industry Research Organisation and completed in April 2007. A detailed Technical Report and Executive Summary have been produced, which provide information on the study's findings and recommendations.

Lower Palaeozoic climate change

Macrofossils and microfossils collected by our mapping programme in central Wales, and analysed with collaborators at Durham, Leicester and Ghent universities, have shed new light on ancient climate





Carboniferous rivers (*above*): extract of the British Mountain Map of the Dark Peak, published by Harvey Maps in collaboration with the British Mountaineering Council, showing how the sandstones of the Millstone Grit Group (yellow) strongly influence the topography.
Elevation data taken from Intermap Technologies' NEXTMap Britain data

Thames Through Time (*left*): a photo-real reconstruction of an ice age landscape which has been specially commissioned for the Thames Through Time book.
© Oxford Archaeology. Artist Peter Lorimer

change and oceanography in the Welsh Basin towards the end of the Ordovician. Biostratigraphical correlation of assemblages of chitinozoa — an extinct class of marine micro-organisms — has shown that changes in climate and oceanic thermohaline circulation associated with the late Ordovician glaciation affected the Basin earlier than previously thought. Analysis of subtle changes in the skeletal morphology of the graptolite *Persculptcograptus persculptus* has allowed early and late evolutionary forms of this species to be distinguished. This has led to more precise biostratigraphical correlation of events at the end of the late Ordovician glaciation, enabling two episodes of sea level rise to be recognised in the rock record, rather than a single event. The first caused widespread drowning of adjacent shelf areas, but it was the second episode, associated with changes in oceanic circulation patterns, which led to reventilation of the basin and its recolonisation by open marine organisms.

Exploring the landscape of the Mendips

We have worked with the Mendip Hills AONB Service, the National Stone Centre and the Mendip Society to produce two new 1:25 000 scale geological maps with accompanying guidebooks for the Mendip Hills, funded by the Aggregates Levy Sustainability Fund and Somerset County Council. The Mendips are one of the most geologically varied regions of the country with a wealth of important geological sites. In addition, a wide variety of landscapes and wildlife habitats are condensed into this small area. This makes the Mendips an excellant place to raise public awareness of geological heritage, and how that heritage influences biodiversity, landscape and the built environment. The role of the aggregates industry in the community and the benefits it has had in increasing the geodiversity of the area is also demonstrated. The maps and guidebooks have been designed for use in the field. The website complements and expands on the information contained in the guidebooks, and hosts two interactive 3D models, giving the user the ability to 'fly-over' the area and link to relevant pages.

Carboniferous rivers of the southern Pennines and Peak District

Mapping in the Glossop district has clarified the impact of ancient climate change during the late Carboniferous, some 315 million years ago. At this time, fluctuations in the volume of Earth's polar ice caps led to sea-level changes, analogous to more recent events in the Pleistocene. Sea level highstands during interglacial warm periods are marked by widespread 'marine bands' of dark fossiliferous mudstones, whereas colder glacial periods led to falls in sea level and spectacular downcutting of river channels to produce deeply incised valleys. The thick beds of coarse sandstone deposited in these ancient valleys, such as the Chatsworth Grit and Rough Rock, now form the spectacular 'Millstone Grit' escarpments of the southern Pennines. The latest BGS mapping has been incorporated on the recently published British Mountain Map of the Dark Peak, published by Harvey in co-operation with the British Mountaineering Council, and aimed at providing walkers and climbers with an understanding of the ancient origins of the Peak District landscape.

Marine operations: the new BGS 15-metre rockdrill being deployed in the Atlantic Ocean.

Geology and Resources

Marine, Coastal and Hydrocarbons

The programme undertakes the strategic geological survey of the UK continental shelf, with projects studying the coastal zone, shelf and slope areas, and the subsurface. The work contributes to our understanding of the marine environment, including the impacts of climate change, Quaternary processes, marine geohazards, the potential for marine renewable energy, marine aggregate resources and the subsurface potential for hydrocarbons. The outputs include the data needed to underpin strategic environment assessments and to meet the requirements of the Habitats Directive.

Extensive collaboration throughout the year allowed us to contribute to many survey operations and programmes funded by a range of institutes. Research focused on seabed geology and habitats with completion of the Bristol Channel habitat study and major contributions to MESH (Mapping European Seabed Habitats, funded through the INTERREG programme). Collaboration with the oil industry continues to support basin research on the Atlantic Margin and in the Southern Permian Basin.

Marine geology

A major analysis of the seabed environment in the Outer Bristol Channel was completed through co-operative research with the National Museum of Wales with funding through the Aggregates Levy Sustainability Fund. Multibeam echosounder, side-scan sonar, seismic data, video surveys and seabed samples were integrated to produce new geological and habitat data. An educational CD-ROM, *Exploring the Sea Floor*, and a touring exhibition were also produced. The work is now being extended into the Inner Bristol Channel with collaboration from the DTI Strategic Environment Assessment programme.

Quaternary geological research has focused on the Summer Isles area with further collaboration with the onshore survey and with SAMS (Scottish Association for Marine Sciences). Collaboration with Imperial College (through a jointly supervised Ph.D. student) has provided unambiguous proof that the British and Scandinavian ice sheets were confluent in the North Sea during the Last Maximum Glaciation in Europe. Work is in progress assessing new evidence provided by bathymetric data acquired by fishing vessels (Olex data) on the decay of the British Ice Sheet at the end of the last glaciation.

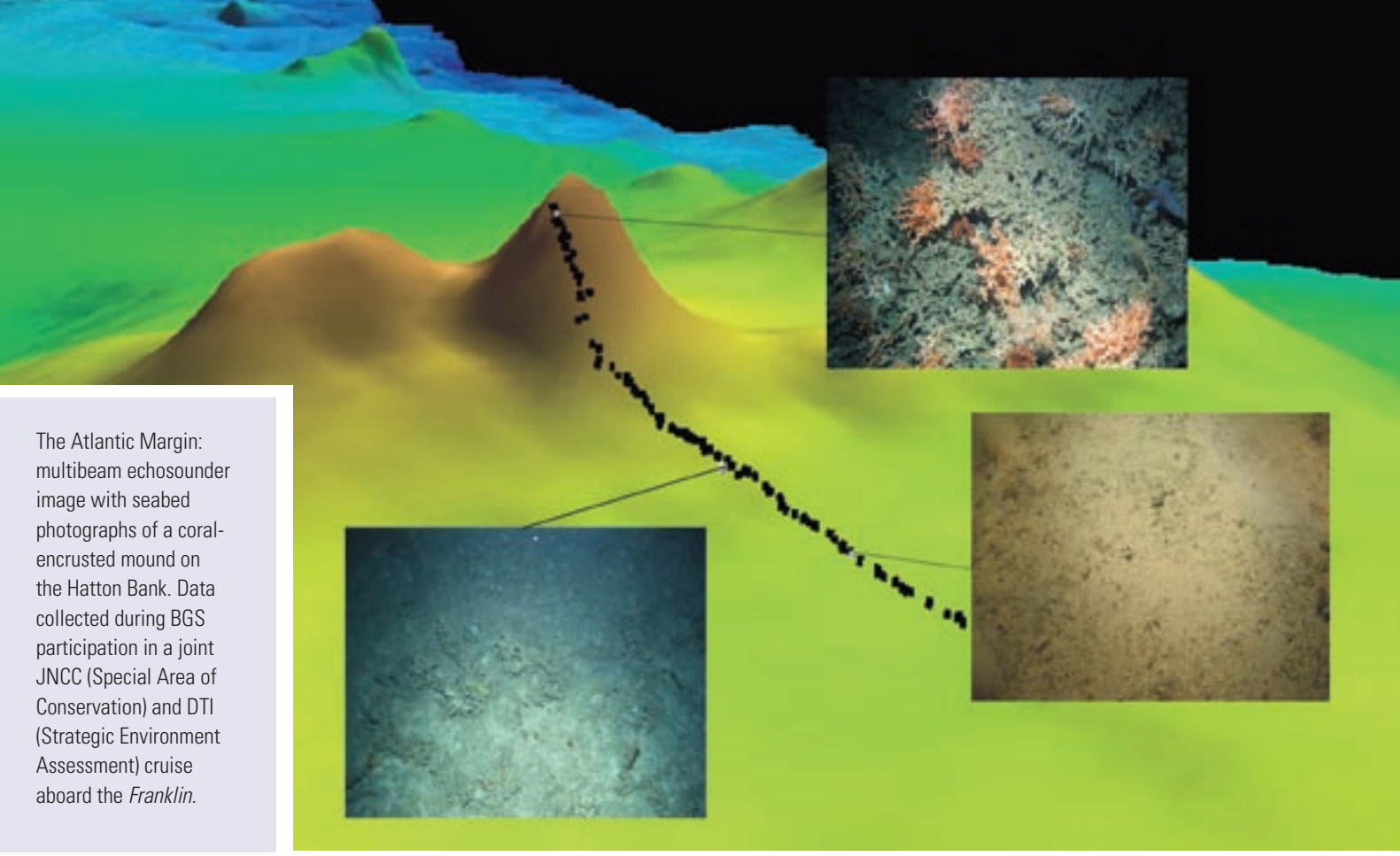
The BGS continues to press for a national marine mapping programme based primarily on multibeam data. The BGS participated in the Marine Data Information Partnership and the Healthy and Biologically Diverse Seas Evidence Group.

Coastal geoscience

Operations were focused on the Firth of Clyde. New multibeam echosounder data and cores were taken to extend studies on the spatial and temporal variability of contaminants in estuarine sediments. This work has been supported by Glasgow City Council and Scottish Environment Protection Agency (SEPA). Changes in contaminant levels with depth in sediment cores can be compared with natural background levels and related to the industrial history of the area and its hinterland. Contamination is being examined in relation to the longer-term evolution of the estuary deduced from new geophysical data (multibeam echosounder and seismic) and core sampling.

Multibeam echosounder and seismic data were also collected in the Firth of Forth in conjunction with Forth Ports plc and offshore from Montrose to support the work of the onshore Midland Valley Project.

Further work in the Thames area was supported by several commissions and analysis of cores was undertaken from the 2006 drilling campaign. A further drilling campaign is planned for 2007.



The Atlantic Margin: multibeam echosounder image with seabed photographs of a coral-encrusted mound on the Hatton Bank. Data collected during BGS participation in a joint JNCC (Special Area of Conservation) and DTI (Strategic Environment Assessment) cruise aboard the *Franklin*.

Marine geohazards

We are participating in a new EU research project evaluating tsunami hazard in Europe, and a report was prepared on the geological evidence for tsunamis around Europe. Further collaborative research on Bermuda has recognised a tsunami origin for sediments 20 metres above sea level previously interpreted as highstand marine deposits. A new Ph.D. project, based at University College London was initiated, assessing the hazard from the collapse of Atlantic volcanoes through facies analysis of sediments from a possible tsunami source.

The Atlantic Margin

The BGS undertook the final NERC cruise with the RRV *Charles Darwin* to collect seismic data along the Hatton Margin and adjacent areas. These data have assisted in our interpretations of the origin of Cainozoic inversion structures and fed into ongoing research with Edinburgh University and plans for a Hatton Basin regional report. We also participated in cruises funded by the Spanish Oceanographic Institute, the UK Department of Trade and Industry (the Strategic Environment Assessment programme) and Joint Nature Conservation Committee (definition of Special Areas of Conservation) in the Hatton area.

Excellent progress was made on completing the main chapters in regional reports for the Faroe–Shetland Basin (in conjunction with the Faroes) and Rockall (in conjunction with the BGS Rockall Consortium). The Rockall Consortium also funded a series of projects, including the first systematic lithostratigraphical scheme for the Rockall area.

Petroleum geology

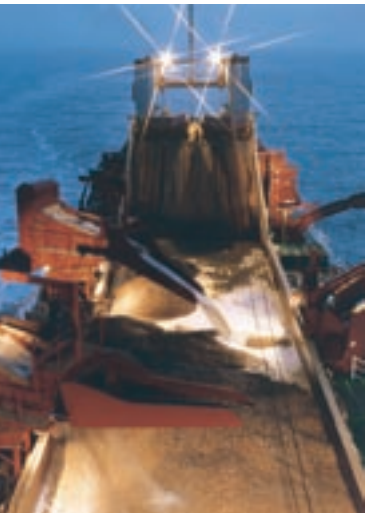
We continued to work closely with the UK Department of Trade and Industry by providing advice on the petroleum geology of the UK. A new promotional CD-ROM was published. Further studies were completed for several oil companies on specific licences and on structure and prospectivity of larger areas. These included seismic interpretation, fault seal analysis and detailed sedimentological studies to help with reservoir modelling.

The biostratigraphy team continued to provide expert services and training in the Middle East and the Former Soviet Union. In the Middle East we are developing high-resolution correlation techniques to identify baffles to fluid flow and enhance reservoir modelling. The work relies on very detailed understanding of evolutionary changes in organisms in response to climate, enabling us to reconstruct how the terrestrial and marine environments responded to ancient climate change.

Integrated Ocean Drilling Program and marine operations

Following missions to the Arctic Ocean (2004) and Tahiti (2005), 2006/07 was a period of planning for future missions to New Jersey and the Great Barrier Reef. The results of the previous cruises are now leading to a range of scientific publications.

The new BGS rockdrill was used by Geomar on the Mid Atlantic Ridge. This was the first mission for the drill, which can recover up to 15 metres of core in up to 3000 metres of water.



Marine aggregates: sand and gravel dredged from the seabed is a strategically important source of construction aggregates in England and Wales.
Courtesy of BMAPA

Geology and Resources

Economic Minerals

In 2006 the activities of the Economic Minerals programme were re-profiled as the 'MineralsUK: Centre for Sustainable Mineral Development', alongside a facelift of our minerals information web portal www.mineralsUK.com. This virtual centre of excellence concept will enhance our visibility to stakeholders and promote collaboration. This is particularly important given current concerns about resource security and the economic impacts of climate change. We are a global leader in the compilation, provision and analysis of mineral statistics, and the major UK provider of national spatial and statistical minerals information. Our research portfolio includes metallogenesis, resource management and security of supply issues.

Improving the managed aggregate supply

Aggregate minerals such as sand, gravel and crushed rock are essential for the construction and maintenance of the buildings and infrastructure on which our society depends. Aggregate resources in England are common, but unevenly distributed. While the greatest demand is in London and the south-east, resources are most abundant in the north and west. To maintain a steady and adequate provision, a system of managed aggregate supply operates in England and Wales. Government guidelines set out production required from each region to meet the anticipated national need for primary aggregates up to 2016. These allocations broadly reflect the ability of regions to produce, based on their underlying geology. Two recently completed research projects are vital in maintaining and improving the effectiveness of this system.

Our research has revealed that reserves of land-won sand and gravel within England declined by 28.5 per cent over the ten-year period 1995–2004. South-east England showed the sharpest decline at 61 per cent. This trend has major implications for aggregate supply into major construction projects such as the London 2012 Olympic Park, Crossrail and the Thames Gateway.

AM2005 is the latest of the four-yearly Aggregate Mineral (AM) surveys. AM2005 provides in-depth and up-to-date information of regional and national sales, inter-regional flows, transportation methods, consumption and permitted reserves of primary aggregates. Results will be used to help monitor and develop effective national, regional and local mineral planning policies in both England and Wales.

These studies are a solid base for further research to enhance the sustainability of our aggregate supply. This includes an in-depth assessment of alternatives for the future supply of aggregates in England, including an investigation of economic and environmental/climate change impacts of alternative supply scenarios.

Strategic importance of marine aggregates

The UK's marine aggregates industry is the biggest in Europe and one of the largest in the world. In 2005, sand and gravel dredged from the seabed accounted for 9 per cent of total primary aggregates sales in England and Wales, but more significantly for 19 per cent of total sand and gravel sales in England and 46 per cent in Wales. The industry is particularly important in regions where land-won supplies are relatively scarce, making a crucial contribution to aggregates supply in London, south-east England and south Wales. The British Marine Aggregates Producers Association (BMAPA) commissioned us to provide an overview of the marine aggregates industry and its strategic importance in the maintenance of national and regional supplies.

Impact of the commodities 'supercycle'

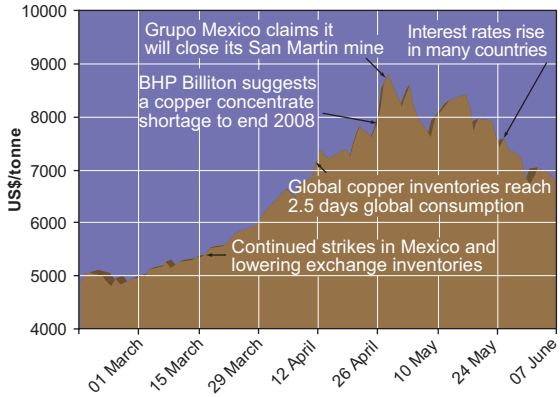
Against a backdrop of soaring commodity prices, greater attention is focusing on security of supply and scarcity of natural resources. Global economic growth, constrained supplies and the appetite of developing economies for raw materials are fuelling the current commodities 'supercycle'. Inflationary concerns related to high oil

Mineral deposit research (*above*): a new style of gold mineralisation, linked to the mixing of surficial waters with basinal brines, has been investigated in this area of County Galway in Ireland.

Mineral deposit research (*left*): the BGS worked with a private sector exploration company to investigate Ni–Cu–PGE mineralisation associated with Ordovician intrusions in north-east Scotland.

prices, speculative activity and geopolitical tension were additional factors contributing to the exceptional rise in metal prices during the year. Accurate and up-to-date information and commentary on mineral production and resources is increasingly in demand.

Our information is widely used by industry, the financial markets, governments, planning and fiscal organisations for more informed decision-making on minerals supply, investment and planning. We continue to expand our minerals and metals expertise and research by developing commodity specialists capable of providing bespoke advice, data compilation and reports. The BGS minerals profile focuses on high-profile commodities such as copper, nickel and uranium. China is the world's largest copper consumer and, as with many other metals, it has begun to exert considerable influence on the global market. Our new 'Mineral Profile' on copper reviews and summarises the industry with detailed information on world production, reserves, trade and prices.



Commodities 'supercycle': critical events linked to changes in the price of copper during 2006, a volatile year on the commodity exchanges.

Mineral deposit research

We have continued our research into the origin of mineral deposits and methods for identifying new resources of metals. In north-east Scotland a new genetic model has been developed for nickel–copper–platinum group element deposits in Ordovician intrusions which have attracted commercial exploration interest for 40 years. The mineralisation is attributed to the mixing of later primitive magmas with earlier magmas that had already differentiated to more evolved compositions. This model will assist in focusing future exploration for magmatic sulphide deposits in the region.

External collaborations with universities and research institutes continue to grow. The diverse range of topics studied include a new style of gold mineralisation in Ireland, which is related to the mixing of surficial waters with basinal brines, and the mineralising potential of active hydrothermal systems in the Solomon Islands. The recent award of a research grant by the NERC Isotope Geosciences Facilities steering committee will fund investigation of the metallogenesis and hydrothermal fluid biogeochemistry in emergent volcanoes.

Tellus: Taoiseach Bertie Ahern presenting Marie Cowan with the Public Relations Institute of Ireland award for outreach.
Courtesy of Fennell Photography

Geology and Resources

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 the DETI, which allows the GSNI to make use of extensive expertise from across the BGS. The GSNI carries work out for other Northern Ireland government departments and collaborates closely with the Geological Survey of Ireland (GSI) on cross-border projects. In association with the GSI and the Royal Irish Academy, the GSNI participated in the development of a Geoscience Strategy for the island of Ireland.

Tellus Project

The data acquisition phases of the new geophysical and geochemical surveys of Northern Ireland were completed during the year. A total of 86 000 kilometres of low-level airborne geophysical surveying was flown over Northern Ireland by the BGS–GTK (Geological Survey of Finland) Joint Airborne-geoscience Capability (JAC). To complement the airborne survey, stream waters, sediments and soils were collected at a distribution of one sample per two square kilometres and in excess of 1.5 million geochemical analyses have been completed.

The quality of the new data is outstanding and initial interpretation has revealed new geological and environmental information. The dramatically increased definition of Palaeogene basaltic lavas and dykes have been revelatory and will have a major impact on both the academic and applied aspects of geology. The data provide a new structural framework for groundwater flow models and resource exploration. In some areas platinum anomalies in soils are closely coincident with the magnetic dykes and mapping of these intrusions under glacial cover will help to identify new construction mineral resources.

The interdisciplinary value of the data has been recognised by the Northern Ireland Government and has stimulated increased levels of co-operation between environmental, agricultural, medical and earth scientists. Furthermore, the data will be used by a wide range of public and private sector organisations. Uptake by universities has been strong with eight research agreements signed.

The high public visibility of the low-flying aircraft and geochemical sampling teams was underpinned by an outreach campaign, the success of which was recognised by three gold awards by professional public relations bodies in the UK and Ireland.

Landscape heritage and public awareness of science

The GSNI hosted the Second International Conference on Geoparks in the Waterfront Hall, Belfast, during September 2006. The event attracted 340 delegates from over 40 countries. Keynote speakers included earth science television presenter Aubrey Manning and Our Dynamic Earth Director, Stuart Monro. At the conclusion of the conference the Belfast Declaration was signed which has focused the future direction for the global development of Geoparks.

Public awareness of science activities were predominantly linked with the W5 Science and Discovery Centre in Belfast and comprised a school challenge day (where pupils debated the development of the natural resource industries), gold panning, photographic competitions, workshops, fieldtrips and lectures.

Mapping and publications

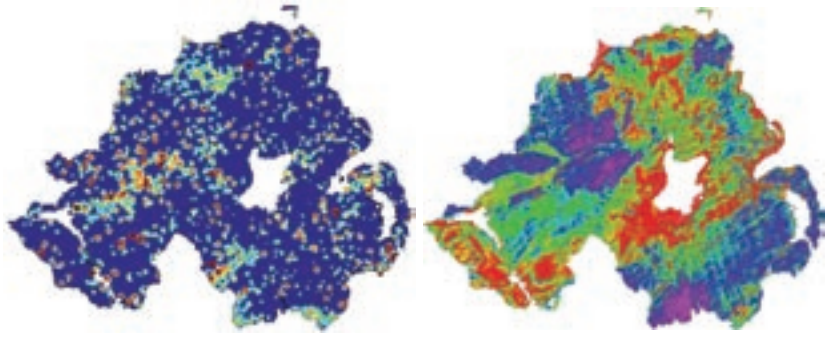
Collaboration with the University of Ulster resulted in the publication of the *The Last Glacial Termination in Northern Ireland.* The book advances new interpretations of the end of the Ice Age and has received positive reviews in the academic press.

Clockwise from above:

Tellus: Secretary of State for Northern Ireland, Peter Hain MP, with BGS Executive Director, John Ludden *(right)* and GSNI Director, Garth Earls *(left),* collecting the last geochemical soil sample at Stormont.
Courtesy of Pacemaker Press

Landscape heritage: Professor Aubrey Manning presenting the keynote address at the Geoparks 2006 conference.

Tellus: gold in soils and low-frequency apparent conductivity.



Images reproduced by permission of Director, GSNI.

The Tellus datasets continue to feed into new 1:50 000 scale maps. New bedrock and superficial geological maps were printed for Maghera and Dungiven. These maps are designed to appeal to both technical and non-technical readers and continue to be well received.

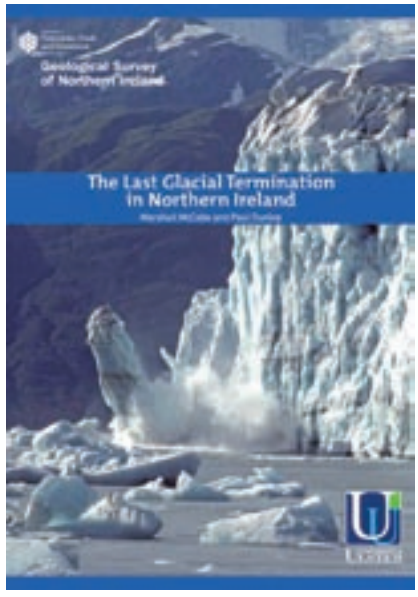
Minerals and energy resources

Mineral and petroleum rights are vested in the DETI. The GSNI advise the DETI on the technical aspects of the licensing framework as well as promoting the natural resources of Northern Ireland.

The GSNI presented the results of the Tellus Project to the international mineral exploration community at the Prospectors and Developers Association of Canada. Feedback from the event was encouraging and has been converted into a record number of prospecting licence applications for a wide range of commodities.

Production has commenced at the Omagh Gold Mine and other mineral licence holders continue to advance the prospectivity of Northern Ireland through exploration. Hydrocarbon exploration programmes are ongoing in the north-west Carboniferous Basin, the Rathlin Basin and the Larne Basin. The GSNI continued to provided data and advice to the companies involved.

The GSNI has received enquiries about natural gas storage in salt beds and is continuing to advise government on the licensing of exploration proposals to discover the suitability of the Northern Ireland salt deposits for gas storage. In addition to this the GSNI and the BGS will be carrying out a seismic survey off the east coast of Northern Ireland to upgrade understanding of the salt beds.



Mapping and publications: *The Last Glacial Termination in Northern Ireland.*

Environment

The demand for GSNI information and advice continues to increase. The main growth area continues to be the necessary geoscientific input to planning applications associated with the development of wind farms. Appraising Environmental Impact Assessments for an ever-widening range of development is a key service provided by the GSNI to the Northern Ireland government.

The GSNI, in association with Minerals Branch, has successfully closed 95% of all mine openings in Northern Ireland classified as 'high risk'. Many of these old workings are in popular amenity areas and represent a real hazard to the general public.

Environment and Hazards

The Environment and Hazards Directorate carries out applied research into and, through survey and monitoring, provides information on those geological processes that particularly impinge on human activity and how that interaction changes with time.

Environment and Hazards

Gas flow in compact bentonite: large-scale gas injection test (Lasgit) 420 metres below ground at the Äspö Hard Rock Laboratory, Sweden (*above*).

The BGS's long-range laser scanner monitoring cliff erosion at Happisburgh, North Norfolk (*opposite*).

The aim of the research carried out in this Directorate is to understand better how the atmosphere, biosphere and hydrosphere interact with the near-surface of the geosphere, where most human activity is concentrated. Consequently, we are seeking to understand how soil is formed from the underlying geological parent materials and how it acts as a 'filter' as groundwater and air moves through it. Similarly, we need to understand how physical and chemical processes act in the near-surface by moving rock and soil either slowly (erosion, dissolution) or more quickly (landsliding) or by transporting natural and anthropogenic chemicals through the system (migration of agricultural nitrates, contamination from past industrial activity). Whole Earth processes can have significant effects at the surface, for example, geomagnetic fields can affect navigation systems and seismicity causes destructive ground movements.

The complex interactions between surface and groundwater at a variety of scales, up to that of a whole catchment, need to be better understood if we are to manage the likely consequences of climate change. Geologists have an important role to play in applying our understanding of how climates changed in the geological past to help us appreciate the significance and likely consequences of climate changes in the near future. Also, they can help mitigate the expected impacts by identifying threats to groundwater resources, predicting where susceptibility to geohazards is likely to increase and by investigating locations where climate-damaging carbon dioxide can be safely stored in the long term.

As technology advances, new ways of measuring the nature and composition of the ground are developed. These are enabling us to model the Earth's structure in the shallow subsurface in three dimensions (3D) and to monitor and model the processes that act upon it over time (the fourth dimension — 4D). However, the development of ever-more sophisticated models places a requirement upon geoscientists to estimate the uncertainties associated with those models. The assessment and definition of these uncertainties can be thought of as adding a fifth dimension to our understanding of the near-surface geo-environment.

The Directorate operates via eight research, survey and monitoring programmes. These programmes cover almost all aspects of the near-surface geo-environment from soils and groundwater to physical, chemical and biological hazards, sustainable and renewable energy and climate change. The past year has seen some important advances and new initiatives, some of which are described in the pages that follow.

As peoples and governments become increasingly concerned about climate change, security and sustainability of energy supplies, and the effects and mitigation of geohazards, the role of geologists in helping to solve these problems will increase. The geo-environmental activities described in this report should be seen as a starting point for establishing a better harmony between the Earth and its inhabitants.

Prehistoric sea level: borehole cores through part of the Holocene fill of the Humber Estuary.

Environment and Hazards

Climate Change

Climate change is a major theme cutting across the BGS's research. The impacts and mitigation of climate change are significant components of many of our research programmes. However, the main initiatives addressing the geological drivers on the ocean-atmosphere system and climatic feedback mechanisms occur in the Environment and Hazards Directorate.

Work on climate change drivers and feedbacks is focused into two core areas. The first involves the evaluation of geological controls on past climate change, concentrating on extreme climates within the past 150 million years, the maximum age of the ocean basins. One of the main purposes of this research is to enable the development of improved palaeoclimate models and, ultimately, improved predictive climate models. The other focus is the evaluation of the geological aspects of carbon storage and cycling in fluvial, coastal and marine systems. A considerable component is based on estuaries and coastal systems in the UK and internationally, including assessment of sea-level controls. Substantial effort is also based on continental shelves and margins and focuses principally on the destabilisation of methane hydrate systems. Research into processes and fluxes will provide improved geoscientific data for climate researchers and modellers to use. Our staff are working to develop links with other partners in the NERC and over the past year we have organised several international events addressing the geological controls on climate change.

Methane hydrates: loading logging-while-drilling tools on the drill ship *JOIDES Resolution* prior to IODP Expedition 311.
P Jackson © NERC, Integrated Ocean Drilling Program

Interpreting prehistoric sea-level records

To predict the impacts of climatically induced sea-level rise on estuaries it is important to be able to interpret how past sea-level regimes have influenced these areas. To date, microfossils have almost always been used to accurately indicate past sea levels and environment but it has been virtually impossible to establish high-resolution records where these are absent. Jointly with the NERC Isotope Geosciences Laboratory, we have been investigating the use of organic $\delta^{13}C$ and C/N within estuarine deposits to determine changes in the source of organic matter, which can be driven by fluctuations in relative sea level, river discharge and catchment disturbance. Results from a comprehensive vegetation and sediment $\delta^{13}C$ and C/N survey of Welwick Marsh in the Humber Estuary were combined with high-resolution $\delta^{13}C$ and C/N analyses of Holocene cores collected previously from the estuary and the Lincolnshire Marshes. The Welwick Marsh $\delta^{13}C$ dataset showed a gradual increase in surface sediment $\delta^{13}C$ with decreasing marsh height, suggesting that $\delta^{13}C$ is controlled by the degree of tidal inundation. However, sediment C/N ratios are less sensitive to tidal changes. It was found that the Holocene $\delta^{13}C$ and C/N records are in general agreement with existing microfossil data and provide additional palaeoenvironmental information. This includes support for an estuary-wide expansion of marine conditions from about 3300 years ago, followed by a contraction of marine

Deep-time climate: artist's impression of a late Cretaceous forest landscape, based in part on BGS deep time palaeoclimate research.

conditions after about 2700 years ago. This work has shown that bulk organic $\delta^{13}C$ and C/N analyses provide a reliable and independent indicator of coastal environmental change and, therefore, they offer a complementary technique to the more commonly used microfossil approach.

Methane hydrates from Hydrate Ridge

Research into methane hydrates in collaboration with the University of Leicester, followed participation in Integrated Ocean Drilling Programme (IODP) Expedition 311, to study gas hydrates on the Cascadia Margin, north-west USA. Gas hydrates represent a reservoir of methane, which may constitute a climate feedback, an energy resource and a geohazard in terms of continental-slope instability (such as the Storegga slides off Norway). Work is under way to enhance the interpretation of resistivity measurements logged while drilling (LWD). This work uses shore-based, laboratory studies of sediment-hosted hydrates that have been preserved in liquid nitrogen, as gas hydrates dissociate at surface temperatures and pressures. Being ephemeral in nature, relatively little is known regarding the formation and disposition of gas hydrates within marine sediments *in situ*. Relationships relating the concentration of hydrate in the pore space (and hence estimates of the Earth's total hydrate volume) to the measurements made down-hole (for instance, using LWD methods) are the subject of intense research at the present time. Our approach of combining scanning electron microscopy with down-hole LWD measurements will contribute to this. LWD measurements proved essential in minimising the effect of drilling disturbance on our measurements — such as the significant borehole enlargement often encountered using traditional drilling methods. Expedition 311 confirmed previous observations that gas hydrate forms preferentially in the coarser sediments.

Deep-time climate

Modellers and geoscientists often take a very different approach to deep-time climate and palaeoenvironmental research. Too commonly, there appears to be a disconnection between the two communities, which is unfortunate, as they clearly have to work effectively together to develop better climatic models. Along with our partners (including Leeds and Bristol Universities) we are adopting an iterative approach, in which geological data are used to identify where models are, and are not, working well and what changes are required to improve them. The project focuses on the hot and extreme climates of the late Cretaceous and early Tertiary. We are developing databases, upon which new models will be based, for these periods. New data are being collected at key locations. For instance, a sequence across the Palaeocene–Eocene boundary from the North Sea has been sampled to provide a high-resolution record. Other sites have been identified in data-poor areas, particularly in low-latitude locations in which the performance of current models has been less efficient than is desirable. Consequently, BGS scientists are working with the University of Leeds on sites that provide outstanding records of the latest Cretaceous of Antarctica. It is expected that markedly improved deep-time climate models will result from this project.

Groundwater flooding: groundwater data collection in the Forres area.

Environment and Hazards

Groundwater Management

The Groundwater Management programme carries out surveys, monitoring and applied research to assist decision makers in the management of groundwater both in the UK and internationally. The programme continues to move towards web-based working and delivery of science, information and data through the Groundwater Portal. Integration of Science Budget and commercial funding ensures that our science is relevant to users. Groundwater flooding is an area of research that is starting to produce results. It requires a multidisciplinary approach both within and outside the BGS. The development of groundwater models is testing conceptual models and providing management tools.

Groundwater flooding, Forres, Scotland

Several towns along the north-east coast of Scotland are prone to serious flooding where groundwater plays a significant and generally unacknowledged role in controlling the extent of flooding. Since 2005, BGS scientists have been working with engineers at Moray Council to improve our understanding of the role of groundwater in regular flooding and, in more extreme and damaging events around the town of Forres. An interdisciplinary team of mapping geologists, hydrogeologists, chemists and numerical modellers has been gathering information to model groundwater flow in the superficial geology. Results show that the superficial deposits store large quantities of water and often help reduce the effect of flooding, although local flooding can occur when the water-table comes close the ground surface. Numerical models of groundwater flow, using the BGS ZOOM3D groundwater flow model, are now being used to help predict the effect of proposed flood defences on local groundwater and test and improve the designs of the engineers.

FLOOD 1

This European Union INTERREG funded project (2004–07) is studying groundwater flooding in the Chalk catchments of Brighton in south-east England and the Somme Valley of northern France. Working with the Bureau de Recherches Géologiques et Minières (BRGM) and Brighton University the main objectives of the project are:

- To understand the hydraulic behaviour of water flow in the unsaturated zone with respect to groundwater flood events.
- To develop unsaturated zone monitoring techniques to reduce cost and environmental impact and to improve areal representation of the data.
- To produce more appropriate methodologies for forecasting groundwater flood events on a much longer timescale than is currently possible (days and weeks rather than hours).

Experimental sites have been installed to the north of Brighton, in northern France in the Hallue valley (a tributary to the Somme River) and in the Pang catchment on the Berkshire Downs. This latter site capitalises on the infrastructure and data available through the LOCAR thematic research programme from this Chalk catchment, the upper reaches of which are also subject to groundwater flooding.

Groundwater and flooding in Oxford

Oxford is situated within a narrow valley underlain by alluvial deposits from the River Thames. The city suffers from recurrent flooding; in 2000 and 2003 around 160 and 250 properties were affected by 1-in-10-year and 1-in-12-year

Sustainable groundwater use in Mongolia *(far left):* on-site sampling of borehole in Chahaertan Oasis.

Flooding in Oxford *(left):* Oxford suffers from recurrent flooding, most recently during the summer of 2007.

events, respectively. The project is a joint venture between the BGS and the Environment Agency (EA), which aims to identify the controls on groundwater flooding in the area and the importance of antecedent groundwater conditions on the occurrence of overbank flooding. The project also aims to provide the basis upon which an assessment can be made of the potential impact of mitigation measures introduced by the EA on natural habitats within the floodplain, including a Special Area of Conservation (SAC) and a number of Sites of Special Scientific Interest (SSSI).

A conceptual understanding of groundwater flow and surface water interaction has been developed from the data gathered and this has been modelled using our ZOOM3D groundwater flow model, which is being developed further to allow flooding processes to be simulated. This will be linked with the EA's river-flow model for the Thames in this area, providing a more effective management tool. The project was nominated for an Environment Agency Project Excellence Award in 2006.

Sustainable groundwater use in Mongolia

Groundwater for irrigation sustains agricultural and economic development in many dryland areas, but without careful management over-abstraction and groundwater quality degradation can occur. In 2006, the BGS worked with AusAID at the Chahaertan Oasis. This is one of only three areas developed for commercial irrigated agriculture in the Alxa League, which covers an area of 270 000 square kilometres in Inner Mongolia, northern China. Chahaertan has a desert climate, with less than 200 millimetres of rainfall per year, but seasonal groundwater abstraction for irrigation directly supports some 6000 people and cash crops grown in the oasis are important to the regional economy.

Our investigation showed that current abstraction from the oasis is some 20 million cubic metres per year and that local groundwater levels have fallen by up to 0.5 metres a year for at least 20 years. Groundwater below the oasis is highly contaminated by nitrate, derived largely from local fertiliser use, with concentrations in some areas of up to 600 milligrams per litre as NO_3. We have carried out numerical modelling which indicates that unless abstraction and nitrate leaching is reduced, water levels will continue to decline — individual wells may have to be abandoned within 10 to 25 years — and nitrate levels will continue to increase. We worked with local government water resources staff and provided on-the-job and formal training in groundwater resource investigation techniques as well as recommendations for increasing groundwater sustainability.

Baseline synthesis research report published

Understanding the baseline chemistry of groundwater in a given aquifer provides a basis for defining the nature and scale of current pollution impacts, the scale of past inputs and the degree of remediation required. This knowledge provides a framework for implementation of European Union legislation aimed at 'good status' of groundwater. The study has quantified the naturally large variability of groundwater chemistry, which varies as a function of rainfall chemistry, aquifer lithology, geochemical environment, groundwater flow paths and residence time. The 'Baseline' project was co-funded by the BGS and the Environment Agency (EA) and field sampling was carried out between 1999 and 2005 to investigate the groundwater chemistry from 26 aquifers in 23 areas across England and Wales.

3D soil modelling: geophysical survey investigation on arable fields, near Shelford, Nottinghamshire.

Environment and Hazards

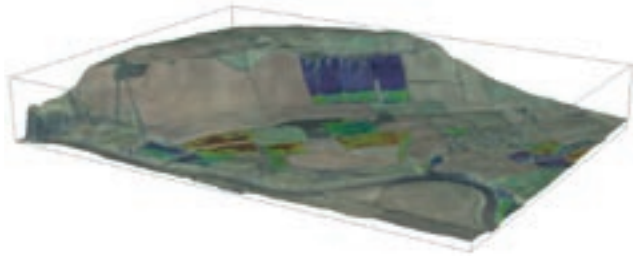
Sustainable Soil Management

The Sustainable Soil Management programme aims to improve our knowledge of how soils may be managed in a sustainable manner. We aim to provide better geological data and knowledge in support of soil survey and soil science within the context of continuing changes in land use and climate. We are also investigating the hypothesis that the majority of soil functions, as defined in policy, are actually functions of the soil–geology continuum. The research programme that underpins these aims consists of three defined projects: parent material mapping, three-dimensional (3D) soil modelling, and subsoil properties and processes.

Parent material mapping

A soil parent material is defined as the original geological material from which its main mineral component originated. In the UK this typically means the geological material underlying the more organic-rich surface soil horizons, which may range in depth from a few centimetres to a metre or more. The Parent Material Mapping project aims to produce a spatial model and associated database containing information on the geological classification and physico-chemical properties of the weathered and unweathered parent material for any given location within the UK. This will greatly facilitate the spatial mapping of the UK soils. It will also provide a database that can be more easily translated to characterise the relative importance of near-subsurface processes such as pollutant degradation and transport.

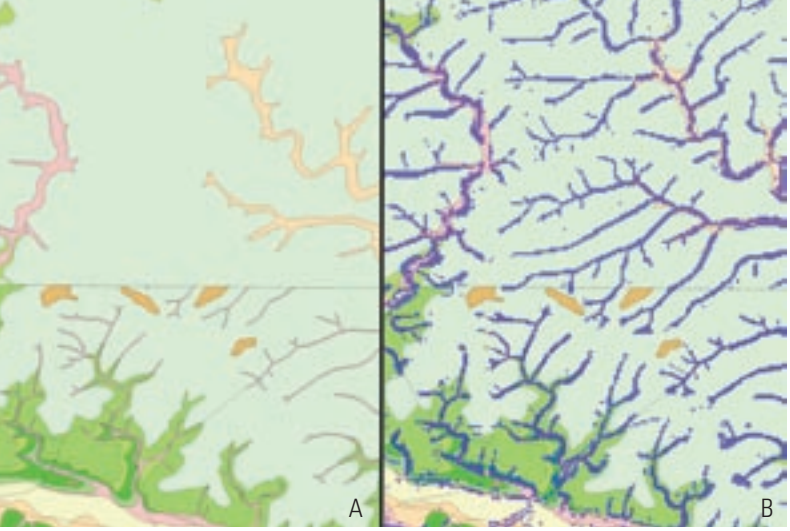
The primary aim of the project's development phase was to produce a preliminary spatial model based on semi-quantitative property information and digital geological map data. This aim was realised in early 2006 and further developments during 2006/07 have included: improvements to the dictionaries and databases underlying the map; development of models to emulate the distribution of colluvial deposits in the landscape; and capture of previously unpublished data concerning the distribution of aeolian cover-sands in Norfolk. Engineering classifications for texture and strength of the parent materials have also shown significant progress this year, and will contribute to the development of a national database of generic engineering descriptions for rocks and superficial deposits.

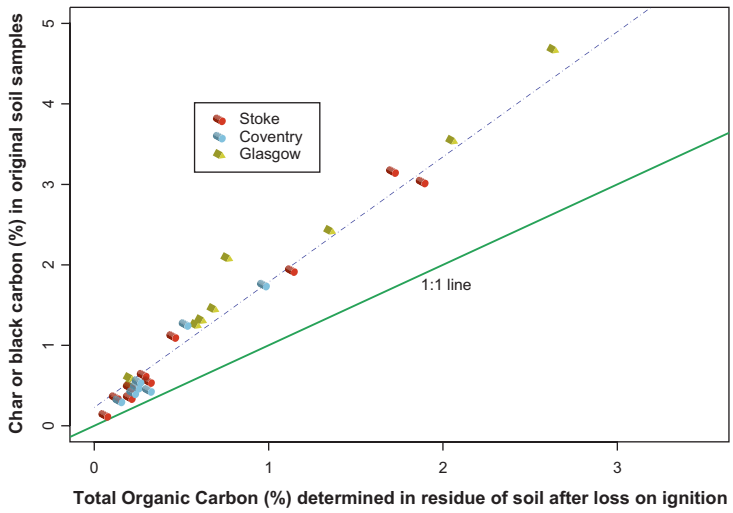


3D soil modelling: digital terrain with superimposed images which include an aerial photo of the Shelford site (Trent Valley) and soil electrical property maps (apparent resistivity mapped with Geocarta ARP technology; ×10 vertical exaggeration).

Three-dimensional soil modelling

Data gathering and related process-based research in the top few metres of the geosphere have traditionally been split between the disciplines of geography, soil sciences, geology and several of their subdisciplines. This has led to different working practices and classifications as well as inconsistent approaches to databasing and modelling of the soil, geology and the interface (transition zone) between these two environments. At a variety of scales this has resulted in significant knowledge gaps and uncertainties, and these can hinder our ability to successfully model environmental processes that traverse the transition zone (for example groundwater recharge and pollutant





Clockwise from left:

Parent material mapping: stream section showing alluvial gravel and boulders with overlying soil development.

Parent material mapping: modelling of colluvium deposits (shown as blue pixels in B, on right) compared with standard DiGMapGB-50 surface deposits (shown in A, on left).

Subsoil properties and processes: linear relationship between the amount of carbon which is left in the soil after traditional loss-on-ignition analysis (x-axis) and the amount of char or black carbon in the soil.

transport). We aim to investigate and spatially model the transition zone through multidisciplinary field surveys and geospatial modelling in representative landscapes across the UK. This work will allow us to test whether established BGS methodologies used to map geology in 3D can be used to successfully model the soil–geology continuum.

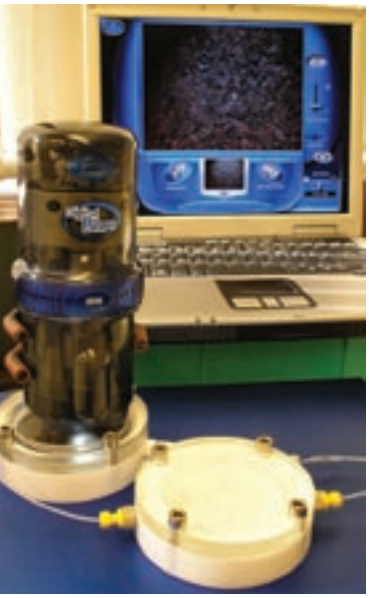
At the beginning of the year we completed our site investigations and spatial modelling of a 25 hectare site at Brackenhurst, Nottinghamshire, dominated by Mercia Mudstone with soils of the Whimple and Worcester series. The resulting spatial model represented the first UK integrated model of the transition zone between soils and geology. During the latter half of the year our modelling and site investigation techniques focused on investigating and developing a 3D model of the soil–geology continuum over a catena (2 kilometres by 500 metres) representative of lowland river terraces at Shelford, also in Nottinghamshire. Through collaboration with other researchers this site is now emerging as an increasingly multidisciplinary research site with input from soil scientists, ecologists, remote sensing specialists, geophysicists and archaeologists. In conjunction with the Centre for Ecology and Hydrology we have also produced our first catchment-scale spatial model, which covers the catchments of the upper Wye and Severn at Plynlimon, North Wales.

Subsoil properties and processes

With increasing awareness of the need for sustainable management of the soil, our focus is to examine the processes and properties that link the soil with the near-surface environment and its underlying parent material. Scientists increasingly view the soil as a continuous system and the functions it supports need to be assessed in this context. For example, many functions of soils as defined within soil protection policy — such as food and fibre production, filtering groundwater, or preserving cultural heritage — commonly involve both the soil and near-surface environment.

During the past year we have continued to develop our portfolio of themes within this project. Our examination of the nature and properties of the soil–geology continuum above the Sherwood Sandstone Group, an important aquifer in the East Midlands, has enabled us to develop spatial and geostatistical models of weathering depth. We have also used a model to predict the cation-exchange capacity of the weathered material overlying the aquifer. While these models emphasise the important contribution that superficial soil, high in organic carbon, plays in attenuating (filter-function) contaminants during groundwater recharge, they demonstrate the more dominant role of the whole of the weathered zone in the attenuation of cationic contaminants.

Other studies undertaken during the year have investigated the concentration, spatial distribution and nature of organic carbon in urban soils, the weathering of clays and the prediction of soil texture. The study of organic carbon demonstrated that previous studies have significantly underestimated the proportion of organic carbon in urban soils. They also contain a significant amount of more refractory ‘black’ carbon, which may impact on the mobility of a range of persistent organic pollutants in soil, and improve soil fertility.



Contaminant transport: flow-through cell used to monitor the growth of biofilms.

Environment and Hazards

Chemical and Biological Hazards

The Chemical and Biological Hazards programme carries out process-related research into the source characterisation, and transport and fate of geogenic and other anthropogenic contaminants arising from industrial and waste-disposal practices. The work programme is built around a mix of field survey and monitoring and innovative leading-edge laboratory investigation. The outputs contribute to an understanding of the role of point-source and dispersed pollution in the environment and human health and to national debates on the disposal of radioactive waste and the remediation of contaminated land more generally.

Environment and Health project

The Environment and Health project has co-ordinated an international inter-laboratory trial of an *in vitro* bioaccessibility test method. The object was to set up and validate the use of a new laboratory-based method to mimic the effects of the human gastro-intestinal tract on the dissolution of arsenic from contaminated soils. The method is undergoing validation using reference soils provided by Ohio State University and will eventually be used to assess the risk to human health from naturally occurring arsenic in UK soils.

Quantifying data quality using fuzzy logic

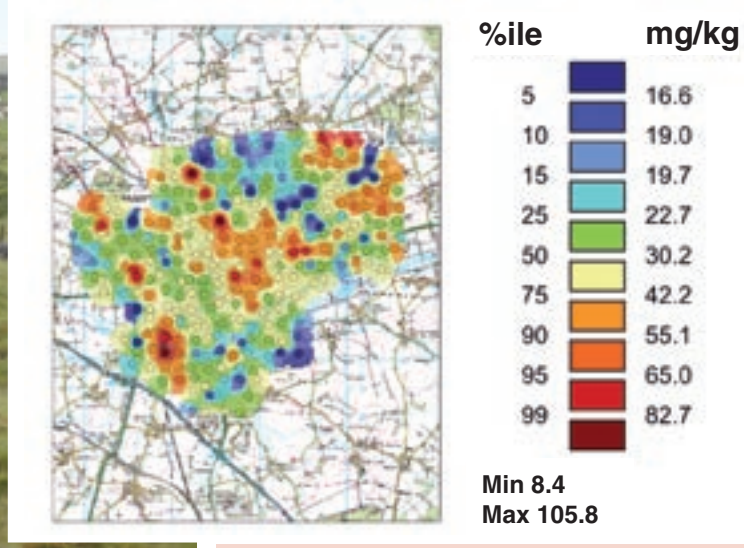
The performance of analytical and numerical models is dependent on the quality of the input data, yet few studies have established methods that quantify uncertainty in both numerical and non-numerical parameters. A methodology has been developed, based on a branch of statistical mathematics termed fuzzy logic, which captures expert judgement to provide a standard tool for assessing data quality. The process involves setting up a number of scenarios where the quality of the controlling factors is varied and an expert judgment is then used to assess the parameter quality score for each scenario. Using an adaptive neuro-fuzzy inference system, fuzzy models 'learn' from the expert judgment data and predict the quality score of the parameter under study in the same manner as the expert. A graphical user interface brings together the ideas outlined in this study into a single software tool that can be used to give an overall quality score.

Geochemical baseline mapping

The Geochemical Baseline Survey of the Environment (G-BASE) has continued to carry out systematic high-density geochemical mapping of the UK land surface area and has extended sample coverage in southern England. Some 50 chemical elements are determined in soils, stream sediments and stream waters collected at an approximate sampling density of one sample every two square kilometres. Collaborative links using G-BASE data include the supervision of Ph.D. projects following up G-BASE work and projects with the Environment Agency (assessment of naturally occurring radionuclides and natural background metal concentrations in stream waters) and the Health Protection Agency (arsenic in soils). G-BASE soil samples have been used by the Sustainable Soil Management programme to study erosion potential and black carbon concentrations. The Metal Baseline Reference Concentrations project, co-funded by the Environment Agency, has used the G-BASE stream-water data to look at the range of natural background concentration of selected elements to help the EA meet its requirements under the Water Framework Directive.

Anthropogenic and mine-related contamination

Diffuse pollution from abandoned metal mines has the potential to seriously impair the chemical and biological quality status of affected watercourses. It is important to quantify this metal loading so that the authorities responsible for developing remediation



Geochemical baseline mapping *(above):* interpolated map and superimposed point symbol map of arsenic concentrations in Northampton surface soils (at depths between 5 and 20 centimetres). The highest values are associated with the underlying Jurassic Ironstone.

Anthropogenic and mine related contamination *(left):* recent mine-water outburst near Rookhope, County Durham.

strategies are fully informed. An integrated approach involving hyperspectral remote sensing, a programme of detailed spatial measurements of the chemistry of stream reaches and inflow sites, and soils and mine-waste characterisation has been used to map the distribution of mining pollution in a research catchment. The contributions from weathering of the unsaturated zone and leaching processes are being evaluated through computer modelling and unsaturated column experiments. A modelling methodology based on a geographical information system is being developed to assess the long-term environmental implications of historical mine-waste piles and abandoned mines.

Geosphere containment

The fluid transport properties of mudrocks and plastic clays are fundamental to their role in several settings: as seals to hydrocarbon reservoirs; in preventing leakage to the geosphere from aquifers and reservoir systems that may be used for CO_2 sequestration; and as potential host formations and barriers for the geological containment of radioactive and toxic wastes. Many of the properties of clay-rich materials stem from the large surface area of the mineral phases, the ultra-small dimensions of the particles and pores, and the complex interactions that occur between the mineral surfaces, water molecules and dissolved chemical species. Their physical properties are also strongly influenced by the rock fabric, flocculation behaviour during deposition in the sedimentary environment, the presence of organic matter, chemical interactions with the clay mineral surface in the sedimentary water column and subsequent diagenetic modifications. The Geosphere Containment project was established to help us understand the complex interrelationships between mineralogical, geochemical, physical and transport properties of plastic mudrocks in the UK. The aim is to produce an atlas of clay properties that can be used to predict properties from a proxy parameter.

Contaminant transport

We are studying how microbes influence the transport of solutes and contaminants in geological media, one aspect being the role of biofilms. Widely found in groundwater systems, biofilms are complex populations of micro-organisms held together by a slimy layer of excreted substances. The growth of biofilms can impact upon the porosity and permeability of geological media, create microenvironments, form new minerals, corrode metal surfaces and restrict groundwater flow by 'bio-clogging'. In this second year of the Bio-Tran project, experiments have been carried out to represent a subsurface geological environment in the laboratory and biofilms were successfully grown by pumping artificial groundwater containing *Pseudomonas aeruginosa* through flow cells and columns packed with crushed rock. Growth of the biofilm was monitored by time-lapse digital microscopy. Experiments will now be undertaken to examine and quantify the effects of biofilms on the porosity of different geological media.

Loess collapse: monitoring collapse of loess at field observatory, Ospringe, Kent.

Environment and Hazards

Physical Hazards

The aim of the Physical Hazards programme is to provide the user community with information on, understanding of, and solutions to its problems with ground conditions and land quality, particularly in urban areas. This is delivered by modelling and visualising the shallow subsurface in three dimensions (3D) and attributing the models, assessing the likely occurrence of geological hazards and their impacts, determining the geotechnical and engineering characteristics of rock and soil formations and measuring, monitoring and interpreting the chemical, physical and mechanical properties of subsurface materials and masses.

Urban modelling: Olympic Park Development Zone

A detailed 3D geological model has been produced of the London 2012 Olympic Park Development Zone (the Lower Lea Valley) in east London. The model can be used to predict potentially difficult engineering ground conditions by assessing the thickness, geometry and distribution of individual geological units. Each unit can be characterised in terms of its lithology and lithostratigraphy and attributed with a variety of ground properties that may include information to aid foundation design, such as strength and compressibility. The 3D model, covering 10 square kilometres, is based upon 2000 borehole records. The Olympic Park development will necessitate the opening up of watercourses, the extension of wetland areas along the riverbanks as well as the construction of deep foundations, all of which can provide new pathways for contaminants. If unidentified soil and groundwater contamination is present, there is a potential that contaminants will migrate via these newly formed pathways posing a significant risk to groundwater quality if unmitigated. The 3D model contains information that will aid in the assessment of these risks and help to mitigate the situation before it occurs. This will assist planners and developers in managing the risks to groundwater and other urban environments.

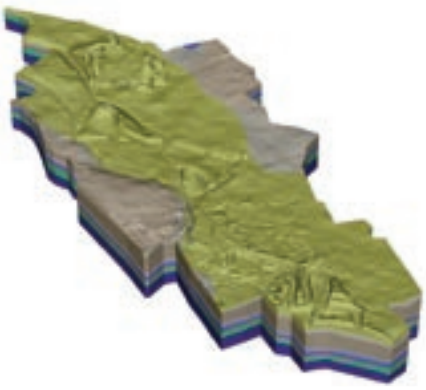
Monitoring urban ground movement from space

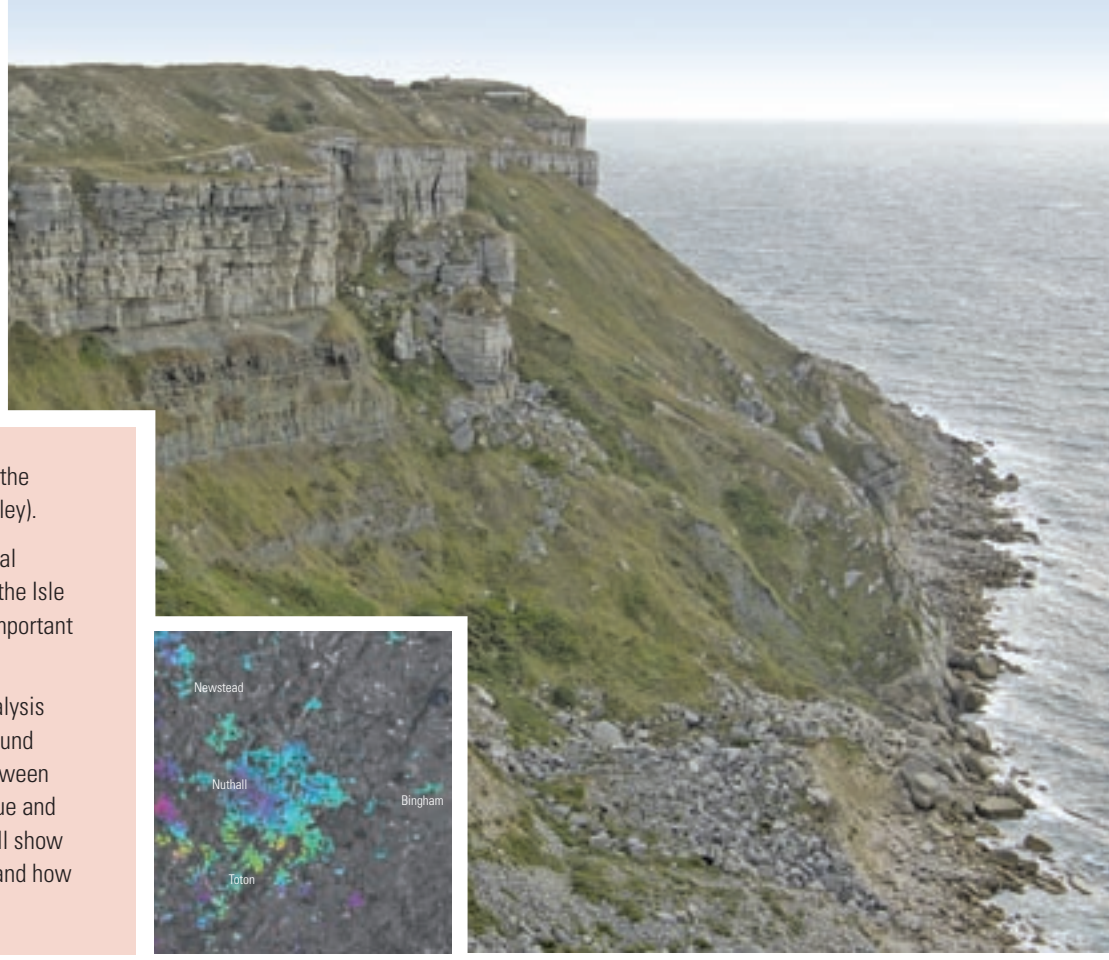
The Ground Movement Monitoring project, carried out in collaboration with Nottingham University, passed an important milestone this year with the installation of eight specially designed corner reflectors across the East Midlands. Each reflector has been positioned to form a 'hot-spot' on the European Space Agency (ESA) ENVISAT InSAR radar image as the radar satellite passes overhead every 35 days. Analyses carried out on images taken since July 2006 show that six of the eight reflectors form image hotspots suitable for image geo-registration. Repeat GPS surveys of these reflectors confirmed that all six reflectors are in stable ground, and are suitable as image calibration sites. This is a major step towards being able to calibrate InSAR in urban areas and takes forward BGS research previously funded by ESA. Initial results were well received in April at the Annual ENVISAT Symposium in Montreux, Switzerland.

The second phase of this research (2007/08) will use this ground calibration to filter out atmospheric effects and other errors, enabling the separation of 'background' movement from 'true' subsidence, caused by undermining, water abstraction or other causes. Improved techniques of data-processing will also benefit users of ENVISAT data across Europe.

Landslides and the impact of climate change

Six responsive surveys were carried out at significant landslide or flood events over the past year. These included the fatal landslide on New Years Day 2007, when the BGS responsive team assisted staff at Copeland Borough Council after a serious cliff fall at Whitehaven, Cumbria. No other fatalities were recorded at other landslide responses, though in other cases appropriate advice was passed on to local authorities.





Urban modelling *(above):* detailed 3D model of the Olympic park development zone (Lower Lea Valley).

Landslides *(far right):* understanding how coastal landslides, such as these on the west coast of the Isle of Portland will react to climate change is an important research focus.

Monitoring urban ground movement *(right):* analysis of results for the Nottingham area showing ground movement modified by atmospheric effects between July and August 2006. These indicate uplift (blue and purple) and subsidence (yellow). Calibration will show how much of the indicated movement is 'real' and how much is caused by atmospheric interference.

We have continued to collaborate with the universities of Loughborough, Portsmouth, Kingston, Newcastle and Durham through the EPSRC-funded Climate Impact Forecasting For Slopes network (CLIFFS). The network provides essential lines of communication between ourselves and academics in other sectors (civil engineering, geography, socio-economics) in tackling the complex question of how landslides will impact on urban areas in the event of climate change.

Landslide surveys have now been completed for the Selby, Vale of York and Bath Districts, at the southern and northern ends of the Jurassic escarpment. Use of satellite and terrestrial LiDAR data enabled the reinterpretation of the largest area of 'foundered strata' in Britain. The new ground model attributes the complex landforms of Bath to a series of large-scale landslides and cambers, probably dating from the Devensian. A successful Ph.D. collaboration with the University of Plymouth has resulted not only in a new landslide model for the south-west of England, but also new probabilistic techniques that will improve the efficiency of mapping landslides across the country.

Activities are now concentrating on the Coastal Landslide Survey of Great Britain. This project records coastal activity, improves our model of cliff processes and helps assess the danger posed by geohazards to coastal communities. Work has started on the Yorkshire coast and the Moray Firth and uses a combination of aerial photograph interpretation, literature review, and field survey. The outcome will be a seamless model of coastal landslides (linked to the National Landslide Database) and an assessment of hazard and risk for the whole coast.

Loess collapse and climate change

Quaternary loessic sediments, formed by aeolian deposition, cover approximately 10% of the Earth's surface. They form vast deposits extending across Europe, Asia and North America, and also form a discontinuous spread across the southern part of Britain (where they are often termed 'brickearth'). These materials characteristically have an open metastable structure, and have the potential to collapse when saturated with water and placed under an applied load. Typically a volume change of 5% or more is observed in the field when loess soils collapse, which makes them a major hazard to the built environment. A partnership involving BGS and the universities of Birmingham, Loughborough, Nottingham and Nottingham Trent has developed a research programme to identify why they form collapsible and non-collapsible fabrics. To investigate this, the nature of the inter-particle bonding, the structure of the metastable fabric and the mechanical behaviour of the loess deposits have been analysed using extensive field and laboratory studies. A new field laboratory was set up in Ospringe, Kent. Here, geophysical methods were successfully used to monitor the stiffness and moisture changes i*n situ* within loess deposits during an artificially induced collapse.

Optical luminescence and isotopic analysis methods have been used to establish the ages and chronology of several deposits of loess. The nature of the authigenic carbonate infillings within the loess deposits, was used as proxy for Quaternary palaeotemperature determinations and, hence, to indicate the palaeoclimate at the time of deposition.

Coastal aquifers: installation of the ALERT arrays one metre below the Andarax river bed, Almería, Spain.

Environment and Hazards

Electrical Tomography

The Electrical Tomography programme has continued to research innovative geoelectric imaging technology to aid the measurement and monitoring of complex earth systems and processes. A particular focus has been the development of electrical tomography for tracking leachate migration in landfills, saline intrusion in coastal aquifers and the assessment of contaminated land clean-up. Proven techniques have been taken up by other programmes in the BGS to monitor *in situ* bioremediation and to assist in the spatial mapping of soils. The work is undertaken in close collaboration with universities, industry and public sector clients.

Non-invasive imaging of landfills

The UK produces approximately 400 million tonnes of waste per annum. Recent legislation (for instance, the EU Landfill Directive) aims to reduce the amount of wastes disposed to landfill but there are still around 1000 operational sites in the UK. Even after closure, landfill sites will continue to represent a significant environmental legacy. In 2003, the BGS was commissioned by Onyx Environmental Trust (now Veolia) and English Partnerships to develop a non-invasive imaging technique for monitoring the distribution and migration of leachate within landfills that would help them manage the waste sustainably and would give early warning of leakage off-site.

We have developed a new 4D electrical imaging system known as ALERT (Automated time-Lapse Electrical Resistivity Tomography) which uses permanent *in situ* electrode arrays and 'smart' microprocessor-controlled instrumentation to remotely capture volumetric images of landfills using advanced GSM (Global Systems for Mobile communications), satellite or internet telecommunications. Tomographic images of the waste and waste fluids can be captured 'on demand' using an office computer — thereby avoiding the need for expensive repeat surveys.

Development of the ALERT system has involved the design of a new instrument, a customised relational database management system to handle the unprecedented data streams, finite-element numerical modelling and novel time-lapse image reconstruction algorithms. A field-scale test pit facility was designed and constructed to provide experimental proof of the new monitoring concept.

Hydraulic experiments were carried out to simulate a range of landfill scenarios including the periodic variation of liquid levels and the movement of conductive saline tracer fluids in water-saturated sand, either under gravity or laterally imposed hydraulic gradients. The experiments were monitored automatically with the new ALERT system with no manual intervention.

The resulting images confirmed the ability of the ALERT technology to volumetrically image and accurately track temporal changes in fluid distribution, hydrochemistry and saturation levels. This project has delivered the first permanent time-lapse ERT system for the real-time monitoring of landfill sites. Further trials are needed but plans are well advanced to commercialise the ALERT technology through a NERC spin-out company.

Contaminated land: assessment of *in situ* remediation

The reclamation of contaminated land presents a serious challenge throughout the UK. A new two-year contract has been awarded to the BGS by the former Department of Trade and Industry to research the use of automated electrical tomographic imaging to (a) help characterise the subsurface and source areas, (b) map the spatial

Non-invasive imaging of landfills (*above*): field-scale hydraulic test pit for analogue experiments under construction; and (*left*): the BGS-designed ALERT instrument.

and temporal distribution of subsurface contaminants before, during, and after remediation and (c) map the movement and distribution of applied reagents to assess the efficacy of the clean-up. Recent research has shown that Electrical Resistivity Tomography (ERT) and two related techniques, Self-Potential Tomography (SPT) and Induced Polarisation Tomography (IPT), have the ability to visualise *in situ* dynamic processes including contaminant transport and hydrochemical or biochemical reactions. Permanent *in situ* sensors are being installed at a test site in Stamford, which will allow remote, real-time, volumetric imaging of the site from the office using BGS-designed ALERT instrumentation. These images should greatly assist decision-making by optimising the injection points for reactive agents or for assessing the longevity of remediation methods. This work is being undertaken with South Kesteven District Council and Interkonsult Ltd with industrial co-funding from VHE Construction Ltd.

Self-Potential Tomography applied to landslides

SPT is one of the few geophysical techniques that can detect electro-filtration effects associated with fluid flow in the subsurface. Research is under way to assess whether real-time SPT monitoring could provide a better understanding of the fundamental triggering mechanisms associated with several types of gravity driven mass flow. A better knowledge of the triggering thresholds, conditions and uncertainties could assist the forecasting of landslides and improve risk management. The research involves theoretical modelling, controlled laboratory experiments, and field studies at active landslides.

Automated real-time monitoring of coastal aquifers

The ALERT system was installed in the normally dry bed of the River Andarax in Almería, Spain in July 2006 to monitor the seawater–freshwater interface in the underlying Quaternary aquifer. The buried electrode array extends for 1.6 kilometres upstream from the shoreline. The depth of investigation is estimated to be about 150 metres below ground level. The unmanned ALERT system is housed in a secure compound and is currently generating a time-lapse ERT image every day according to a pre-programmed schedule. These images are transmitted automatically to the BGS database using a dedicated network server and web portal. The images are still being analysed but are providing significant new insights concerning the large-scale hydrogeological property distributions, and the saline interface. This work is funded by the European Commission Framework Programme (FP6) and is led by the BGS. The consortium has partners in the UK, Spain, Germany, Greece, Denmark, Poland, Belgium and Morocco. This generic technology has wide-ranging implications for other geoscientific problems including the remote monitoring of incipient physical hazards, safety-critical civil infrastructure and the understanding of extreme events such as flooding or drought. Transient Earth processes can now be observed, which could not previously be captured by labour-intensive field sampling and measuring campaigns.

Geomagnetism and directional drilling: recent improvements to insulation and heating control around fluxgate magnetometer instrumentation at Port Stanley magnetic observatory, Falkland Islands.

Environment and Hazards

Seismology and Geomagnetism

The Seismology and Geomagnetism programme operates the UK seismic network and magnetic observatories, both components of global systems monitoring seismicity and changes in the near-Earth space environment. The data collected supports a wide range of scientific research. A responsive information service serves government, industry, the media, and the public. This is particularly important following significant UK and global earthquakes. Global datasets are used for seismic hazard studies and to produce geomagnetic field models. Expertise in multicomponent seismology, seismic anisotropy and fundamental rock physics is applied to provide better images of hydrocarbons reservoirs and to characterise fractures and their fluid content.

Tsunami monitoring

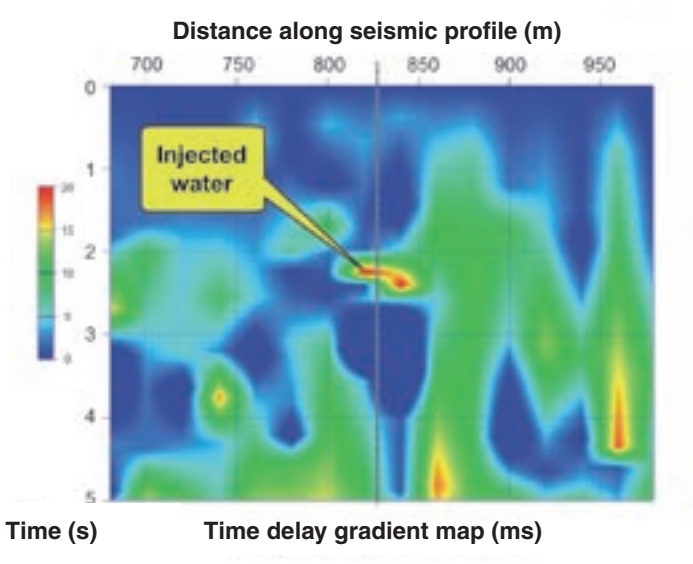
Recent studies have shown that there is a small but non-negligible risk to the UK coast from tsunami originating in the north-east Atlantic region. As a result, DEFRA (the Department for Environment, Food and Rural Affairs) asked the BGS to carry out further work to examine the possibility of seismic detection of tsunamigenic events and the generation of automated alerts. We have secured agreement to access and integrate data from seismic stations around the Atlantic with data from the UK. To process data in near real-time, we have implemented the EarlyBird software, used by the US West Coast and Alaska, Pacific and the Caribbean Tsunami Warning Centres. As a result, we can now reliably detect and locate significant seismic events across the North Atlantic. Events detected include a magnitude 6.0 Mw earthquake at the Azores–Gibraltar Fault Zone, close to the epicentre of the catastrophic 1755 earthquake that destroyed Lisbon and generated a devastating tsunami.

National earthquake monitoring

Five new broadband seismometers were installed in 2006/07, giving a total of fourteen broadband instruments across the UK. The new instruments give better data quality and improve the scientific value of the data. Continuous data from all broadband stations are transmitted in real-time to Edinburgh, where they are incorporated into automatic detection and location schemes. The value of the broadband data is demonstrated by our analysis of the magnitude 4.7 Mw Viking Graben earthquake of 7 January 2007, the largest earthquake on UK territory since the Bishop's Castle earthquake in 1990. We applied full waveform moment tensor inversion to determine the earthquake mechanism, using long-period data in the range 10–100 seconds that are only reliably recorded by broadband seismometers. This is the first time that an earthquake of this size in this region has been analysed using data from the broadband stations in the UK, Denmark and Norway that have been installed over recent years.

Edinburgh Anisotropy Project

The Edinburgh Anisotropy Project, supported by a consortium of oil industry companies, solves problems associated with the imaging and assessment of hydrocarbon reservoirs. It does this through improving methods of characterising fractures and fluid flow by wave analysis and modelling. The orientation and size of fluid-filled cracks are determined through analysis of their effects on seismic waves of different wavelengths. Innovative modelling is used to understand the complex effect of different fluids and enable interpretation for cost-effective applications. Time-lapse studies and rock physics models allow fluid



Edinburgh Anisotropy Project (*above*): in this image of a vertical slice through a reservoir, sudden changes in shear-wave time delay (red) identify areas with high pore pressure caused by water injection for oil extraction.

Geomagnetism and directional drilling (*left*): Lerwick magnetic observatory is one of three UK observatories used to supply near real-time geomagnetic reference data to the oil industry.

flow to be investigated, while converted wave processing allows imaging of subsurface structures in conditions where conventional methods fail, such as under gas clouds.

Climate and broadband magnetometry

We are collaborating with the University of Bath in developing long-term monitoring of high-frequency magnetic variations. At frequencies of 0.1 to 1000 hertz, electromagnetic measurements can provide insights into atmospheric electrical processes such as the lightning associated with tropical thunderstorms. Magnetic variations also correlate closely with water vapour and temperature changes on a global scale. By recording these data over many years we should be able to independently monitor climate variability. An induction-coil test system has been reliably operating at our Eskdalemuir magnetic observatory since summer 2006. This will be upgraded to form a key component of the global network of high frequency magnetometers planned by the University of Bath. Initial results show that Eskdalemuir is an excellent location for low-noise measurements in the pico-Tesla range, compared with the nano-Tesla accuracy of our current observatory instruments. The broadband nature of the induction coil also provides a suitable 'test bench' for the development of future generations of observatory magnetometers and electronics systems.

Modelling the Earth's magnetic field

We produced a series of global mathematical models of the Earth's magnetic field using magnetic field observations from observatories around the world and magnetic survey satellites. As well as being used to provide directional information for navigation with a compass or magnetic survey tools when drilling for oil, these models provide information about the dynamics of the Earth's core and magnetosphere. This work requires collaboration with many institutes around the world for data and, at the start of 2007, we significantly expanded our role as a World Data Centre for Geomagnetism to take on the maintenance of one-minute and hourly-mean datasets for over 250 observatories. The NERC-funded GEOSPACE project, through which we are working with the universities of Edinburgh, Liverpool and Leeds to unravel the various sources of the Earth's magnetic field, is discovering that there may be a new impulse-like feature in the field coming from the Earth's core during 2003. This is the first time such a feature has been identified in satellite data; all previous impulses have only been seen in observatory data.

Geomagnetism and directional drilling

The reliable operations of BGS magnetic observatories in the UK and overseas, where variations in the magnetic field are continuously monitored, are fundamentally important for the oil industry application of directional drilling, where the Earth's magnetic field is used to navigate boreholes towards the target. We developed a technique in the 1990s called Interpolation In-Field Referencing (IIFR) where corrections for the geomagnetic field, which we supply, are applied to magnetic borehole surveys in near real-time. This remains a highly successful project and we continue to develop our observatory operations and computing systems to improve data quality and real time availability. During the past year, IIFR has continued to be effectively applied for operations in the North Sea and Alaska. It was also successfully introduced in Western Canada, in collaboration with the Geological Survey of Canada, to incorporate data from their magnetic observatory at Meanook to derive the external field variations.

CO_2 GeoNet: coal will remain the major fuel in power generation worldwide for many decades. Delivering the science and technology to enable widespread deployment of CO_2 capture and storage is crucial to achieving rapid CO_2 emission reductions. The BGS continues to be at the forefront of this aim.

Environment and Hazards

Sustainable and Renewable Energy

The Sustainable and Renewable Energy programme focuses on clean fossil fuel technologies, underground energy storage and the interface between renewable energy infrastructure and geology. The programme delivers core science and technical advice to support UK strategic energy and environment priorities. This advice is provided to the Department of Trade and Industry, Department for Environment, Food and Rural Affairs, the UK Research Council Energy Programme, oil and gas and power companies. It also has a significant international profile working with intergovernmental agencies, foreign governments and global energy companies engaged with reducing carbon dioxide emissions from fossil fuels.

CO_2 GeoNet

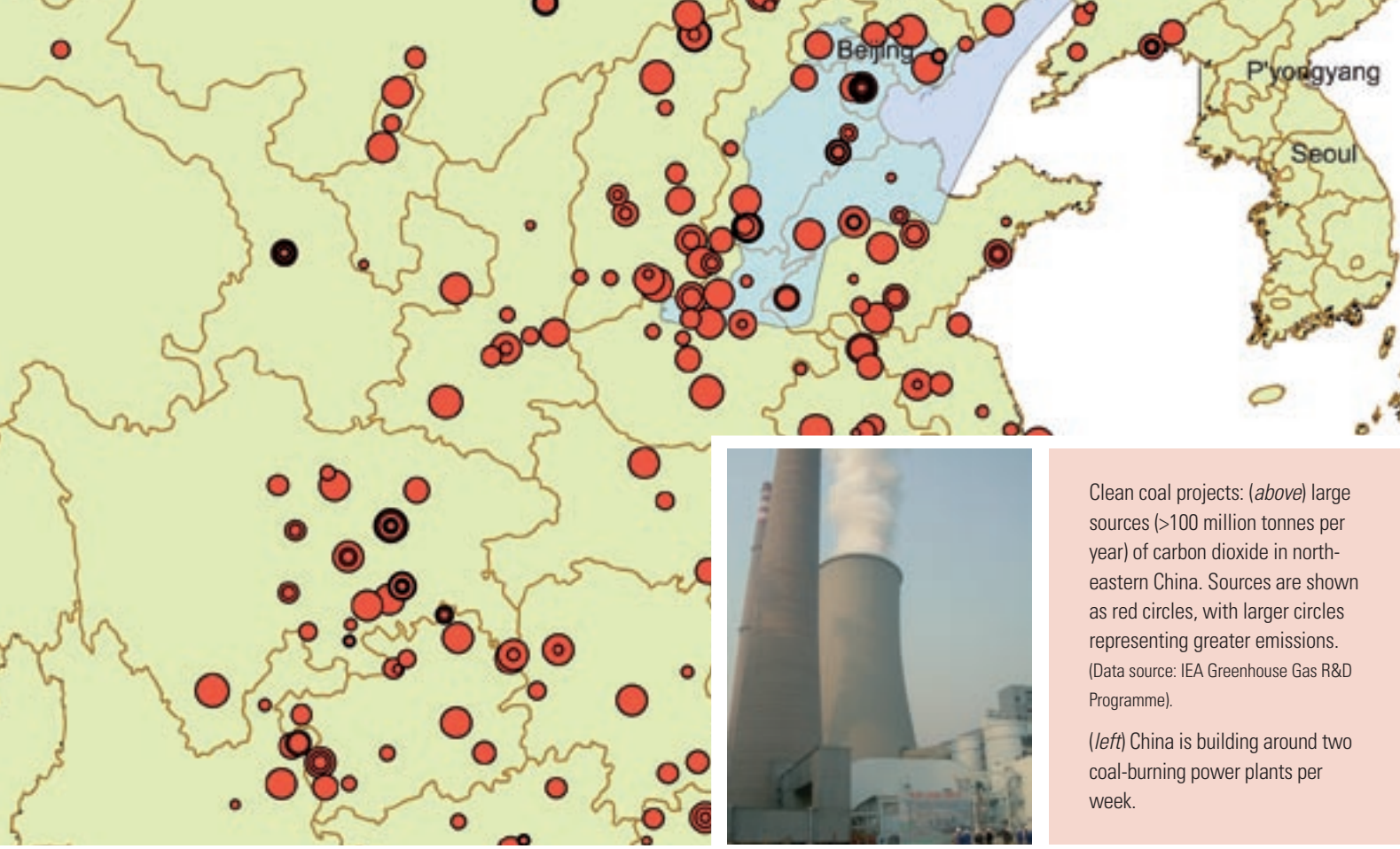
CO_2 Capture and Storage (CCS) involves capturing carbon dioxide (CO_2) from the use of fossil fuels at large industrial sites (power plants, oil refineries, cement manufacture, gas processing, iron and steel production) and placing it underground in depleted hydrocarbon fields and deep saltwater filled aquifers. This prevents CO_2 emissions to the atmosphere, thereby reducing the threat of climate change and ocean acidification. It is the only technology that can deal directly with fossil fuel emissions at a large scale. Only recently has this technology gained a high profile with respect to policy on climate change mitigation (for instance, in the Stern Review), though the BGS has been at the forefront of CCS research and development since the early 1990s. The programme co-ordinates the European Union's Research Network of Excellence on the Geological Storage of CO_2 (www.co2geonet.com). It comprises 13 research partner organisations from across Europe, which together represent the most experienced research grouping on this topic in the world. These partners align their research activities and share facilities, knowledge and staff to form a durable integration. The research focus continued this year by studying natural geological CO_2 emissions in marine, terrestrial and freshwater settings. This research is necessary to find out how we might monitor CO_2 storage sites to the levels of confidence needed to ensure safe storage. Ecosystem information is also needed to inform future strategic environment assessments and regulations for proposed CO_2 storage sites. The European Commission has recently announced that it intends to have all new fossil fuel power plants built in Europe fitted with CO_2 capture by 2020. The network has a crucial role in providing the underpinning scientific knowledge to enable this to happen and in providing training to industry so that they can deploy CCS.

International Energy Agency greenhouse gas programme

We have designed an online CO_2 storage site monitoring tool. This free download (www.co2captureandstorage.info/co2tool_v2.1beta/) is designed to inform regulators and industry about the range of CO_2 storage monitoring technology and ranks the appropriateness of each technology according to the type and location of a CO_2 storage site. It can also be used as a training tool. We are involved in several international working groups hosted by the International Energy Agency Greenhouse Gas Programme which address technical issues regarding CO_2 storage.

Clean coal projects in China

China is building around two coal burning power plants per week and is currently responsible for about one



Clean coal projects: (*above*) large sources (>100 million tonnes per year) of carbon dioxide in north-eastern China. Sources are shown as red circles, with larger circles representing greater emissions. (Data source: IEA Greenhouse Gas R&D Programme).

(*left*) China is building around two coal-burning power plants per week.

quarter of global CO_2 emissions. Whereas it is vital that Europe leads by deploying CO_2 capture and storage, it is also vital that China follows and curbs its emissions. This year we took part in two workshops in China in collaboration with the Chinese and UK governments and the EC to address what role CO_2 capture and storage could play in China. This year also saw the launch of the EC/industry funded project 'COACH', of which we are a partner. It is seeking to locate and build a coal-based polygeneration plant (producing both electricity and fuels) with CO_2 capture and storage in China. We are also involved with the UK/China Near Zero Emission Coal (NZEC) initiative which was borne out of the UK's presidency of G8. NZEC aims to identify a suitable location to build a coal-fired power station in China fitted with CO_2 capture and storage.

Europe's Technology Platform for Zero Emission Power (ZEP)

Along with several of our CO_2 GeoNet partners we have played a significant role in the launch and strategy of this industry led initiative, which aims to accelerate deployment of zero emission fossil fuelled power plants in Europe. Its strategic research and deployment documents are published at www.zero-emissionplatform.eu.

Regulatory framework for underground CO_2 storage

Regulation of CO_2 storage is still being formulated at international, European and member state level. It is essential that regulation ensures secure and safe storage of CO_2 beneath the ground. We have been involved in several initiatives providing scientific advice to support regulators. Significant among these has been the decision by the parties in the London Convention and Protocol to accept storage of CO_2 in geological formations beneath the sea. The Intergovernmental Panel on Climate Change (IPCC) published its international guidelines on CO_2 capture and storage. This will form the basis for regulation of CCS under the United Nations Framework Convention for Climate Change. We are also engaged with the Oslo Paris Commission (OSPAR), the European Commission (DG Environment) and the UK government (DTI, DEFRA, Environment Agency).

Underground natural gas storage

We played a major role in advising a public inquiry into a proposal to store natural gas in salt caverns in north-west England (Preesall), as well as assisting local government with regard to a planning application to store natural gas in a depleting oil field in the East Midlands (Welton). The UK Health and Safety Executive has commissioned us to review the geotechnical and safety aspects of underground natural gas storage operations worldwide. Along with industry we held several regional meetings for the public to help explain the technology of underground natural gas storage and the UK's need to have natural gas storage infrastructure to maintain security of gas supply and safe national gas grid operation now that the North Sea gas fields are depleting.

Information

Dr Harvey Thorleifson, Director of the Minnesota Geological Survey, USA addresses delegates at the OneGeology kick-off workshop in Brighton in March 2007.

BGS conceived and is leading a new initiative — OneGeology. This international venture to make web accessible geological map data for the Earth now has 68 national partners and considerable momentum and public profile.

Information

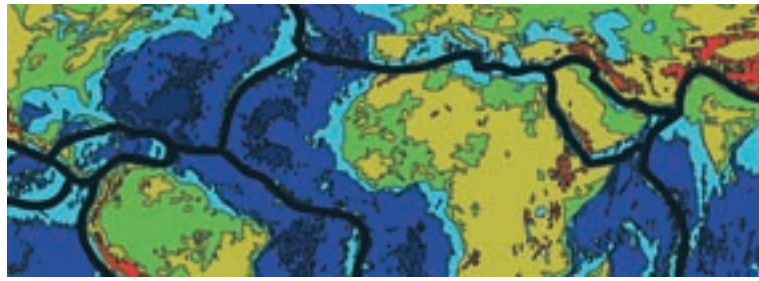
Geohazard products: two new hydrogeological hazard products have been produced this year; a 'susceptibility to groundwater flooding dataset' and a 'geological indicators of surface water flooding dataset'.

The management and delivery of data and information within the BGS is the responsibility of the Information Directorate, which is made up of four closely aligned programmes: Information Management; Information Delivery; Information Products and Information Systems Development. Together these programmes develop and maintain systems to acquire, generate, store, and make available the wealth of geoscientific information that we hold. The investment that we make in enabling better access to information represents a considerable proportion of the total BGS resource.

During 2006/07 we continued to see significant benefits from that investment and we are regarded as an exemplar within the UK public sector, the NERC, and other national geological surveys, for the innovative way that we manage and deliver environmental information.

Summaries of progress are covered within each of the four programme reports that follow, but there are a number of aspects that stand out. In October 2006 we launched the Ground Stability Report Service with our partners, the Coal Authority. This service provides the homebuyer and developer with rapid, cost effective and straightforward reports on a variety of natural and mining stability hazards. In this context it is worth noting that the BGS received a very positive report in the Office of Fair Trading's review of access to Public Sector information and was also re-awarded Information Fair Trader accreditation from the Office of Public Sector Information.

In the research and development domain, and in association with a commercial company, BGS information specialists and geologists made excellent progress with the development of a prototype for a groundbreaking concept — virtual field reconnaissance. In a sentence this is a digital visualisation system that allows display and interaction with all the digital spatial geoscientific data that we hold in a high-resolution virtual UK landscape. This provides our geoscientists with the opportunity to visualise and manipulate data as an aid to planning their fieldwork, but also enables our users and clients to better appreciate the impact, influence and relevance of geology.



We are making a major contribution to international developments in geoscientific information. We were original partners in the growing International Union of Geological Sciences Information Commission Working Group that is developing the global geoscience interchange standard, data model and mark-up language, GeoSciML. GeoSciML will dramatically improve the interoperability and sharing of geoscientific data and interest in it from commerce, academia, agencies and standards bodies is increasing. GeoSciML looks likely to play an important role in implementation of the new European Commission Directive on spatial information, INSPIRE.

Finally BGS conceived and is leading a new initiative — OneGeology. This international venture to make web accessible geological map data for the Earth now has 68 national partners and considerable momentum and public profile. OneGeology will demonstrate the first prototype web portal giving access to national geological map data by December 2007.

Information

Information Management

The Information Management programme is responsible for the management of all records, data and other information within the BGS. This includes all digital databases and collections such as paper records, maps and 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 and NERC scientists.

BGS Information Management Handbook

The BGS manages a wealth of data and information but finding the individual element required can be daunting. At times the sheer volume and diversity of holdings militate against success. To address this problem the first edition of the BGS Information Management Handbook was published this year. The handbook is designed to provide an outline of information management practice within the BGS. Its target audiences are our staff and those outside the BGS who are interested in how we manage our information.

Query layer — simpler access to data

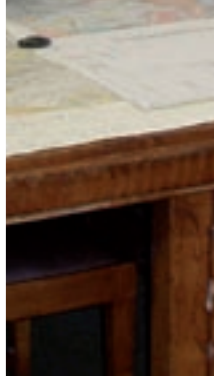
We use Oracle® databases to manage much of our digital data. Our in-house standards for the efficient design and management of these databases have been defined with reference to industry 'best practice'. By following good design practice we benefit from increased data integrity while reducing the opportunity for data inconsistency. Recently, we have developed the concept of a 'query layer'. Users are asked how they normally wish to view the data. Tables are created in the query layer to show these data in the way the users prefer, concealing the underlying complexity from them and making querying simpler. The query layer tables can be optimised for rapid querying, making database access faster as well as easier. An additional advantage is that viewing applications using the query layer are entirely independent of the underlying database objects. The query layer tables are created dynamically from the underlying database tables on a nightly basis to refresh their data content. After the success of initial trials a growing number of query layer objects have been created to make all manner of BGS data more accessible to a spectrum of users. The 'query layer' model makes access to BGS data much simpler for users.

Kidston collection

A major achievement during the year was the addition of more than 7000 samples of the Kidston Collection of fossil plants to PalaeoSaurus, the BGS biostratigraphy collection online database. Dr Robert Kidston (1852–1924) was one of the eminent palaeobotanists of his time. Dr Kidston worked closely with Survey geologists for over forty years, authoring a series of monographs and papers, many of which were published by the Survey. His collection was bequeathed to us on his death, and has been studied by innumerable visitors ever since. It was highlighted in the 2006 Archives Awareness Campaign open day and has been recently studied as part of International Geological Correlation Programme Project 469: Variscan Terrestrial Biotas and Palaeoenvironments.

ImageBase

During 2006/07 significant advances were made towards the population of the BGS ImageBase. Thanks to the efforts of volunteers working alongside BGS staff, more than 10 000 geological photographs originating from the British Association for the Advancement of Science (BAAS) were scanned and made ready for addition to the ImageBase. Once all matters relating to intellectual property rights are agreed, the images will be uploaded to the database and this vast new resource will be promoted.



Clockwise from opposite page:

Kidston collection: a fossil specimen of *Sphenopteris incurva* Kidston from Dumfriesshire, Scotland, figured by Kidston in 1923 (GSE5566).

Archive Awareness Campaign: visitors examining the displays in the National Geological Records Centre during the BGS's archives 'open day', part of the National Archives Awareness Campaign in 2006.

Student visits: Nottingham Trent University engineering students using the NGDC.

Improving the quality of geochemical data

Our procedures for the management of geochemical data have been strengthened. A new procedure covers all our projects and activities concerned with the gathering or generation of inorganic analyses determined on geochemical samples from the UK land area (excluding groundwaters). This procedure has greatly improved the quality control of data being loaded to the database.

Technical report scanning

The BGS has produced numerous Technical Reports for both internal and external customers over the past few decades, and these have now been merged into a single master analogue collection comprising over 18 000 documents. The collection has now been scanned by external contractors producing over 400 000 page images. The originals have been vacuum-packed to help long-term preservation and to reduce storage space. Copies of the reports may be ordered from the BGS Online Bookshop.

Student visits

The National Geoscience Data Centre (NGDC) is an important resource which is available to industry, academia and the public as well as BGS staff. Increasing numbers of universities are using the NGDC 's resources for teaching purposes. The wide range of professionally produced data and associated specimens and borehole cores held by the NGDC provide valuable experience to students. During the year one group of students from Nottingham Trent University undertook an exercise to select sites for a hypothetical new bridge across the River Trent.

Infrastructure investments

The BGS's continuing commitment to managing information in the most effective and efficient way continued with the installation of additional rolling shelving in the National Geoscience Data Centre (NGDC) at Keyworth. The installation provided an additional 560 metres of shelving and replaces filing cabinets which used the available space inefficiently. The additional storage is needed to cope with the increased rate of accession of data and documents. Over twenty companies deposited records with the NGDC this year including one which deposited over 1000 site investigation reports.

Archive Awareness Campaign

Organised as part of the National Archives Awareness Campaign, 'Neighbourhoods and Woods', the BGS held an archives 'open day' in December 2006. Although the event was aimed at the general public, a number of professionals also attended. Over 130 people toured the site and saw presentations and displays in the National Core Store, National Geological Records Centre, Library, Fossil Museum, and the 3D Visualisation Suite. The day was themed around the earliest known fossils from Charnwood, the Kidston fossil plant collection and the 300-million-year history of coal, its exploitation and site reclamation at the National Forest Centre. John Holmes from BBC Radio Nottingham visited the BGS and previewed the event on his show.

Sales: the Geology Shop, Murchison House.

Information

Information Delivery

The Information Delivery programme transfers and exploits BGS science in the wider community. It does this through the BGS website, the Central Enquiry Service, the Communications unit, the Sales network and the Libraries. The Intellectual Property Rights section manages the licensing of an ever-growing range of BGS data and information products.

Web delivery

Over 1.5 million visits to the BGS website were made in 2006, a 50% increase on 2005. The amount of material available for free download from the website increased considerably. UK coverage of digital geological mapping at 1:625 000 scale (DiGMapGB-625), for example, is now available free of charge for non-commercial use. The online shops were enhanced with additional products and services, and online GeoReports recorded a 33% increase in demand. Some commercial customers are now able to access specific BGS data holdings through secure web access. Three such extranet systems were launched in 2006 and more are planned.

Enquiry Service

The Enquiry Service responded to 22 000 email, phone, letter and visitor enquiries on all aspects of BGS science in 2006/07. This figure includes over 8000 general interest queries from the public, academic and school communities, including an increasing number through the online Ask-about-Geology facility. The GeoReports service provided 9000 reports, and saw a surge in demand for its Water Borehole Prognosis report driven by increased interest in groundwater resources during the drought in south-east England. The continuing drive in house-building contributed to a growing demand for the Geological Assessment and Radon Protective Measures GeoReports.

The GeoRecords service provides professional access services to the National Geoscience Data Centre and dealt with over 5000 individual enquires during the year. Visitor facilities were further improved at all sites, including better access to on-screen viewing of the scanned records.

Sales

The Sales Desk network disseminates BGS publications and related products to our wide range of customers. In 2006/07 just over 15% of sales were made online, and the online shop is attracting increasing numbers of overseas orders. A catalogue of publications and licensed data is produced annually, and is available both in print and online. The Sales department also provides an important channel for customer feedback on our publications.

The shops at the BGS offices in Keyworth, London and Edinburgh sell geological specimens and items made from geological materials. In 2006/07 the BGS launched an Ethical Buying Policy. All our suppliers must now demonstrate an ethical sourcing policy and carry out checks on the sustainability and manufacturing conditions of the goods they sell. The BGS does not use suppliers that are unable to comply with the standards laid out in the Ethical Buying Policy.

Communications

During the year the media office and public outreach activities were brought together in a new corporate communications unit. The unit works very closely with the science programmes to gain maximum media exposure for BGS science, and there has been a sharp increase in media coverage. One notable success was the featuring of BGS ground stability information in a BBC 'Real Story' documentary.

The outreach programme aims to improve the public understanding of geoscience, and does this principally through publications such as *Earthwise* magazine, the BGS website, public events, and activities for schools. Support for schools is mainly delivered via

Library (*left*): the refurbished reading room, Murchison House.

Communications (*above far left*): Professional Development Placement day for secondary science and geography teachers; experiencing the Immersive 3D Visualisation Facility, Keyworth.

Enquiry Service (*above centre*): GeoReports saw a surge in demand for its Water Borehole Prognosis report driven by increased interest in groundwater resources during the drought in south-east England.

Communications (*above right*): children examine 'their' rock sample during the Celebrity Rock Idol event.

the Department for Trade and Industry's Science and Engineering Ambassadors (SEA) initiative. Our 67 SEAs deliver hands-on science and enterprise activities in schools covering curriculum topics, such as a popular exercise in which students role-play their response to a volcanic eruption.

A highlight of the year was the 'Celebrity Rock Idol' project, run with Richard Bonington Primary School in Nottingham with support from the Royal Society. The aim of the project was to inspire pupils using a popular television programme format. The project involved scientists visiting the school and a return visit by Year 5 pupils to Keyworth, where they were able to examine their rock samples using state-of-the-art laboratory equipment.

A new initiative is Professional Development Placement days for secondary science and geography teachers. Two day-long seminars on 'Hazard Mapping' were run with the help of Education Leeds and the Lincolnshire and Rutland Education Business Partnership. The success of these events has already led to repeat bookings for 2007/08.

Library

A major collaborative initiative among the NERC research centres aimed at increasing access to research outputs was launched during 2006/07. The NERC Open Research Archive e-Repository is being implemented through the NERC libraries network and will make research outputs available to users through a web interface. The e-Repository is scheduled to go live during the summer of 2007.

Electronic access to internal and commercial publications through the main catalogue — GEOLIB — increased this year through the scanning of over 21 000 internal reports and subscriptions to a number of back catalogues of environmental science journals.

The library in our Edinburgh office, Murchison House, was completely refurbished, thereby improving visitor facilities and expanding capacity for the ever-increasing volume of material available for consultation.

Information services and information trading

The demand for BGS digital data and information continues to grow. A new Ground Stability Report Service was launched jointly with The Coal Authority in October 2006. This offers, for the first time, a service providing hazard information related to coal mining packaged with natural ground stability geohazard information in a single report.

In September 2006 the BGS was awarded continued membership of the Office of Public Sector Information's 'Information Fair Trader Scheme'. The audit team identified several examples of information trading best practice at the BGS. Similarly, the final report of the Office of Fair Trading's study of the Commercial Use of Public Sector Information identified examples of good practice in place at the BGS.

Mining hazard: Great Consols Mine, Devon. Last worked in the first part of the 20th century for arsenic.
Photo courtesy of Richard Shaw, BGS

Information

Information Products

The Information Products programme aims to produce digital datasets covering the whole of Great Britain that are based on the outputs of the BGS survey and research programmes and our substantial national data holdings. Geoscientific knowledge and data are combined to provide products relevant to a wide range of users in central and local government, insurance and housing industry, engineering and environmental business, and the British public.

DiGMapGB

Digital geological map data for Great Britain (DiGMapGB) is being created and updated at a range of scales. For the most detailed dataset, DiGMapGB-10, accelerated map digitisation has been facilitated by a highly successful capture contract with a company based in India. Version 3 of the medium-scale dataset: DiGMapGB-50, has been released following updates. This is the basis of many information products derived from DiGMapGB-50. A new version of the small-scale 1:625 000 Bedrock dataset: DiGMapGB-625, created by the generalisation of medium-scale data will be released in 2007.

National borehole information capture

Borehole information is vital to the production of many BGS products and services. Tools and methodologies using the expertise of our scientists have been introduced to identify boreholes that define the geology of the UK and its continental shelf. At the same time, methods and systems have been designed and implemented to translate historical and localised geological terminology into standardised nomenclature. These systems will store geological data and expertise for the future.

Models of superficial deposit thickness

Superficial deposits thickness is modelled from borehole and DiGMapGB-50 datasets. These deposits are key factors in assessing ground stability and also in site investigation, foundation design and mineral exploration. Superficial deposits thickness models have been upgraded through inclusion of 5500 new borehole interpretations and detailed assessment of selected deposits. A geologically interpreted model has been derived which incorporates geologists' knowledge to improve the mathematically modelled interpretation, especially in river valleys. This new layer will help to improve the GeoSure datasets.

Geohazard products

GeoSure: Ground stability products

The BGS's GeoSure digital datasets provide information about the hazards beneath the ground that may affect homeowners, planning decisions, network operators and insurers. The data includes six separate layers that identify areas of hazard relating to landslides, shrink–swell clays, running sand, soluble rocks and collapsible and compressible deposits. Subsidence can be a major problem in some parts of the UK, the effects range from cracking in walls or pipelines, to complete destruction in the most severe and rare cases. GeoSure data can help to provide answers to concerns and indicate when more specific investigation is required. Geosure information is updated annually to take account of any new mapping that has become available or improvements in the scientific understanding of hazard mechanisms.

Mining hazard

A national mining hazard information system is being developed for underground mining, excluding coal. Methodologies have been completed for the chalk, vein mining and evaporite workings and are well advanced for most of the remaining commodities that have been mined underground in the UK. Scanning and indexing

GeoSure: landslide at Lochearnhead, August 2004, one of the biggest in the UK in recent years (*left*); landslide, Aldbrough, North Yorkshire (*top*); map of landslides in the Edale area, Derbyshire (*above*).

mine plans relating to non-coal mine workings in the UK is ongoing, both from its own collections and plans held privately. All plans held in the Exeter and Edinburgh offices have now been scanned and work is progressing on those held at Keyworth and on indexing the information.

Geochemical hazards

Certain naturally occurring elements are, depending on environmental circumstances, potentially harmful to life (plants and animals, including people). Understanding the spatial distribution of these potentially harmful elements — which include arsenic, lead, chromium and nickel — is important for planning purposes. Work to map their distribution has been ongoing for some time. Work on the new digital datasets is focusing on arsenic. A dataset that combines stream sediment data, rural soils and urban mapping data will soon be available for Great Britain. Radon data have been generated for England and Wales in collaboration with the Health Protection Agency (HPA). The preparation of a new radon hazard map for Scotland is under way.

Hydrogeological products

Two new hydrogeological hazard products have been produced this year; a 'susceptibility to groundwater flooding dataset' and a 'geological indicators of surface water flooding dataset'. A map has been developed based on two groundwater flooding scenarios and hydrogeological information that can be used to characterise relative susceptibility to groundwater flooding. The 'geological indicators of flooding map' was produced by classifying superficial deposits in terms of their likely vulnerability to surface water flooding. This dataset shows areas prone to the two types of flooding — fluvial flooding and coastal/estuarine inundation A revised version of the BGS Permeability Index dataset has been released and research is being undertaken into the development of new groundwater quality products (salinity and hardness).

Research into markets and pilot products

Together with the UK Business Development section, the Information Products programme continues to identify new markets, and new products to meet market demands, and investigate markets for planned new products. A variety of pilot products and datasets that contribute to hazard assessments have been developed, including land use from historical Mining Permissions maps, Quaternary mapping in parts of Scotland and Wales, and a 1:1 million scale Offshore Quaternary map of the UK. Other datasets in development include a springs database and a GIS to assist in the siting of pipelines offshore.

Virtual field reconnaissance: BGS ESRi UK award winners for technical development in central government.

Information

Information Systems Development

This programme develops new information systems designed to enhance knowledge delivery at the interface of geoscience and information technology. The programme provides systems for visualisation, 3D modelling and digital field capture. Our systems have helped the BGS to win national industry awards. The programme provides a co-ordinated and controlled approach to system development within the BGS through the role of an Applications Architect. Continued improvements to geographical information and digital publication systems are also responsibilities of the programme.

3DG

The main role of the 3DG project is to maintain and develop the geological survey digital workflow and the three-dimensional modelling infrastructure. During the year particular effort was made on a digital field capture system and there was close liaison with field geologists to ensure it met their requirements. New spatial technologies were investigated, in particular ESRI ArcServer™, as a means of enabling more complex geo-processing to be carried out over the Internet.

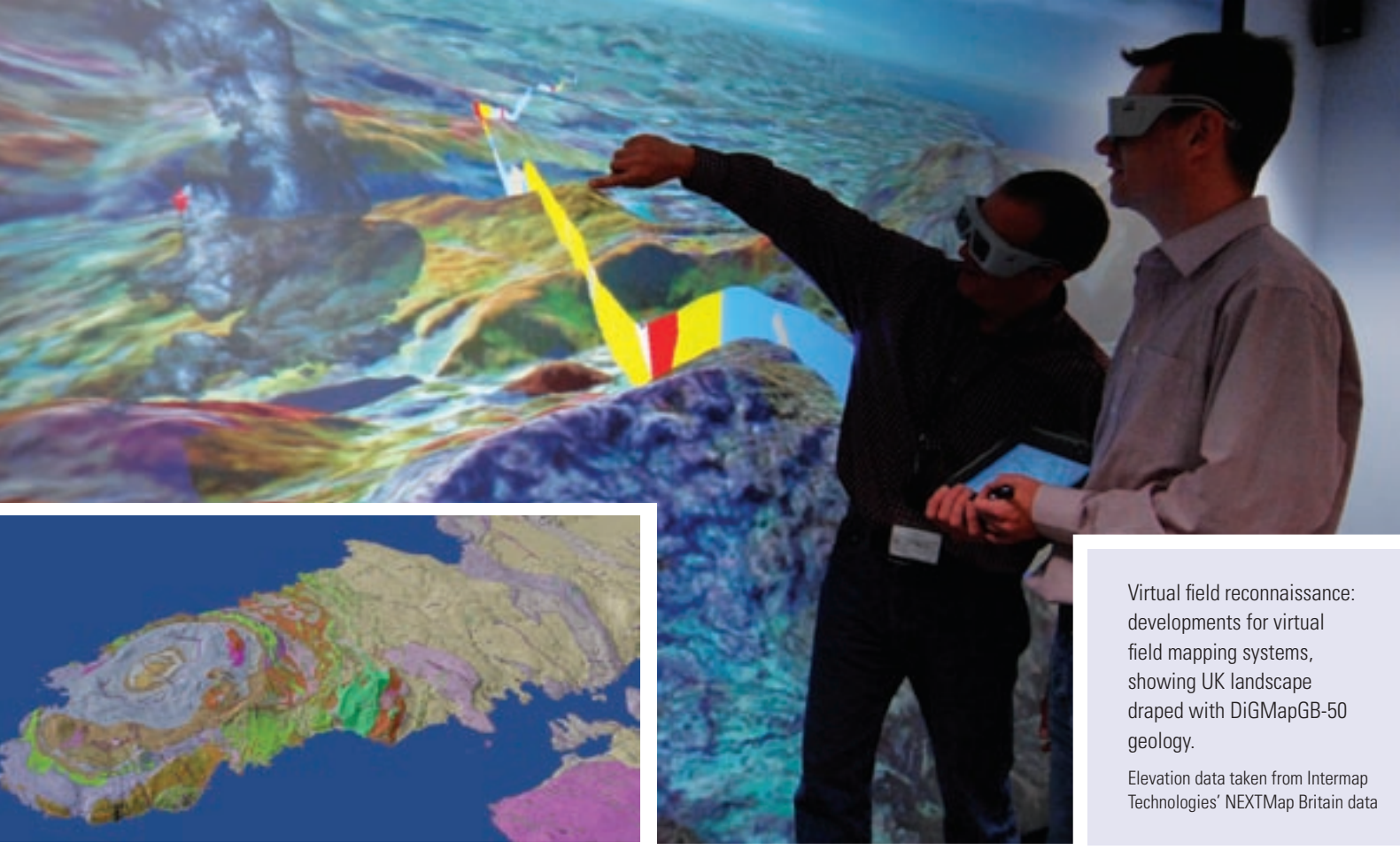
Virtual field reconnaissance

We have successfully completed Phase 1 of development and built two virtual field reconnaissance systems that allow geoscientists to gather rapidly available 3D data from BGS corporate databases and display them within both a geographical information system (GIS) and high-end immersive visualisation interface. The systems have been developed in collaboration with the National Geoscience Framework programme and won the UK ESRI Technical Excellence award for UK Government for the GIS-based system. The most sophisticated system, while still under development with Virtalis Ltd, has already attracted considerable interest as a generic 3D visualisation tool.

Low cost spatial technologies

We continued investigating and building up expertise in open-source and low-cost spatial technologies, including web-GIS and spatial data management software. We have successfully investigated rapid ways to develop lower cost technology in the 2D and 3D spatial data domains that will enable us to be more cost effective and efficient, particularly in our international work.

Low cost spatial technologies: using MapServer to provide BGS Digital Geology data as an OGC Web Map Service (WMS), visualised here using the Dapple geoscience data viewer.



Virtual field reconnaissance: developments for virtual field mapping systems, showing UK landscape draped with DiGMapGB-50 geology.

Elevation data taken from Intermap Technologies' NEXTMap Britain data

Geoscientific computing

During the year, we have supported the development of a confidence modelling system that will help ensure that the BGS provides geoscientific data products of reliable quality. We have developed an easy-to-use graphical user interface for capturing expert user knowledge. We have also worked collaboratively in areas such as eScience, high-performance computing (HPC) and the development of coupled IT systems.

Application architecture

The majority of BGS information is stored, processed and delivered using software. The quality of our software has a direct impact on the quality of our information and services. This project is co-ordinating our approach to software development and drawing on 'best practice' to deliver rigorous software quality standards.

Open Geospatial Consortium (interoperability)

Exchanging geoscience information and data with other organisations in the UK and abroad is an important part of our work. We are collaborating internationally to develop a computer language (XML schema) for geoscience data exchange. GeoSciML version 1.1 was launched in September 2006 and development is continuing for version 2. The programme also built up strong links with the UK and Ireland Open Geospatial Consortium (OGC) group, holding a major seminar at our Keyworth headquarters early in 2007.

Research Centre Infrastructure Fund (RCIF)

Digital field mapping

The RCIF funding, which ended this year, allowed us to equip our mapping geologists with rugged Tablet PCs that run bespoke digital field data capture software. The project supported the operational deployment of this equipment as part of the integrated digital workflow.

Cartographic production system development

The final part of RCIF funding allowed the completion of the cartographic production systems known as AEGIS. Digital cartographic systems have been in place since the 1980s, and AEGIS is a new cartographical workflow using ESRI software to fully integrate with the procedures used elsewhere in the BGS. The system was fully launched during the last quarter of 2006/07. AEGIS provides customised data capture and cartographical GIS techniques, and has robust workflows to handle data generated by both traditional and modern digital field survey.

Commercial Projects

IGME geoinformation system

The project has virtually completed work to develop an integrated geoinformation system for the Greek Geological Survey (IGME). We completed this work under a subcontract to Intracom SA, a Greek IT company. We delivered the geoscientific components of the system including the geodatabase design, WebGIS interface and a Geology Map Tools application. Currently the system build is undergoing final testing and will be completed within 2007/08.

Geoscientific Skills and Facilities

Scientific capability *(above):* the BGS Dando drilling rig in operation.

Scientific capability *(left):* vehicle-mounted laser CO_2 analyser.

The Geoscientific Skills and Facilities Directorate ensures that human and physical resources are available to deliver the BGS's scientific programme, and develops scientific capacity so that our capabilities remain in line with both our present and future requirements.

Geoscientific Skills and Facilities

Scientific capability *(above):* whole Jurassic ammonite extracted in Dando core at a research site in the Oxford Clay.

University collaboration *(below):* trainees studying complex volcaniclastic deposits during the metallogenesis field training course, Milos, Greece.

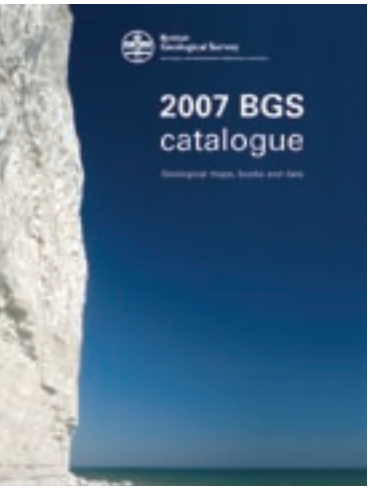
Scientific and technical staff are managed and deployed by four Heads of Discipline (HoDs). A separate HoD is responsible for staff in Administration and Finance. The Geoscientific Skills and Facilities Directorate (GSFD) also manages the BGS's scientific infrastructure including laboratories, information technology facilities, and publication services: each of these areas is overseen by a Head of Facilities responsible for strategy and operational matters. We take staff training and development seriously and run an extremely active training section headed by a training manager responsible for meeting the development needs of all staff.

Optimising BGS resources and developing our staff

The GSFD's key function is to ensure that staff and physical resources are directed in the most appropriate manner for the benefit of the BGS programme. This is done largely through a 'best team' approach. Within the organisational matrix, multidisciplinary teams are brought together to focus on a specific task or project. Any skill shortage is identified at an early stage and addressed through retraining or recruitment. Laboratory and IT infrastructure requirements, equipment purchases and technical specifications of individual equipment items are regularly reviewed and updated to ensure they keep pace with the demands of the diverse and changing BGS mission. Staff are encouraged and funded to take up scientific opportunities to broaden their experience and thus strengthen our capabilities. The GSFD co-ordinates a wide range of activities such as conference attendance, secondments, publication of key commissioned research data and results; along with the involvement of staff in learned societies and professional bodies, and the wider geoscientific community.

University collaboration

The GSFD acts as a focal point for scientific collaboration between universities and the BGS. There are currently two collaborative schemes operating: the School of Field Geology and the BGS-Universities Funding Initiative (BUFI). BUFI funds research students at B.Sc., M.Sc., and Ph.D. levels as well as post-doctoral research fellows and targeted research projects between collaborating scientists at the BGS and specific universities. The projects are spread across a wide range of universities, involving a large number of academic researchers. Project themes are closely linked to the BGS science programme and include research areas such as seismic anisotropy, economic minerals, environmental geochemistry, structural geology, climate change, fluid–rock interaction, volcanology, isotope geoscience, sustainability and remote sensing. BUFI cultivates a strong sense of mutual support, with research students benefiting from the range of scientific expertise, laboratory facilities and work culture present within the BGS and university departments. BUFI held its first field training excursion in 2006 on the island of Milos, Greece, involving BUFI-trained researchers focusing on metallogenesis.



Publishing: BGS Map Catalogue 2007; cartography, photography, graphic design and print management all performed in-house.

Geoscientific Skills and Facilities

Publications

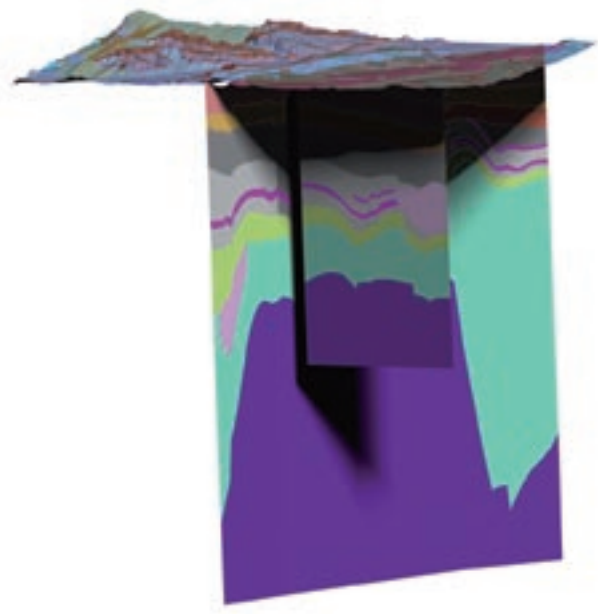
The Publications programme produces the BGS's formal output of maps, books and reports in hardcopy and digital format. We are a major contributor to digital databases such as the Digital Geological Map of Great Britain (DiGMapGB) and the National Archive of Geological Photographs. We also design and produce traditional and digital multimedia output including websites. This year has seen some exciting developments in computer animation to illustrate 3D and 4D geological models and processes.

Cartographic Production

We use geographical information systems (GIS) to capture geoscientific information to build digital map databases (DiGMapGB, *page 48*) and produce cartographically enhanced hardcopy. The year has continued the trend for increasing digital production of survey-scale map data (1:10 000 scale), submitted to us through our in-house digital mapping methodology. These are enhanced to cartographic publication standards for licensing and print-on-demand maps. We are also pleased to see completion of our 1:1 million scale Magnetic Anomaly, and Gravity Anomaly map series, released in two packs, ten maps per pack. Eighteen thematic maps were produced for the Welsh Assembly showing bedrock geology, superficial deposits, engineering properties, mineral resources, flood risk and landslide potential.

Other studies of natural resources and hazards required us to generate GIS map data for Ghana, Madagascar, European Geoparks, South Wales coalfields, mineral sites of England and Wales, landslides, radon and historical flooding, and UK-wide historical land use.

Towards the end of the year, a new cartographic production system (AEGIS, page 51) was available and introduced into the production environment. New 1:10 000 scale maps are now started in AEGIS, and this promises to enable modern GIS technology and encourage increased data and skills sharing, with lower operating costs.



Cartographic Production: geological map data draped over the topographic surface above a 3D model of underground cross-sections.

NEXTMap Britain elevation data from Intermap Technologies

Graphic Design and Publishing

A range of high-quality books has been published, including an addition to the 'Classical areas of British geology' series on the Glencoe caldera volcano, and Sheet Explanations to accompany the 1:50 000 scale Geology Series maps. Research reports into the aquifers of the

Clockwise from top left:

Graphic Design: construction of objects within the 3D virtual environment from wireframe to rendered and textured models.

Graphic Design: A Geological Time Machine, part of a 3D movie of the Earth's geological history.

Reprographic Services: digitisation of glass plate photographic images to archival quality for registration within the Geoscience Imagebase.

Dumfries Basin, and the Chalk systems of Lincolnshire and Yorkshire were also produced. Special publications included sixteen booklets for the United Arab Emirates project. The service continues to be in high demand for traditional output, and for multimedia products including: *Planning4Minerals* and *Explore Quarry Restoration* websites. Computer animation is proving a very effective medium to illustrate 3D/4D geological processes, and animations have been produced for the Charnwood area, geohazards, volcano and dome collapse, and the geological history of Assynt.

Reprographic and Photographic Services

The digitisation of the National Archive of Geological Photographs continued in order to safeguard the image quality of the collection. Some 15 500 images were scanned to archive quality, including those on glass plates, and medium- and large-format colour negatives. Location scientific photography was carried out in the UK in support of the geological mapping programme. As part of the Afghanistan Geological Survey institutional strengthening project, we provided 'imaging' training in Kabul and undertook photography of local mining and marble factories.

Output in 2006/07

Digital map and book data and printed media included:

- additions to the 1:25 000 and 1:10 000 scale map databases (data coverage stands at 11% of Great Britain);
- 185 approved maps for print-on-demand at 1:10 000 or 1:25 000 scale;
- 14 new litho-printed maps published at 1:25 000 and 1:50 000 scale;
- 15 litho-printed maps published as folded editions;
- 10 magnetic anomaly and 10 gravity anomaly maps of the UK published at 1:1 000 000 scale;
- 23 commissioned projects generating GIS map data;
- 1 geological Memoir;
- 4 Sheet Explanations;
- 5 annuals;
- 27 'special' or research publications;
- 2 titles in the popular publications series;
- 25 multimedia projects;
- 6 computer animation projects;
- 13 newsletters;
- 82 'projects' for promotional/marketing designs; and
- approximately 15 500 photographs scanned to archive.

Suites of pollutants harmful to human health can be analysed using Gas Chromatography-Mass Spectrometry (GC-MS).

Geoscientific Skills and Facilities

Laboratory Operations

The Laboratory Operations programme is responsible for the strategic management of all of the BGS's wide range of laboratory facilities, ensuring that they provide a high-quality, cost-effective and scientifically well-aligned input to the BGS core strategic and commissioned programmes.

The range of laboratories includes: sample preparation and testing, thin sections, analytical geochemistry, mineralogy and petrology, biostratigraphy, groundwater properties, engineering geology and geophysics, radiochemistry and radiometrics, and specialist research facilities.

Ultrasonics laboratory — BIAS

An experimental ultrasonics simulator is being established in the Keyworth laboratories.The facility is dedicated to a consortium project supported by the Basic Technology Research Programme of the Research Councils UK and brings together BGS, university and industry researchers in the fields of animal acoustics, mathematical and signal processing theory, the design of acoustic transducers, and the implementation of experimental engineering systems in human, medical and geological environments. The objective is to harness the acoustic capabilities of biological systems (for instance, bats and dolphins) and, through bio-inspiration, to develop novel engineering applications and apply these to a range of disciplines associated with imaging or detecting the physical properties of objects or materials.

New gas-monitoring capability

A suite of new gas-monitoring equipment is being used for surface gas measurements at test sites for the geological storage of carbon dioxide. It can also be used to measure hazardous gases on landfill sites, above old mine workings and around volcanoes. The equipment includes new vehicle-mounted laser analysers for carbon dioxide (*page 52*) and methane that will enable BGS scientists to carry out a rapid survey of large areas. Rapid initial surveys will allow more detailed follow-up investigations to be better targeted. Other equipment, including an eddy covariance system, will allow potential sites of gas leakage to be monitored continuously. The first trials of the equipment are planned on natural carbon dioxide vents in Italy and Germany.

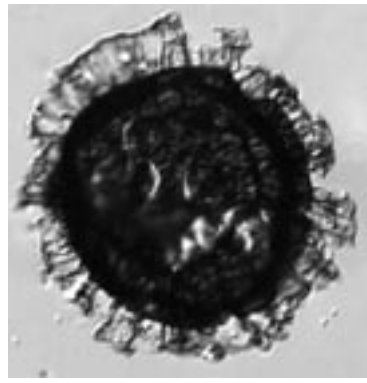
Arsenic and earthworms: estimating risk from arsenic-contaminated soils

Joint research undertaken through a Ph.D. studentship at the BGS and the University of Leicester aims to provide a better understanding of the risk assessment of contaminated soils by investigating the accessibility of arsenic to humans. Earthworms have been studied as useful indicator species in close contact with soil to monitor direct uptake and provide a comparison of ecotoxicity. The toxic effects of arsenic are well documented, although exposure is not well understood in the assessment of risk. Analysis of earthworms from contaminated soils surrounding disused mines in Devon, revealed a correlation between the accessibility of arsenic and direct uptake in earthworms. By studying the DNA of earthworms from contaminated soils it should be possible to assess what impact the arsenic has on the worms. Accessible arsenic will be compared to DNA damage in earthworms to provide an holistic approach to risk assessment.

Researchers testing wideband ultrasonic transducers at the BIAS Ultrasound Research Laboratory at BGS Keyworth.

Geoscientific Skills and Facilities

Maintenance and Development of Capability



Skiagia compressa an Early Cambrian acritarch, approximately 525 million years old, from the North West Highlands of Scotland (diameter of central body is approximately 30 μm).

The Geoscientific Skills and Facilities Directorate carries out strategic research to underpin the BGS's core strategic and commissioned programmes. The Maintenance and Development of Capability programme comprises many small- to medium-scale initiatives covering a diverse range of scientific disciplines, including laboratory operations, remote sensing, geophysical equipment and software maintenance, and palaeontology.

Palaeontological applications to stratigraphy

The BGS supports its capability in palaeontology and biostratigraphy through two research strands. The first, Taxonomy Online, uses the Internet as a forum to publish systematic taxonomic data using fossil specimens held in the BGS collections and those of collaborating institutes. Early Cambrian phytoplankton assemblages from Scotland are comparable with contemporaneous assemblages from Greenland, the east European Platform and Siberia, and record the flourishing of phytoplankton communities in the early Phanerozoic oceans, 525 million years ago. Their taxonomy impacts on understanding fluctuations in their biodiversity and the processes that underlie them. The second strand is the application of fossils in palaeoenvironmental reconstructions and early diagenetic modelling. For example, carbonate concretions from the Cretaceous Santana Formation of north-east Brazil preserve three-dimensional fossils that reveal the early diagenetic history and the chemical evolution of the surrounding sediment, including specific generations of calcite growth. Analysis of carbon and oxygen isotopes is revealing information on the environment, timing and mechanism of growth.

Developments in organic geochemistry

Organic geochemical analysis of both natural and man-made compounds in soils, sediments and waters is a flourishing area of science within the BGS. Changes in the chemistry of organic polymers and molecules can provide an indirect estimate of past sea-level rise and climate, enabling scientists to monitor climate change over millennia rather than the one or two centuries for which direct measurements are available. Similarly, environmental monitoring of soils and sediments for persistent organic pollutants protects human life by providing a scientific basis for contaminated land assessment. To this end, several advances have been made within the organic geochemistry laboratories at Keyworth, including the development of a technique for the determination of polynuclear aromatic hydrocarbons (PAHs) in water samples as small as 10 millilitres. The organic geochemistry team at BGS have also successfully isolated dissolved organic matter from groundwaters and characterised these using analytical pyrolysis to enable the reconstruction of past environments.

Imaging radioactivity on the microscopic scale

A modern digital phosphor storage autoradiography system is being used to understand the processes that control the distribution of radioactivity and the transport of radionuclides in the environment. Through collaborative research with Loughborough University, data can now be collected in a few days instead of the months required previously. The technique is capable of discriminating thousands, rather than tens, of different levels of radioactivity and the digital data allows sophisticated image processing. We are already applying this new technique to natural uranium accumulation; depleted uranium particles distributed during weapons fire; sorption of anthropogenic radionuclide contamination into rock; and perhaps most surprisingly measuring the distribution of potassium from clays and feldspars in marine cores.

Aral Sea: extreme desiccation resulting from large-scale irrigation strategies.

Geoscientific Skills and Facilities

NERC Isotope Geosciences Laboratory

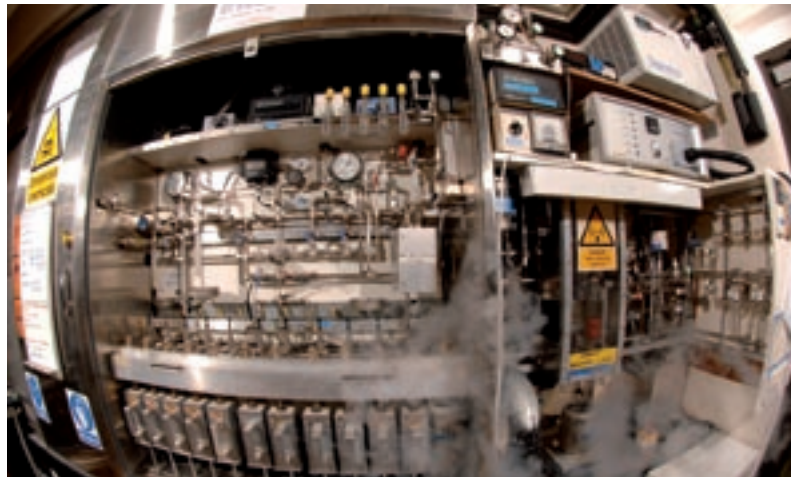
The NERC Isotope Geosciences Laboratory (NIGL) is a comprehensive stable and radiogenic isotope facility that undertakes environmental, life, archaeological and earth science research for universities, the BGS and other NERC institutes, and external clients. A primary focus is the training of NERC Ph.D. students in a collaborative research environment.

Quantifying climate change through the last glacial–interglacial transition

Hydrological and isotope mass balance models were used on a lake sediment sequence in the eastern Mediterranean. These allow changes in evaporation and precipitation to be quantified and their relative importance evaluated. We were able to show that it is the volumetric flux rate of water passing through the lake system and not the precipitation to evaporation ratio which controlled the stable isotope record in the lake sedimentary sequence. Early Holocene precipitation is shown to be much greater than that during both the latter part of the last glaciation and the present day. We also tested these calculated values against other records in the same region. This reveals a contrast between precipitation values before and after the last glacial maximum in Turkey (wetter and drier, respectively), and also suggests that during the last glacial–interglacial transition there was a more marked precipitation gradient than at present between northern/interior and southern/coastal parts of the East Mediterranean region. The work was published in Jones et al., 2006. *Geology,* 34, 361–364.

New combined silicon and oxygen isotope facility

This year the NIGL established a technique for the analysis of silicon and oxygen isotope ratios from the same aliquot of biogenic silica. We used this technique for a calibration study with groups across Europe to provide international comparison of silicon isotope data. The results from this study are in press (Reynolds et al., 'An inter-laboratory calibration of Si isotope reference materials.' *Geostandards and Geoanalytical Research*). The NIGL is continuing to support the user community in the use of silicon isotopes, and as part of this effort hosted a workshop on Isotopes in Biogenic silica (IBiS) in April 2007 (see www.bgs.ac.uk/ibis/). This meeting reported the description of the new methodology.



Silicon and oxygen isotope facility: the fluorination line used at the NIGL for the combined extraction of silicon and oxygen isotopes.

Evaporation and shrinking of the Aral Sea

Once the world's fourth largest freshwater body by area, the Aral Sea is undergoing extreme desiccation due to large scale irrigation strategies implemented in the Soviet era. As part of the INTAS-funded CLIMAN project into Holocene climatic variability and the evolution of

Clockwise from above:

Archaeological populations: early Norse skeleton from the Outer Hebrides. Tim Neighbour © CFA Archaeology

Palaeodiet: einkorn (*Triticum monococcum*), an ancient variety of wheat. Modern (*left*) and Bronze Age grains from Greece preserved by charring (*right*). Because charring has little effect on nitrogen isotope ratios, we can use them to study ancient manuring practices.

Quantifying climate change: a lake in the Eastern Mediterranean from which sediments are being used to model climate change.
Courtesy of Dr Matthew Jones, University of Nottingham

human settlement in the Aral Sea basin, investigation of the lake's sediment archive shows three severe episodes of sea-level regression in the past 1600 years. The severity of these low stands is primarily linked to anthropogenic irrigation activity and military conflict in the region rather than significant climatic shifts and reduced moisture availability (Austin et al., 2007, *Quaternary Research*, 67, 383–393).

Southward ductile flow of Asian crust beneath Southern Tibet

Whether middle–lower crust of the Asian Plate, southern Tibet, was extruded southwards by ductile channel flow is a hot topic. A test of this is that a north–south trending mid-Miocene (12 to 9 million years old) igneous dyke swarm intruding the Tethyan sedimentary cover has new strontium and neodymium isotopic data consistent with derivation within Asian Crust north of the Indus–Tsangpo suture. This implies melting of Tibetan lithosphere south of the suture, as predicted by channel-flow modelling and demonstrates that channel flow was under way before 12 million years ago (King et al., *Geology in press*). This is the first evidence of southward ductile flow of Asian crust beneath Southern Tibet.

Resolving archaeological populations

Strontium isotope analysis of tooth enamel is a powerful provenancing technique used in the investigation of the geographical origin and residential mobility of ancient people. At two sites in the UK this method has been used to distinguish populations, despite their overlapping datasets, because of the structure of the population data. In human and herbivore tooth enamel data from the Outer Hebrides, Scotland, two populations can be separated based on the geological substrate: Machair (modern carbonate sand), or silicate bedrock terrain. Machair dwellers have isotope values close to modern sea-water with a relatively high strontium concentration, the concentration enhanced by the use of seaweed as a fertilizer. Silicate dwellers define a mixing line that connects the geological strontium signature of Paleocene igneous rocks and Lewisian Precambrian rocks. Both contrast with chalk dwellers from southern Britain. This work was carried out with J Montgomery and R Cooper of the University of Bradford.

Interpreting palaeodiet using nitrogen isotopes

The first study of the effect of manuring on the $^{15}N/^{14}N$ ratios of a food crop has yielded important results for the use of isotopes in palaeodietary investigations. Despite the widespread evidence for Neolithic crop cultivation in Europe, the high $^{15}N/^{14}N$ ratios found in the bones of these communities have previously been interpreted as indicating a largely meat-eating diet. Our results suggest, however, that such ratios could result from a plant-based diet if animal manure was used in crop cultivation. The significance of these findings, published in Bogaard et al., 2007. *Journal of Archaeological Sciences*, 34, 335–343, formed the basis for obtaining an NERC research grant for further study.

Clastic sedimentology course, Bridport, Dorset.

Geoscientific Skills and Facilities

Staff Development and IT Infrastructure

Through its training programme, the BGS aims to provide development opportunities for its staff in order to achieve corporate business objectives and where possible, fulfil personal aspirations and career goals. BGS staff require access to first-class computer facilities and these have to be maintained and supported by professional and dedicated IT support staff; the Systems and Network Support (SNS) team provides this service.

Training and staff development

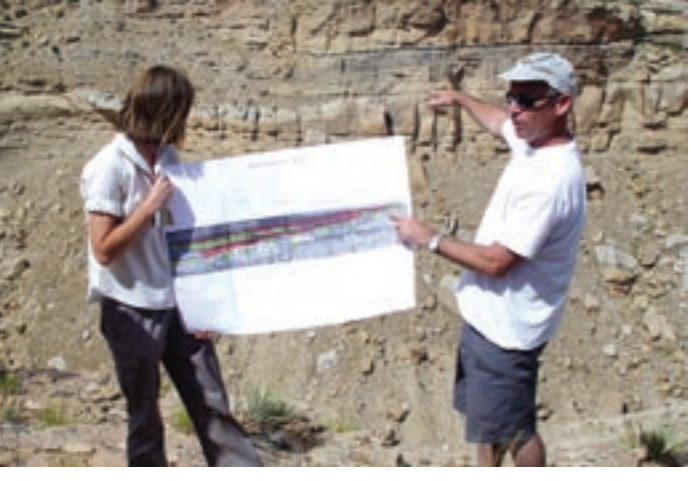
During 2006/07 the BGS continued to provide training and development opportunities for its staff in order to enhance the skills base of the organisation and support the BGS scientific programme. Training priorities reflected BGS corporate strategy and business needs.

In the IT sector, emphasis was placed on Oracle database and GIS development training and support for the roll-out of a digital mapping workflow. Training also covered 3D visualisation and geological modelling software, web-based information delivery and graphic design as well as the corporate software applications used widely by staff. Additionally, training in IT security awareness was provided for all staff.

Scientific training included in-house courses in extension tectonics, hydrogeology, landslides, engineering geology, photogeology and remote sensing, and both statistics and geostatistics. Laboratory operations were supported with training in the new Laboratory Information Management System and the operation of a variety of specialist analytical equipment. Field-based courses in sequence stratigraphy and basin analysis, geological feature mapping and highland Quaternary geology were run in conjunction with the School of Field Geology and were attended both by BGS staff and by 10 postgraduate students.

Personal development training covered a range of leadership, management, communication and other workplace skills. Senior staff attended a series of NERC-organised leadership and change management workshops and forty-one new recruits attended BGS induction courses. Language training was provided for staff working overseas.

Training in the use of a tablet PC at Arthur's Seat, Edinburgh.



Staff Development (*left*): field training in sequence stratigraphy in Utah.

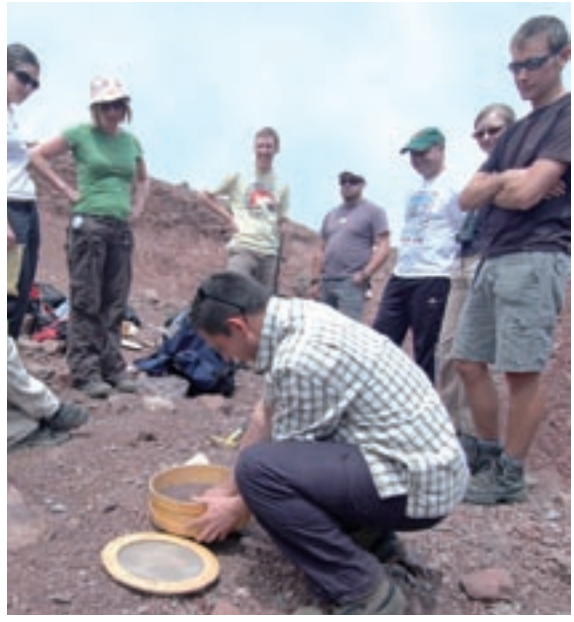
Fossil desert dune systems studied on the sequence stratigraphy and basin analysis course, Utah (*below*).

A variety of health and safety courses covered standard topics such as fire awareness and first aid as well as more specialist areas including drilling rig operation, radiation protection, quarry safety, sea survival and landmines awareness.

Workplace coaching for new recruits and those undertaking major job changes continued to receive funding and support was provided for 35 staff working towards further education qualifications. Eight staff successfully obtained further education qualifications during the year with BGS sponsorship.

IT infrastructure

IT infrastructure services are provided by the Systems and Network Support (SNS) team with staff at the Keyworth and Edinburgh offices. The effectiveness of SNS is monitored via Computer Users Groups that have input to the BGS Computer Advisory Group and then on to the BGS Executive Committee. Main development areas during 2006/7 have been in Oracle (up to version 10g with plans to implement failover capability between Keyworth and Edinburgh), Blackberry mobile services, greater wireless Local Area Network (LAN) capability, and high-availability firewall. Advances in data storage have also been made and the two large BGS sites now each have over 100TB of Storage Area Network (SAN) with modern LTO (tape storage) technology to satisfy data backup and archive needs. IT security awareness talks have been given to staff and remote access services have been further developed with strong authentication. The SNS team is moving towards IT Infrastructure Library compliance and will continue with this initiative over the coming years. The Cardiff office will very shortly enjoy access to the full range of corporate IT services, greater use will be made of personal video-conferencing systems, Linux will grow in popularity and SNS will implement virtualisation as a means of reducing the number of physical servers and the environmental footprint.



International field geochemistry training course, Anti-Atlas mountains, Morocco.

Business Development and Strategy

Commissioned Research accounts for nearly half of the BGS's activity. Promoting our capabilities, marketing, and stakeholder engagement are the main functions of the Business Development and Strategy Directorate.

Business Development and Strategy

Since early 2006, the BGS has been engaged in geological mapping and mineral prospecting over the Aïr massif of northern Niger. An important component of the project involves the training of counterpart geologists from the Ministry of Mines and Energy.

The Business Development and Strategy Directorate (BDSD) has a number of functions including corporate marketing, strategic planning, supporting the Board and the Executive Committee, maintaining links with clients and stakeholders in the UK and internationally, and managing large, multidisciplinary overseas projects.

In its marketing role, the BDSD works closely with all BGS programmes to promote capabilities, understand market needs, 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 seven sector marketing staff, who are based at the principal BGS sites. The team has devoted a large amount of effort to marketing information products to current and new clients, including those in the insurance and home-buying markets. This has led to a further increase in revenue for 2006/07 within 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 further engagement with devolved, local and regional government that has secured new externally funded commissions and heightened the profile of the BGS, and stronger links have been built with the Environment Agency.

There are three regional managers for overseas work, whose responsibilities are based around language skills that are especially necessary in francophone and lusophone Africa. International activities included several large, long-term projects in the UAE, Madagascar, Ethiopia, Ghana, Afghanistan, Mali, Niger, Papua New Guinea, Mozambique, Montserrat and elsewhere. The main focus of these projects is institutional strengthening through geological mapping, natural resource exploration, natural hazard mitigation and data management. They all also place a great emphasis on training and knowledge transfer. These projects are externally funded by clients such as the European Union, the World Bank and the Department for International Development.

This well in northern Niger provides a vital lifeline for the local community. BGS geologists helped to repair the wellhead pump which was found broken.

Pondering the rocks: geologists from the Ministry of Mines and Energy, Niger.

Business Development and Strategy

International

Institutional strengthening of overseas geological surveys has the potential to help developing countries alleviate poverty and generate wealth. The BGS continues to work with several countries for this purpose.

Searching for kimberlites in south-west Mali

In April 2006, the BGS began a 19-month project under the European Development Fund (EDF) SYSMIN Programme with the aim of determining whether airborne geophysical data can be used to detect concealed kimberlite intrusions. Kimberlites are a potential source of diamonds, but they are of rare occurrence. An earlier EDF-funded project had identified a number of interesting aeromagnetic anomalies in the Bougouni region of southernmost Mali in sub-Saharan West Africa. The form of these anomalies, together with the reported discovery of some alluvial diamonds in the region, raised the possibility that they might indicate the presence of concealed kimberlite 'pipes'. We re-evaluated the airborne geophysical data with a view to identifying a prioritised list of targets for further detailed examination. This latter activity has involved ground geophysics together with the digging of trial pits at 40 sites for sampling purposes. The samples have been analysed for so-called kimberlite indicator minerals, but to date, no evidence has been found that would indicate the presence of concealed kimberlites beneath the deeply weathered regolith of the region. Scarce outcrops of intrusive ultramafic and mafic rocks may help to account for the geophysical anomalies.

Avoiding the use of mercury

Mercury amalgamation is the most widespread method employed by artisanal and small-scale gold miners to separate gold that occurs in a very fine-grained state. Most of this mercury escapes into the environment where it poses a significant hazard to the health of miners and their families. In March 2007, we completed a project aimed at developing an alternative gold extraction process that avoids the use of mercury. The project, based in Ghana, formed part of an EDF Mining Sector Support Programme and was undertaken in collaboration from Wardell Armstrong and the University of Mines and Technology in Tarkwa, Ghana, under the supervision of the Ghana Minerals Commission.

All the principal alluvial and hard-rock gold mining districts in Ghana were visited in order to establish the practices and attitudes of artisanal and small-scale miners. Gold samples were subjected to a characterisation survey, particularly with respect to grain-size distribution, which is clearly a significant factor in the gold recovery process. The results were used to define the mineral processing problems involved and to identify which alternative gold separation technologies should be tried. Laboratory tests have shown that direct smelting recovers finely divided gold from black sand concentrates with an efficiency of over 99 per cent, which is significantly greater than amalgamation, at an estimated 90 per cent recovery. A simple furnace for gold smelting was designed, and field trials conducted at the University of Mines and Technology, Tarkwa, and at mining sites. The results show that direct smelting is a viable alternative to amalgamation for the recovery of gold from these concentrates.

Geological mapping in northern Mozambique

The government of Mozambique has embarked upon a Mineral Resources Management Capacity Building Project with funding from, among others, the World Bank and Nordic Development Fund. The overall aim is to encourage mining investment, which is seen as having an important role to play in the social and economic development of the country. The availability of up-to-date geological maps accessible within a geographical information system (GIS) framework is a necessary prerequisite for mineral exploration. At the beginning of 2003, the BGS was subcontracted by Norconsult International AS to undertake

Avoiding the use of mercury (*above*): a simple furnace being tested at Tarkwa, Ghana, for smelting gold concentrates.

Geological mapping in northern Mozambique (*far left*): the BGS base camp at Ribaué, north-east Mozambique.

Diversifying Ethiopia's export potential (*left*): surveying the site of a borehole for gold exploration, southern Ethiopia.

reconnaissance geological mapping of ten 1:250 000 scale map sheets in the northernmost provinces of Niassa and Cablo Delgado bordering Tanzania. The mapping was completed in 2005 and all project outputs delivered to the client in December 2006. We also prepared accompanying reports on the geology, mineral potential and land-use planning of the region. Field training of counterpart staff at Direcção Nacional de Geologia (the National Directorate of Geology) and input to a National Geoscience Database and Minerals Information System formed an important part of the project requirements.

The results of the project represent a major advance in our understanding and interpretation of the geology of a critical part of the East African orogen, and have important regional implications for reconstructing the former supercontinents of Rodinia and Gondwana, the evolution of which involved cycles of amalgamation and dispersal. A total of sixteen tectonostratigraphical complexes were recognised for the Meso- to Neoproterozoic basement in northern Mozambique, separated by at least five major tectonic boundaries. These include the enigmatic Lurio Belt, now redefined on the basis of the BGS-led mapping and potentially representing a Pan-African delamination zone with major events bracketed between 580 and 530 million years.

Diversifying Ethiopia's export potential

Ethiopia's mineral resources include gold, tantalum, platinum, soda ash, potash, bentonite clay, diatomite, and kaolin (china clay). Yet, despite the existence of significant mineral potential this sector has so far made only a minor contribution to the national economy. Although the current economic policy of the country gives higher priority to the agricultural sector, the mineral sector has the potential to help the Ethiopian government realise its aim of alleviating poverty by serving as an engine of growth. This would provide raw materials for industry (including fertiliser production), a source of foreign exchange, and creation of new employment opportunities. Development of the mineral sector is also seen as the best option for reducing the country's over-dependence on coffee, which is highly vulnerable to international price fluctuations, as an export commodity.

We recently completed three assignments under a World Bank funded Energy Access Project: Mineral Component, which is designed to promote the Ethiopian minerals sector. These were: (1) Mining Title Cadastre Management System; (2) Geological Survey and Investment Promotion Study; and (3) Industrial Minerals and Artisanal Mining Study. We designed and installed a mineral occurrence database and minerals information system for the Geological Survey of Ethiopia and have also formulated a strategy to promote mineral investment. This strategy includes recommendations on organisational restructuring, revision of methods, provision of new equipment, and additional training and recruitment. With respect to industrial minerals, recommendations were made for the development of deposits of kaolin, ilmenite, apatite, bentonite, diatomite, zeolite, graphite, kyanite, garnet, talc, mica and magnesite. An industrial minerals map of the country and two promotional leaflets (for diatomite and bentonite) have been produced.

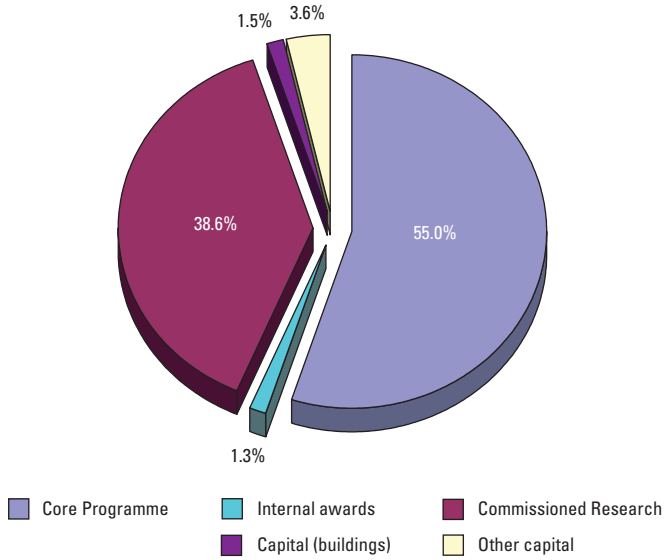
Administration and Operations Support

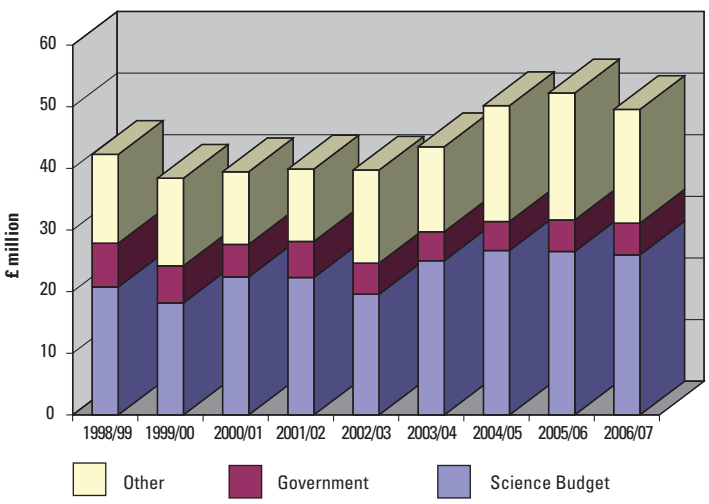
Finance

BGS expenditure during the financial year 2006/07 (*below*).

Sources of BGS income from 1998/99 to 2006/07 at 2006/07 prices (*bottom*).

Approximately 52% of the BGS's non-capital funding is provided by our parent organisation, the NERC, to carry out our Core Strategic programme. Funding is under a five-year Science Programme which began in 2005/06. For the financial year 2006/07 this funding amounted to £25.4 million. This provides for both the funding of the BGS core science programme and the NERC contribution to BGS infrastructure.





Summary of BGS's income and expenditure 2006/07 (excluding the NERC Isotope Geosciences Laboratory)	£ million
Income	
NERC resource allocation (Science Budget)	25.397
NERC capital allocation	2.925
Other income	24.172
Total income	**52.494**
Expenditure	
Salaries	30.465
Capital	2.650
Other expenditure	18.975
Total expenditure	**52.090**
Excess	0.404

From 2005/06 the NERC has also provided capital funding towards the rebuilding of six office blocks, an ongoing project over the next three years.

The BGS earns approximately 48% of our non-capital budget from research commissioned by external partners and customers, chargeable services, products and data licensing. The commissioned research programme enhances the Core Strategic programme through funding, ideas, data and review as well as making a vital contribution to our infrastructure. In 2006/07 the total operating income received from these sources amounted to £24.17 million. This included significant commercial projects such as the Montserrat Volcano Observatory and mapping in Madagascar.

In 2006/07 we continued to invest in the fabric of the buildings, including refurbishment of numerous areas of the Keyworth site as part of the redevelopment programme. The development of the site was funded partly from a Science Budget contribution towards infrastructure and partly from infrastructure contributions from the commercial programme.

Administration and Operations Support

Personnel

Recruitment has focused on specific business requirements and accounted for 48 new employees. Our policy is to encourage applications from people with disabilities and from minority groups. Staff turnover remains low at 6%.

Kim Grant, Dr Mohammed Aslam (guest speaker) and Prof. Mike Petterson at the diversity 'awareness day' held at the National Space Centre, Leicester (*left*).

Macmillan Cancer Support 'The World's Biggest Coffee Morning': staff raised over £1100 in 2006 (*below*).

New legislation covering flexible retirement is now a manpower planning challenge but the BGS has retained flexibility to ensure that individual and business needs are met. During the year 16 staff who reached the Research Councils Pension Scheme pension age elected to remain and 9 staff retired but were rehired on different contracts. In addition 18 staff retired completely.

We continue to review our skills base and as part of the strategy discussions all our staff were classified within skill groups.

During the year we have continued to implement diversity initiatives. We launched our first 'awareness day' in Leicester where we invited members of the community to attend a presentation on the work of the Survey. This was very successful and further days are planned for Derby and Nottingham. We have also implemented the first phase of a mentoring scheme for staff. We have continued work experience arrangements with locally based schools as well as supporting placements for voluntary workers.

A major part of the year has been spent working with the Research Councils UK project team to define the business case for the Shared Services initiative. The Shared Services centre will be based in Swindon and will undertake the Human Resources (HR) transactional process as well as those of Finance, Grants and Information Technology for all of the six research councils. The BGS will retain a focused HR partner model, providing a partnership with the BGS and NERC business to shape and develop the people strategy to achieve 'Next Generation Science for Planet Earth'. During the planning and implementation phases Personnel will have the challenge of ensuring staff numbers and staff morale are maintained.

The new Directorate suite, one of several offices recently upgraded and converted to open plan.

Administration and Operations Support

Estates and Health & Safety

The past year saw substantial progress on a major redevelopment of part of the Keyworth site which will replace Blocks A to F with a purpose-built, environmentally friendly, building designed to meet the needs of the Survey and its staff over the next fifty to sixty years. The new building will be named after William Smith, the pioneering British geologist. The design has been completed and much preparatory work undertaken. It is expected that a call for tenders will be issued early in the 2007/08 financial year.

Work has also been undertaken to refurbish areas of the site for occupation by those staff who need to be relocated during the development work. Blocks A, B and C have been vacated prior to demolition and the refurbished areas have been generally well received by the decanted staff. The staff restaurant kitchen in Keyworth has also been refurbished.

In Edinburgh, work has started to improve the central corridor of Level One at Murchison House in order to make it a more useful space.

In parallel with these major initiatives, work has continued across the Survey's sites to operate the maintenance regimes already in place and to meet the ad hoc requests from staff for a wide variety of works in support of BGS science.

Quality and environmental management

This year has seen continued progress on the rollout of management systems and their implementation throughout the Survey. The driving force behind this initiative has been the business needs of the BGS and the requirement of the quality management standard ISO 9001:2000 for systems to be in place that encourage a climate of continuing improvement and for the organisation to be able to demonstrate this. Systems continue to be implemented which reflect the way that the Survey works and manages its science.

The infrastructure to support these initiatives is firmly established and a programme of internal audits is being carried out to benchmark performance against the standards. An ongoing external audit process carried out by British Standards Institution has continued to give confidence that the BGS's structure and existing operational organisation will allow compliance with the standards by fine-tuning the way we work rather than requiring radical widespread change.

The BGS environmental management system continues to develop and improve. In 2005 the BGS became the first NERC research centre to be registered to ISO 14001:2004, the environmental management standard.

Waste management

Both the Keyworth and Edinburgh sites have comprehensive recycling systems in place. In 2006/07, for example, 41 tonnes of paper/cardboard, 36 tonnes of scrap metal, 21 tonnes of wood, 5.4 tonnes of glass, and 8.6 tonnes of obsolete IT equipment were recycled at Keyworth.

The Keyworth office now uses only half the amount of paper it used in 2004.

West elevation of the proposed design for the William Smith Building (*above*). © Pick Everard

The kitchens in the staff restaurant at Keyworth were completely refurbished this year *(opposite)*.

Energy

All the electricity which BGS purchases is 'green', that is, generated from renewable energy sources. Planning permission has been granted for the installation of a wind turbine on the Keyworth site and it is hoped that permission will also be granted for smaller turbines in Edinburgh.

Health and Safety

The NERC/BGS Health and Safety support arrangements are continually reviewed throughout the year to reflect organisational changes and to ensure legislative requirements and current best practice are fully adopted. Staff are encouraged to participate in all aspects of the management process, enabling the BGS to forge strong communication links and to benefit from our in-house experience and expertise. Our open policy and proactive approach to promoting a positive safety culture is a key contributor to raising our standards and strengthening our profile. Health and safety management 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 BGS staff on a wide range of health issues. Sessions to raise awareness and address specific concerns relating to occupational health issues have been arranged throughout the year, and our investment in promoting a healthier lifestyle, through well-being, sports and relaxation sessions, has been well received.

Accidents and incidents

All accidents, near-miss and occupational ill-health incidents are investigated and reported to the NERC Board through the BGS Executive Committee. An online reporting system, designed to give clarity, accuracy and ease of reporting, has been developed and is due to go 'live' within the BGS towards the end of 2007. According to our current statistics, we have achieved a 7% reduction in our 2006/07 accident rate compared with 2005/06. This is one of the indicators for measuring the success of our Safety Management Systems. By maintaining a robust risk management strategy and safe working practices, and in accordance with the Health and Safety Commission's strategy for revitalising Health and Safety, we aim to achieve a further 10% year-on-year reduction.

Health and safety training

The BGS has continued its commitment to staff training, engaging in a variety of methods to improve its skills base and maintain competency levels. Appropriate training is arranged for all staff to enable them to carry out their work safely and efficiently, whether in the office or out in the field. This year, in addition to our core induction and health and safety modules, we have joined with the NERC in focusing on training a number of staff in Display Screen Assessment and Manual Handling techniques, equipping us with competent staff to give instant advice when it is needed.

Audit and review

In line with their annual schedule, the NERC carried out a health and safety audit of the Keyworth Workshops. Recommendations for minor improvements were made which have been followed up and implemented. We will continue to follow our formal health and safety audit schedule in order to monitor progress and make necessary improvements.

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