2005-06

Annual Report

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

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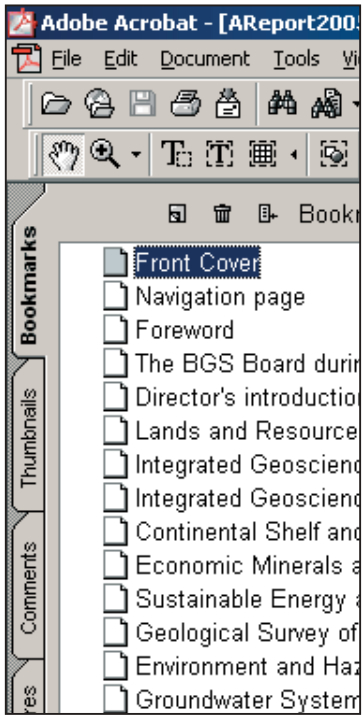

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Centre for Ecology and Hydrology
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Proudman Oceanographic Laboratory
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www.pol.ac.uk

The NERC also funds collaborative centres in partnership with other organisations. For the full list of NERC centres see the website at: www.nerc.ac.uk

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NATURAL ENVIRONMENT RESEARCH COUNCIL

The British Geological Survey (BGS) is a component body of the Natural Environment Research Council (NERC) — one of the eight research councils that fund and manage scientific research and training in the UK. The NERC uses a budget of around £375 million a year to fund independent research and training in the environmental sciences. About half of its budget goes to universities, and half is invested in its own research centres.

The NERC's vision is to advance knowledge of the Earth and its environments to help secure a sustainable future for the planet and its people. The NERC's work covers the full range of atmospheric, earth, terrestrial and aquatic sciences — from exploring deep oceans to observing the Earth with satellites. Investment is made in a broad spectrum of research from non-directed 'blue skies' work, through a range of directed investments, to more applied and long-term strategic research and survey activies that underpin national and international needs.

The NERC's current strategic priorities are:

- Earth's life-support systems: water, biogeochemical cycles and biodiversity.
- Climate change: predicting and mitigating the impacts.
- Sustainable economies: identifying and providing sustainable solutions to the challenges associated with energy, landuse and hazard mitigation.

Some of the research reported here is still in progress and may not yet have been peer-reviewed or published.

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British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

THE MISSION OF THE BGS IS TO:

Advance geoscientific knowledge of the United Kingdom landmass and its continental shelf by systematic surveying, long-term monitoring, effective data management, and high-quality applied research.

Provide comprehensive, objective, impartial, and up-to-date geoscientific information, advice, and services to the client and user community in the United Kingdom and overseas, enabling safe, sustainable and efficient choices to be made in managing the environment and utilising its resources; thereby contributing to national economic competitiveness, the effectiveness of public policy, and the quality of life.

Disseminate information in the community, and promote the public understanding of science, to demonstrate the importance of geoscience to resource and environmental issues.

FUNDING BGS SCIENCE

The BGS is a Public Sector Research Establishment, partly funded by the Science Budget, via the Natural Envirnment Research Council (Strategic Data and Knowledge), and partly from independent research commissions, sales and services. The BGS is a 'public good', not-for-profit organisation. The commissioned portfolio itself includes a significant proportion of fully funded geoscience that directly enhances the Core Strategic Programme and increases the skill base of the organisation. Income from sales and chargeable services also feeds back into enhancing the Core Strategic Programme and developing additional products and services.

CORE STRATEGIC SCIENCE

Our principal business is the execution of the Core Strategic Programme in furtherance of the NERC's mission supported by, and in synergy with, an active portfolio of commissioned research. The Core Strategic Programme is delivered through three user-facing directorates: Lands and Resources, Environment and Hazards, and Information Services and Management. These directorates are underpinned by development of capability projects administered by the Geoscience Resources and Facilities Directorate. The programme entails long-term surveying, monitoring, databasing, undertaking key environmental research, and the provision of scientific advice (knowledge transfer).

COMMISSIONED RESEARCH

This programme comprises strategic commissions and partnerships with a wide range of clients. Our customers include government departments, agencies, local authorities, the European Union, international aid agencies, the World Bank and overseas governments, as well as UK industry, commerce and the public. The Commissioned Research Programme enhances the Core Strategic Programme through funding, ideas, data, and review. It facilitates more vigorous multidisciplinary work than could otherwise be afforded, including the development of expertise and the maintenance of a critical mass of scientific expertise within each project area. This enhancement constantly demonstrates the relevance of our science to government, industry, and society.

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Foreword

Mr Derek Davis
Chairman of the BGS Board

As you will see from the Report, 2005-06 has been a strong year for BGS. Turnover and earned income have continued to grow and welcome new investment in infrastructure from the Science Budget is under way.

The Survey's strengths are centred in its unique data holdings and the expertise of our staff in keeping the knowledge base fresh and actively integrated into new science and new applications. The scope of the role increased during the year with the transfer from DTI of responsibility for offshore drilling cores. The new National Geoscience Data Centre, Gilmerton Corestore, was opened by Mr Nigel Griffiths, MP for Edinburgh South and Deputy Leader of the House, on 12 October 2005 and the BGS now provides a comprehensive service covering the full drilling record. The innovative Tellus airborne survey in Northern Ireland was also completed and is yielding a wealth of new near-surface information whose scientific, economic and environmental potential will be tapped for years to come. On the applications front, the joint BGS–Coal Authority Ground Stability Report has been specified as one of the authorised documents for the new Homebuyers' Information Pack and will be launched in the autumn. It will provide prospective homeowners across the country with clear read-out about the geology on which their property stands. This is an excellent example of BGS knowledge harnessed systematically for the benefit of the whole community.

The Report details more fully the span of thriving activity that marks the culmination of Dr David Falvey's term as Executive Director. Dave revitalised, energised and quite literally brought BGS into the twenty first century. We all owe him an enormous debt of gratitude and wish him every success in his new role at the Australian Research Council as Executive Director, Physics, Chemistry and Geosciences.

Challenges before us include finding ever more productive ways of promoting and supporting new science and the take-up in exploitation of investment in the geosciences. There are major opportunities across the whole environmental agenda and in areas such as the coastline, nuclear waste disposal issues and energy. We are giving particular attention to our interface with the academic community and to the combination of means best suited to advance and maximise exploitation.

The BGS is extremely fortunate in having secured the services of Dr John Ludden as our new Executive Director. He returns to the UK after a 30 years absence in the USA, Canada and France, most recently as Research Director of the Earth Sciences Division at CNRS, and is already fully engaged on the task ahead.

The BGS Board during 2005/06

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 NERC 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

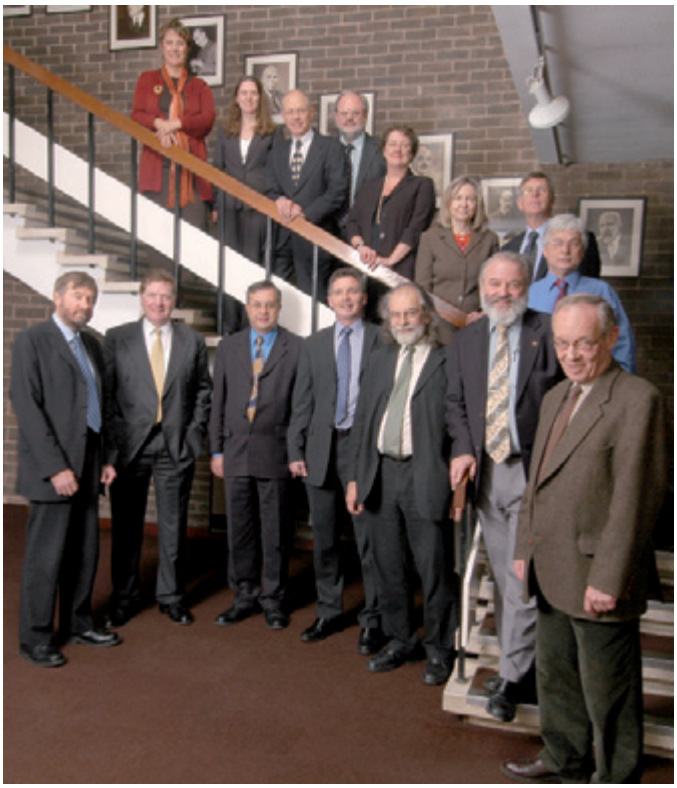
Mr Derek Davis	(Chairman), formerly of the DTI
Dr O Bavinton	Head of Exploration and Geology Anglo American plc (until December 2005)
Mrs R Johnson-Sabine	Vice President Maersk Oil UK Ltd
Dr R Scrutton	Reader in Marine and Applied Geophysics, School of Geosciences, Edinburgh University
Mr Jeff Smith	Managing Partner, Wardell Armstrong
Professor P Styles	Director of Research Institute for the Environment, Physical Sciences and Applied Mathematics, Keele University
Professor L Warren	Zoologist and Emeritus Professor of Environmental Law at the University of Wales
Dr S Wilson	Director Science and Innovation, NERC
Dr B Marker	Office of the Deputy Prime Minister (Observer until December 2005)
Mr P Bide	Office of the Deputy Prime Minister (Observer from December 2005)

BGS Executive Committee

Dr D Falvey	Executive Director
Mrs K Grant	Director, Administration and Operations Support
Mr D Holmes	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

Ms G Ager, BGS



The BGS Board, November 2005: *(l to r)* back row: Professor L Warren, Ms G Ager, Dr R Scrutton, Professor P Styles, Mrs K Grant, Mrs R Johnson-Sabine, Dr M Lee, Professor M Petterson; front row: Mr P Bide, Mr J Smith, Mr D Ovadia, Mr I Jackson, Dr B Marker, Dr D Falvey, Mr D Davis.

Director's introduction

John N Ludden, Ph.D.
Executive Director

The BGS label is known worldwide and is synonymous with delivery of high quality strategic information in surveying and monitoring underpinned by, and as a prime resource for, research in the geosciences. It is an honour to have been invited to direct the BGS and I am looking forward to leading the Survey as part of the NERC executive.

I would like to express my gratitude to Dr David Falvey, who would normally have signed off the 2005–2006 Annual Report. David moved on early as the opportunity to take on an exciting role as a director with the Australian Research Council developed.

This report highlights the move that the BGS has taken into the digital delivery of data. The Survey is leading the world, from the production of high-resolution site-specific maps, through 3D digital models, to data essential to the end-user. The increased demand from the end-user for strategic environmental information will be a challenge for information delivery that the BGS will meet.

Mapping, coupled with the geophysical, geochemical and physical properties baseline, is the fundamental product of the BGS. The Survey has recently been innovative in applying these products in strategic environmental domains, most notably in mapping the continuum from the bedrock to the Quaternary deposits of the UK landmass. The TELLUS high-resolution airborne survey of Northern Ireland, carried out for the Department of Enterprise Trade and Investment (DETI), is now almost complete. These data and those to be obtained in future surveys will radically change the interpretation of the UK landmass. This strategic geo-environmental mapping will include numerous end products and opportunities for add-on science for the entire spectrum, from academic research to stakeholders in the building industry.

Climate change has a real and demonstrable environmental impact, and as outlined below, the BGS will play a key role in studying the vulnerability of the landmass to climate change and also mitigation strategies. Nonetheless, geologists know that the Earth has changed at various rates throughout its history and much of the mapping of the BGS has led to significant discoveries in this area. For example, work under way with university collaborators in the Charnwood Forest area appears to be pushing back the limits of our understanding of the radiation of life on the planet about 600 million years ago. Despite the environmental emphasis of the BGS, key groups working on providing new discoveries in the ancient Earth must be maintained.

Research centres provide science information for public good and, as such, must have the ability for rapid reorientation of their science objectives. The BGS has, and will in the next decade, play a major role in studying the geological hazards affecting the Earth and specifically UK interests. The work in monitoring volcanic activity in Montserrat provides an excellent example

of the BGS's abilities in this field. The environmental changes related to the changing climate will have the most notable effect on the coastline, the soils and the hydrogeology and hydrology of Britain and of the rest of the world. The science presented in this report shows how the BGS has already redefined its science delivery focus in these areas, all of which could also be integrated better with academic research in universities and other NERC, UK and international research centres.

The BGS has a long history of international activities and a significant proportion of its commissioned research is undertaken internationally. The BGS should be seen to be active internationally and recently the focus has been mapping and digital data delivery in developing countries for which the BGS must bid competitively through the World Bank and other agencies. The end product is the establishment of a geological infrastructure for capacity building and economic development and building long-term trust and economic and scientific ties with these countries.

BGS science is underpinned by administrators who have developed one of the best project management schemes in NERC and I thank them for their quiet competence that is often hidden behind the exciting science. I am excited by the prospect of adding to the scientific results which are developed in this 2005–2006 Annual Report. On behalf of all of the BGS staff I thank David Falvey for bringing the BGS into the twenty-first century during his period as Executive Director from January 1998 to July 2006.

In 2005/06 the BGS's work programme was organised around three Programme Directorates: Geology and Resources; Environment and Hazards; and Information. 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.

Executive Director				
Geology and Resources Directorate				
National Geoscience Framework	Geology and Landscape (Northern Britain)	Geology and Landscape (Southern Britain)		
Marine, Coastal and Hydrocarbons	Economic Minerals	Geological Survey of Northern Ireland		
Environment and Hazards Directorate				
Groundwater Management	Sustainable Soil Management	Chemical and Biological Hazards	Physical Hazards	
Electrical Tomography	Seismology and Geomagnetism	Sustainable and Renewable Energy		
Information Directorate				
Information Management	Information Delivery	Information Products	Information Systems Development	
Geoscientific Skills and Facilities Directorate				
Publications	Laboratory Operations	NIGL	Training	IT Infrastructure
Geology	Geophysics	Geochemistry	Information Systems	Support Services
Business Development and Strategy Directorate				
UK Business Development	International	Corporate Policy and Science Coordination		
Administration and Operations Support Directorate				
Finance, Accounts and Contracts	Personnel Administration	Estates		

Overview of the BGS Programme

Summary

The BGS's Core Strategic Science Programme has been comprehensively revised for the period 2005 to 2010 to enhance and develop our role as a world-leading geological survey.

The new programme builds upon strengths identified in the NERC 2003 Science and Management Audit (SMA) of BGS, and takes into account changing user needs identified through engagement with stakeholders. The SMA fully endorsed the BGS mission and made a number of recommendations, which have been brought forward in the new programme.

The BGS's Core Strategic Science Programme, which has been successfully implemented during 2005–2006, consolidates previous successes and implements some fundamental strategic changes in emphasis and approach. Embodied in the programme are several key objectives, including:

- An initial step towards a comprehensive, three-dimensional characterisation of the physical surface and subsurface of the UK landmass, onshore and offshore.
- Four-dimensional models that describe the complex interactions between the human, physical, chemical and biological processes that occur beneath our feet — linked to other Earth system science processes (atmosphere, hydrosphere, biosphere and oceans), and developed with partners.
- Strong data management, delivery, and accessible decision support systems (highly dependent on visualisation) for use by the public and private sectors in land and resource assessment and use, waste disposal, infrastructure development, climate change and hazard mitigation.
- Contributing knowledge that will sustain the global environment in the context of growing population, expanding wealth and unrelenting resource demands (particularly for water and clean, affordable energy), applying these skills and expertise to assist international development and post-conflict reconstruction in the broader interests of UK diplomacy, policy and trade.

The programme is built around eight strategic science themes, which have been defined from an analysis of a range of external drivers. The eight themes are:

- 3D Geoscience Framework of the UK Onshore Landmass.
- Geoenvironmental Information.
- 3D Characterisation of the Coast, Continental Shelf and Margins.
- Sustainable Water Management.
- Sustainable Soils Management.
- Sustainable and Secure Energy Supplies and Mineral Resources.
- Physical, Chemical and Biological Hazards in the Geosphere and their Impacts.
- Monitoring Tectonic and Whole-Earth Processes.

A functional framework has been established as the delivery mechanism for the new programme *(see figure, page 7)*. The framework encompasses seventeen geoscience programmes across three Directorates: Geology and Resources, Environment and Hazards, and Information.

The geoscience programmes are detailed within the pages that follow. They contribute significantly to, and impact on, the improved understanding of high-level science and policy issues of global importance. Five issues have been defined that encompass specific NERC priorities and contribute to Government targets and policies. Each element of the BGS programme addresses these five 'cross-cutting' issues, which are:

Rural Economies and Land Use, Land Quality: The sustainable use of land in the UK is essential to support continued economic and social development and an improved quality of life. The BGS contributes to the protection of the natural environment, including viable agriculture and forestry, water resources and soil

functions. We provide geo-environmental information to underpin land management strategies, environmental risk assessments, planning and development at local, regional and national scales. For example, geological surveying and 3D modelling work is allowing revision of the geological framework for areas where current maps are inadequate to support greenfield and urban development such as the South East England Development Zone, including the Thames Gateway.

Climate Change: Climate change is one of the most important issues of our times. The science undertaken by the BGS contributes to a better understanding of the causes of climate change, its potential impacts on the environment and landscape of the UK, and how society can decrease the rate and amount of change. With our partners, we are evaluating the geological controls on past climate change. We are assessing geological aspects of climate change mitigation through, for example, the potential storage of greenhouse gases so that they do not enter the ocean-atmosphere system. We are supporting the integration of renewable energy generation and the development of sustainable energy solutions, such as ground source heat pump technology, to reduce our dependency on fossil fuels.

Earth's Life Support Systems: The cycling of key natural and man-made chemical elements and compounds influences the health of the Earth system. It is important to understand the interactions between the shallow subsurface of the Earth and the water cycle, the atmosphere and living things. The BGS programme includes study of processes at critical interfaces such as in soils, the zone underlying rivers and lakes, groundwater, freshwater–saline interfaces and ocean margins. For example, our work in the area of hazards is increasing understanding of the processes that control hazards, assessing the effects of changing land use on the uptake of natural and man-made toxic contaminants by living things, and developing understanding of long-term ecosystem stability in response to external influences.

Energy and Natural Resource Security: BGS geoscience seeks to support government initiatives to maintain the reliability of energy supplies. We work closely with the energy sector to support oil and gas exploration and development. Our geological models of the subsurface can help to identify suitable sites for underground fuel-storage facilities. These will need to be developed for security of supply and public safety as the UK's North Sea oil and gas production declines and the UK imports more energy. The BGS is an international centre of excellence for underground carbon dioxide storage and is working closely with governments and industry to develop the next generation of near zero-emission power plants. We also support associated geohazard and environmental programmes in the UK and around the world.

International Development: Two essential components for economic development are a soundly based knowledge of a country's natural resources, such as groundwater, minerals and energy, and an understanding of the geological environment. The latter includes the potential effects of earthquakes, volcanic eruptions and landslides. A key objective of the BGS's international work is to help developing countries to acquire this knowledge and to apply it to promote economic growth, sustainable livelihoods and the protection of people. Our international work includes institutional support and staff training, assessment, prediction and mitigation of natural geological hazards, and assessment of groundwater resources.

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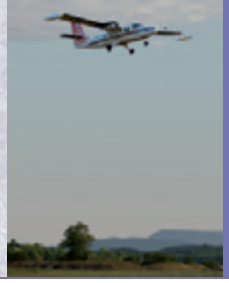
Geology and Resources Directorate



The **Geology and Resources Directorate** (**GRD**) operates through six multidisciplinary survey and research programmes. These are designed to define the three-dimensional geology and environmental characteristics of the UK landmass and continental shelf, and provide information on the distribution and exploitation potential of energy and mineral resources. The aim is to provide a sound geoscientific 'evidence-base' to underpin decisions on the utilisation and protection of the land, coast and seabed and the sustainable development of the nation's natural resources. The BGS-funded work programme in the UK is enhanced by external funding in the form of commissions from government departments, regulatory agencies and industry-sponsored research consortia. We also operate in Europe and worldwide through international research projects and commissioned contracts. The work carried out by GRD directly underpins that of the Environment and Hazards Directorate *(see pages 24–39)* and generates many of the publications and digital products delivered through the Information Directorate *(see pages 40–49)*.

Two major advances during the past year have been the establishment of a National Geoscience Framework of baseline geological, geophysical and geochemical data (*right*) and the generation of 3D geological models as a standard output from an increasing number of projects. The value of 3D geological information was also recognised externally and has resulted in several commissions to provide detailed 3D structural models of key areas. Further advances were made in the development of digital field data capture systems for geological mapping with the successful trial of a new ruggedised tablet PC. This enables mapping teams to take an entire project GIS into the field and update the geology dynamically, based on all the available data.

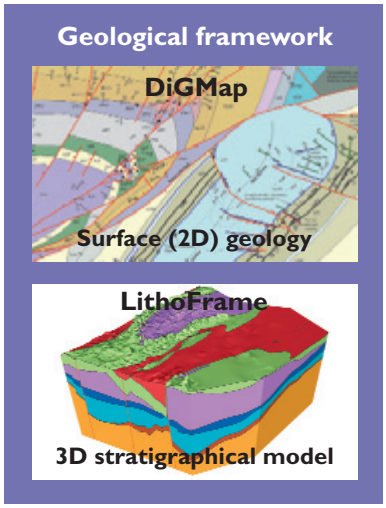
A major highlight was the launch of the Tellus airborne geophysical survey in Northern Ireland and the successful completion of the western half of the province. The survey was carried out by the Joint Airborne-geoscience Capability (JAC), established between the BGS and the Geological Survey of Finland (GTK) in 2004. The Twin Otter aircraft is equipped with magnetic, radiometric and electromagnetic (EM) sensors and the initial results highlight many previously unknown features. A major upgrade of the EM system (from two to four frequencies) was also completed, providing much greater 3D resolution of conductivity anomalies in the shallow subsurface related to pollution, mineralisation and concealed structure.

In the marine domain, a major highlight was the completion of the Tahiti Sea Level Expedition for the Integrated Ocean Drilling Programme, which successfully cored Holocene reefal limestones in shallow water. Two multibeam surveys were also carried out as part of the new seabed-mapping programme. Data from around the Summer Isles (north-west Scotland) resolved spectacular submarine glacial features, such as moraine ridges and fjord troughs, that link with new mapping of the Quaternary geology onshore and provide new insight into the evolution of the British Ice Sheet.

An important milestone in the minerals sector was the completion of the flagship Mineral Information Online system for England; a web-based geographical information system providing a range of spatial, text-based and statistical information for planners and the wider community. The hydrocarbons sector remained active and a new project was established to develop a comprehensive atlas of the Southern Permian Basin in collaboration with oil companies and European geological survey organisations. Geo-heritage activities have again been prominent and continue to raise the profile and relevance of geoscience in the tourism, education and conservation sectors.

(Opposite) The NERC Twin Otter aircraft, equipped with upgraded electromagnetic survey equipment, in operation during the TELLUS airborne geophysical survey project in Northern Ireland.

National Geoscience Framework: The establishment of a National Geoscience Framework (NGF) is a central theme of the new BGS programme for 2005–10. Its development is coordinated by the NGF programme (*see page 12*) but all BGS programmes will contribute to its population. It comprises four components as illustrated below.



National Geoscience Framework

Programme overview

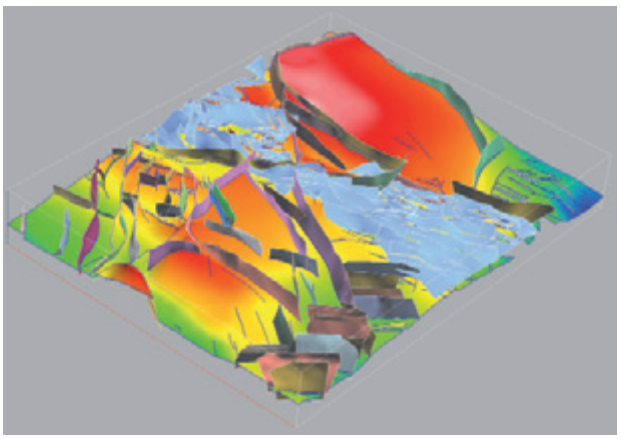
This programme was established in 2005 with a remit to manage the development and population of the National Geoscience Framework through projects within the programme itself and more widely across the whole of the BGS. It is directly responsible for the delivery of integrated, regional-scale data and information on the 3D geology and geophysics of the onshore UK. This provides the evidence base for a range of applications, 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 information also provides a consistent national framework for higher resolution maps, 3D models and value-added data delivered by other BGS and NERC programmes. In addition, the programme develops and updates the geoscientific standards and best practices required to manage and assure the quality and consistency of scientific output across the entire BGS scientific programme.

Spatial knowledge base of UK regional geology

The Digital Geoscience Spatial Model project (DGSM), completed in 2005, developed a wide range of powerful new digital tools and methods for modelling, visualising and analysing the subsurface environment in three dimensions. These are now being deployed across the entire BGS programme, and are providing a growing number of new services and products to BGS clients in the local government, environment and resource sectors.

LithoFrame models are digital 3D representations of the stratigraphy and structure of the geological subsurface. Essentially, they are the 3D equivalent of a geological map and are likewise constructed to a defined resolution of stratigraphical and structural detail. Regional LithoFrame models define the subsurface to a depth of ten kilometres; they include lithostratigraphical units to Group level and faults with vertical displacements of more than 100 metres, broadly equivalent to the resolution of a 1:250 000 scale geological map. Regional LithoFrame models provide geological knowledge to support the UK's growingly sophisticated requirements for strategic management of energy resources, groundwater, underground gas storage and geological disposal of wastes. They also form a consistent framework for construction, by other BGS programmes, of higher resolution LithoFrame models, which provide 3D geological information for local planning, regulatory and site-specific applications.

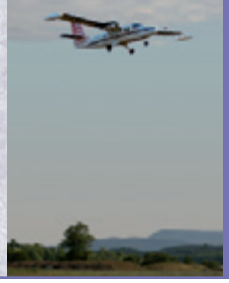
The Craven Basin of north-western England will be the first Regional LithoFrame model to be released and is also being used to refine modelling procedures. Construction of the model requires use of sophisticated software and interpretation of large amounts of diverse geological data in an integrated and consistent way. The first stage of construction, completed during the year, incorporates the stratigraphical surfaces and faults interpreted during compilation of the Craven Basin Subsurface Memoir, published by the BGS in 2000. These surfaces provide a reliably interpreted framework, based on high-quality seismic profile data and boreholes. The second stage will be to complete the model by interpolating other stratigraphical surfaces, adding lithological attributes and tying the model to the surface geological map. Work has also commenced during the year on production of Regional LithoFrame models of other areas, including Yorkshire and the East Midlands.



Spatial knowledge base: extract from the Regional LithoFrame model of the Craven Basin, showing the Caledonian unconformity surface (coloured according to depth) and the top of the Lower Carboniferous Chatburn Limestone (pale blue). Also displayed are a number of fault surfaces generated by linking fault gaps between horizons.

Enhancing regional airborne survey capability

The BGS's airborne geophysical survey capacity is provided through the Joint Airborne-geoscience Capability (JAC), based on an NERC-owned Twin Otter aircraft, and operated in collaboration with the Geological Survey of Finland. Major developments were completed during the year, using the TELLUS airborne geophysical survey project in Northern Ireland as an operational platform for training staff and deploying new, state-of-the-art equipment. The BGS airborne survey team is now fully trained in airborne geophysical equipment operation, quality control of the large amounts of data that are acquired daily, and post-survey data processing.



A research and development programme was completed to install and test a major upgrade of the electromagnetic (EM) survey equipment carried by the JAC aircraft. The system now employs four frequencies (from 900 to 25000 hertz), providing unique capability on a fixed-wing aircraft, and has been deployed for the first time on phase II of the TELLUS project which commenced in March 2005. Numerical algorithms have been developed for the inversion of the four-frequency data that will enable increased resolution of subsurface EM properties in both vertical and horizontal dimensions. The resulting interpretations will improve mapping of the geology in terms of its electrical properties and allow greater depth discrimination when investigating and modelling EM anomalies related to pollution in the subsurface. Additional development has focused on enhancing data quality management and validation systems, including more efficient methods for removing man-made artefacts ('deculturing') from aeromagnetic survey data and installing ancillary systems (a laser altimeter and a digital video system) on the JAC aircraft.

Enhancing regional airborne survey capability: new JAC four-frequency electromagnetic survey system installed on wing-tip pods and magnetometer in nose 'stinger'.

Improving geoscience information standards and consistency

The Geoscience Standards and Nomenclature project was established this year to update the standards and nomenclature used in the BGS's digital data and publications, and communicate these to users through lexicons, glossaries and research reports on the BGS website.

Substantial updates to classification of Lower Cretaceous, Middle Jurassic, Triassic, Carboniferous and Devonian successions have been delivered via the online BGS Lexicon of Stratigraphical Units. New downloadable research reports include the holostratigraphy of the Albian Stage (Lower Cretaceous) of the UK and continental shelf, and the lithostratigraphy of the Upper Cretaceous Chalk of England and Scotland. An overview of onshore Quaternary and Neogene deposits was also published and describes the rationale for a radical overhaul of the classification of natural superficial deposits based on lithostratigraphical principles. This new scheme is now being applied to BGS maps and 3D models and will substantially improve understanding and documentation of climatic and sea-level changes preserved in the Quaternary and Neogene geological record.

The BGS Rock Classification Scheme (RCS) remains the only comprehensive system for describing and classifying rocks and unconsolidated deposits that is widely available on the internet and designed specifically for use in digital databases. The RCS is the most popular download from the BGS website (30 000 downloads in 5 years) and has been widely adopted by numerous organisations and researchers worldwide. A scoping of the latest international research on rock classification was completed during the year and work is in progress to upgrade the downloadable RCS reports and online dictionaries. Updates will be released progressively on the BGS website as they become available.

Implementation of an integrated digital workflow for field data recording and map compilation has required a substantial overhaul of the quality management system for validating and approving BGS high-resolution digital maps. The system will also be applied to validate the 1:10 000 DigMapGB data delivered by digitisation of the BGS national dataset of large-scale geological maps, currently progressing within the BGS Information Products programme.

Improving geoscience information standards: cover photograph for the Upper Cretaceous Stratigraphical Framework Report: Chalk cliffs and the Pinnacles stacks near Swanage, Dorset.

Geology and Landscape

Programme overview

The Geology and Landscape Northern Britain programme is responsible for providing two- and three-dimensional strategic geological and rock-mass information for northern England and Scotland. These data, delivered in analogue and digital formats, 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. Survey and modelling activity was focused on the Assynt, Crianlarich, Killin, Ben Alder, Montrose, Loch Doon, Ettrick, Hexham and Kirkby Lonsdale districts, and a range of maps, books and peer-reviewed papers were published during the year.

Volcanic terrains of the western Highlands and Islands: BGS–university collaboration

University collaboration is an important element of the programme. During the year several key maps and texts were completed. The 60-million-year-old Hebridean Igneous Province is one of Scotland's geological 'jewels'. The Small Isles, parts of Skye, Ardnamurchan and northern Mull have been resurveyed on behalf of the BGS by staff of the universities of Durham and Glasgow. Fruits of this collaboration published during the year include a 1:25 000 scale map of the Skye Central Complex and a new edition of *The Palaeogene volcanic districts of Scotland*, part of the *British Regional Geology* series that provides comprehensive regional overviews for the informed amateur, undergraduate and professional geologist, planner or civil engineer.

The Siluro-Devonian volcanic sequence at Glen Coe has undergone a new appraisal by staff of the University of Liverpool. In this area, almost 100 years ago, Survey staff made the first detailed analysis of how a large volcano was plumbed by magma, resulting in the influential 'cauldron subsidence' model. The new investigations have built upon and modified their model so that, in the words of the authors, the Glencoe volcano can now be regarded as 'the world's best exposed, tectonically controlled, multi-subsidence, piecemeal caldera-volcano'. A new 1:25 000 scale map is accompanied by a book in the *Classical Areas of British Geology* series that emphasises the volcanic processes and environments as well as their regional significance.

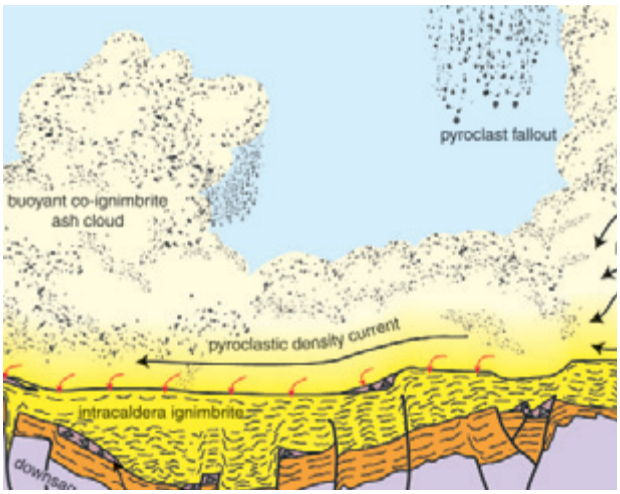
North-west Highlands — lateral ramps, dating and landscape evolution

Bedrock and superficial deposits mapping of over 2400 square kilometres in the north-west Highlands has now been completed, covering four 1:50 000 sheets, including the renowned Assynt Special Sheet. Structural analysis and LithoFrame profiles have demonstrated that the Assynt Culmination comprises several kilometre-scale, dome-shaped thrust stacks. New radiometric dates on minor intrusions show that the Moine Thrust Zone was emplaced later than 437 million years ago. To the east of Assynt, a major, ductile lateral ramp in the overlying Moine Supergroup rocks is associated with the classic mullion locality in Glen Oykel. Farther north, a BGS-supported Ph.D. project at the University of St Andrews has demonstrated the presence of a low-strain zone, with abundant large-scale sedimentary structures in the Moine rocks. In the foreland, a possible Archaean terrane boundary in the Laxford area has been recognised through field and geochemical studies.

A giant field of glacially sculpted grooves, cut up to ten metres deep into Moine bedrock near Ullapool, has been identified using NEXTMap Digital Surface Model data. These megagrooves suggest the existence of a Late Devensian ice-stream, draining into the Minch. A BGS-supported Ph.D. study (University of St Andrews) has resulted in the reconstruction of a previously unidentified Younger Dryas ice cap in the Ben Hee area.

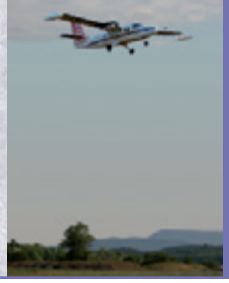
Orcadian lakes — fossil fish and palaeolimnology

High-resolution sampling and analysis of a single lacustrine cycle within the Caithness Flagstones has provided an insight



University collaboration: figure illustrating the caldera model from the Glen Coe classical areas book *(detail)*.

Northern Britain



Orcadian lakes: *Coccosteus cuspidatus*, a fossil fish typical of the Achanarras Fish Bed which formed in the deepest and most extensive lake within the Orcadian basin. Image courtesy of Roger Jones.

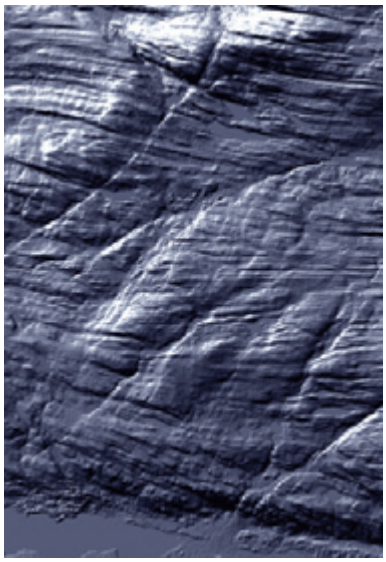
into palaeoenvironmental changes that occurred as water levels rose and fell in lakes that developed in the Devonian-age Orcadian basin of northern Scotland. Variations in lake level produced repeated transgressive and regressive sedimentary cycles that ranged from mixed fluvial and aeolian sandstones, through very shallow water ripple-marked siltstones, into laminated carbonate rocks. Fish beds developed when each lake was at its deepest and most extensive, and many contain spectacular fossil fish faunas that have allowed correlation of the succession throughout the basin. Core samples from boreholes drilled for NIREX and UKAEA as part of the Dounreay site-decommissioning programme, have revealed systematic changes in the ratio of terrestrial spores to lacustrine algal matter, and in total organic carbon and amounts of organic $\delta^{13}C$. These are all probably related to changing water salinity as the lake expanded and deepened, and also to changes in the atmospheric carbon dioxide concentration during Mid Devonian time.

Safeguarding Glasgow's stone built heritage

A 'stone health-check' of over two hundred buildings has been undertaken in Glasgow, designed to enable the city to plan a strategy for the future maintenance and repair of its valuable built heritage. Small diameter core samples have been extracted from over one hundred 'landmark' buildings in order to identify the most appropriate stone types required for repairs. Results from the study are also being used to ensure the training of sufficient skilled stonemasons for the future. The research, thought to be the first of its kind in the UK, was commissioned by the Scottish Stone Liaison Group and funded by Scottish Enterprise Glasgow and Glasgow City Council.

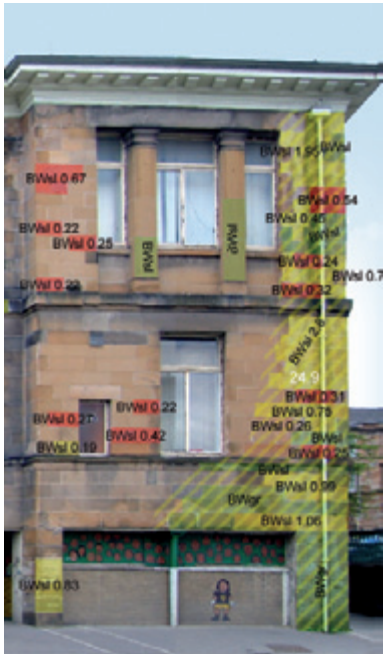
As part of the project, a methodology for the assessment of stone decay in buildings has been developed. The results of field and photographic surveys are displayed as digital overlays on rectified images of building facades showing different categories of stone decay. The data produced are intended to provide information on mechanisms and causes of stone decay, and to quantify the amount of stone required for repairs. Samples of stone from the buildings have been prepared as thin sections and compared with stone from quarries throughout the UK from the BGS building stone collections. This 'stone matching' is essential in order to select stone types for repair that are compatible in the long term with the original stone used in the buildings.

North-west Highlands: NEXTMap Digital Surface Model hillshade image of the area East of Ullapool. The east-west stripes represent megagrooves cut between five and ten metres into Moine psammites. Ice flowing from right to left. Image is 4 × 6 kilometres.



NEXTMap elevation data from Intermap Technologies

Safeguarding Glasgow's stone built heritage: rectified image of part of a surveyed stone building in Glasgow, with digital overlays showing categories of stone decay, enabling calculation of volumes of stone required for repairs.



Geology and Landscape

Programme overview

The programme undertakes high-quality integrated geological surveys and plays a key role in gathering data which enhances our understanding of the three-dimensional geology of the Southern Britain landmass, providing the geological framework which underpins research and development in other BGS programmes. It has an important role in ensuring that the detailed knowledge and understanding of the geology throughout the onshore UK landmass are maintained, thus enabling comprehensive and authoritative geological advice to be provided to stakeholders. Surveys were completed in the Fishguard, Llandovery, Newquay (Cornwall), Devizes, Dudley and Bedford districts during the year, and development of three-dimensional LithoFrame models was undertaken in several areas including Ipswich, Merseyside, north Nottinghamshire–south Yorkshire and part of the Thames Gateway.

Blakeney Esker Explored

The BGS collaborated with Norfolk County Council and Queen Mary College, University of London for the Blakeney Esker Explored project, funded by the Aggregates Levy Sustainability Fund (ALSF) and administered by English Nature.

The geology of North Norfolk provides a unique insight into recent climate change. Glacial processes have shaped the region and ice sheets have covered the area and deposited material at least five times during the past 800 000 years. Blakeney Esker started life during one of these recent cold periods. Fast-flowing meltwater filling a tunnel between the ice sheet and the land surface deposited large amounts of sand and gravel. Although the glaciers have long since retreated, the meandering sand and gravel ridge, the esker, remains as a prominent feature of the coastal landscape near the village of Blakeney.

The project's main aim was to raise public understanding of this well-preserved glacial feature. Local teachers were consulted throughout the project and provided useful advice on all aspects of the end products, which comprise a website and an information board at the esker. Topics covered include climate change, esker formation, biodiversity and eskers and man. For the general public, there are summary pages, a virtual field trip and a printable leaflet.

Dating igneous activity in Pembrokeshire

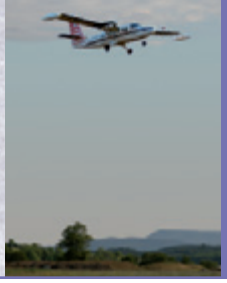
The Fishguard Volcanic Centre (Pembrokeshire) is volumetrically one of the largest Caledonian igneous centres in Wales, but the onset of magmatism and the age of certain components are poorly constrained. Understanding the timing of activity is crucial to clarifying the centre's relationship to the wider tectonic setting and to resolving the timing and dynamics of the initial stages of closure of the Iapetus Ocean. Collaboration between the BGS and the NERC Isotope Geosciences Laboratory is providing a chronological framework in support of the primary mapping of the area and allowing the supposed equivalence of chemically affiliated intrusive and extrusive units to be tested. Two high precision uranium–lead zircon ages have so far been obtained: one for a rhyolite from the Sealyham Volcanic Group and the other for a micro-granite of possible Precambrian age. The first gave an age of 471.7 ± 1.5 Ma (2σ), placing the Sealyham Volcanic Group astride the Lower/Middle Ordovician boundary. The second gave an age of 473.9 ± 1.2 Ma (2σ), placing the poorly constrained intrusion within the Arenig. Two more samples from the area are undergoing analysis before the focus moves north into central and north Wales over the next few years.

Roade railway cutting, Northamptonshire

Roade railway cutting, near Northampton, displays a fine sequence of Middle Jurassic limestone and mudstone strata of the Blisworth Limestone Formation, forming mural exposures up to 6.5 metres high and some hundreds of metres in length. The cutting has been afforded Site of Special Scientific Interest status on geological grounds, and is protected by English Nature. It lies on the main line between London and Birmingham, and engineering works proposed by Network Rail will render very difficult any future access to the exposed strata.

Blakeney Esker Explored: notice board at the Wiveton Downs Local Nature Reserve. The reserve is situated on the southern end of the esker, near the village of Glandford on the north Norfolk coast.

Southern Britain



We were commissioned to make a full description of the geology of the site and identify geological features that are of particular interest, and that would be visible from viewing points. For railway operational reasons, access to the sections was limited to the early hours of Sunday mornings between November and February, and a special mobile elevated working platform has been used to reach the higher parts of the sections. The sections have also been systematically photographed, producing synthetic panoramas, and parts have been laser scanned, generating three-dimensionally referenced data. Early results have shown the lateral variability of the Blisworth Limestone Formation and collections of its prolific bivalve fauna have been made.

Roade railway cutting: using the mobile elevated working platform to reach the higher parts of the cutting sides.

Revising the South Wales Coalfield

The bedrock geology of the South Wales Coalfield was surveyed in detail fifty years ago, at a time when hundreds of deep mines were still in operation. Today, only one deep mine, Tower Colliery, is active, but a number of major opencast sites are still extracting sizeable tonnages of coal from pits over two hundred metres in depth and several square kilometres in area. Recent revision surveys have focused on improving the superficial deposits mapping and delineating the extensive areas of artificially modified ground. A closer examination of mass movement deposits is also included in the revision.

The Swansea district is the first area in Wales to be completed with new 1:10 000 digital geological maps being produced. These have been prepared using a comprehensive set of scanned and georegistered historical Ordnance Survey six-inch topographic maps, and the latest NEXTMap orthorectified radar images, which very clearly highlight areas of ground disturbed by man. Our recent acquisition of full coverage of large-scale georectified colour aerial photograph images has enabled additional verification of artificial and superficial deposits aided by selective field checking.

A fresh look at the glacial deposits of the Midlands

At a time when groundwater supply and aquifer recharge are topical issues, it is appropriate that we should look at how we can better provide information on the nature of the superficial deposits that overlie many of our important aquifers. In rural areas, where there is often a dearth of borehole information, the relationships between deposits, their lateral variability and likely hydrogeological performance are often poorly known; this is particularly true of glaciated terrains. In a move to acquire additional information in such areas we have set up our own shallow drilling capability.

Glacial deposits of the Midlands: Dando rig in action in the Midlands.

Field trials in support of the resurvey of East Staffordshire have already produced exciting results that raise doubts about the accepted interpretation of the scattered glacigenic deposits of this region. Organic material recovered from between two tills near Burton upon Trent has been dated within the range of the Upton Warren Interstadial (circa 46 000–38 000 BP). This places the Devensian glacial maximum, which is poorly constrained in this region, at least twenty kilometres east of its previously mapped position, and indicates a chronology of multiple phases of ice advance and retreat. The recognition of a new and more complex glacial stratigraphy has wider implications for understanding the sequence of Quaternary events in the Midlands and highlights the importance of being able to carry out low cost, targeted drilling in support of ongoing survey activities.

Marine, Coastal and Hydrocarbons

Programme overview

Reorganisation of our marine and petroleum science means that for the first time there is a combined marine and coastal programme within the BGS. This is leading to improved integration between projects in the Keyworth and Edinburgh offices. A series of tasks focus on developing new methods to evaluate the unmapped coastal strip (the 'white ribbon'), and the launch of a new high-resolution marine and coastal mapping project based on sidescan and multibeam sonar data. During the year multibeam sonar and seismic data were collected in four offshore areas around Britain. Petroleum geology research is also benefiting from an integrated approach with regional studies in progress in the Southern Permian Basin, the Rockall Trough and the Faroe-Shetland Basin.

Petroleum geology

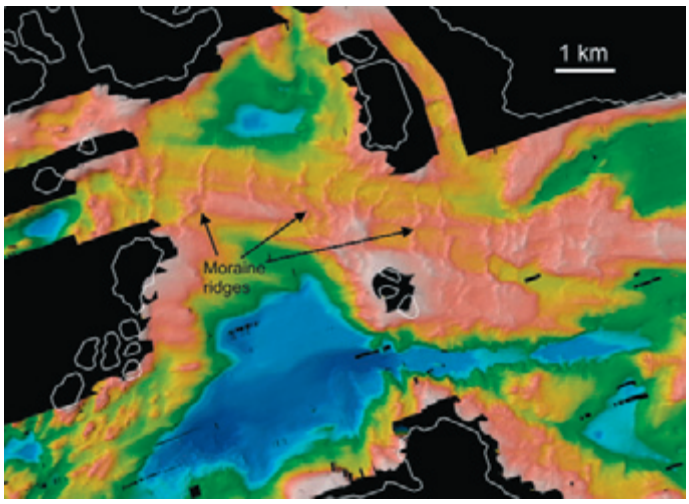
We received excellent support from the oil industry to enhance the core science programme, which focused on three major regional offshore reports. The Southern Permian Basin Atlas project is being lead by TNO in the Netherlands; the BGS is one of six national geological survey organisations participating in the project, which brings together the geology of the basin from eastern England to the Polish–Russian border. The first regional report for the Rockall area is being produced with support from the BGS Rockall Consortium, which includes five oil companies and the Department of Trade and Industry (DTI). A new report for the Faroe-Shetland Basin, supported by licence holders in the region, is being produced in partnership with the Faroes Geological Survey.

The commissioned research sector is also very strong, with further work being undertaken for DTI, the Falklands Islands Government and in the Middle East.

Seabed mapping

The BGS recognises the importance of new, detailed maps and models of the seabed for sustainable development of our marine resources. Increased exploitation and development pressures and directives from the EU require detailed information. We have participated in the development of a case for a new national mapping programme based primarily on multibeam sonar data, in collaboration with the Centre for Environment, Fisheries and Aquaculture Science, the UK Hydrographic Office, the Joint Nature Conservation Committee and others.

As part of our scientific programme, five new surveys were completed during the year, including new data in the Bristol Channel, around the Summer Isles off north-west Scotland, in the eastern English Channel and in the Rockall area. Some of these projects were completed in conjunction with the DTI Strategic Environment Assessments programme.

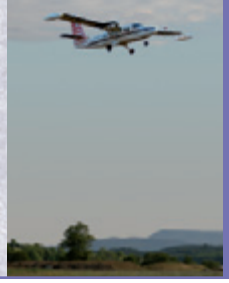


Seabed mapping: colour-shaded high-resolution bathymetric image of the sea floor around the Summer Isles, north-west Scotland. Shallow moraine-covered banks are white/pink; deep fjord troughs are blue/dark blue.

The project in the Summer Isles area has provided an excellent link across the onshore-offshore boundary and has enhanced our understanding of the last glacial retreat.

Estuaries and the open coast

Research this year has focused on the Holocene sequence of the River Thames in order to understand the evolution of the river during the past 10 000 years or so — research that is aligned with national and regional concerns about sea-level rise and potential future environmental impacts. The project has mostly involved the collation, evaluation and processing of existing map and borehole data held by the BGS to produce three-dimensional digital (LithoFrame) models. During winter 2006, a drilling campaign was undertaken to acquire core samples of the Holocene sequence suitable for subsequent engineering properties tests, Carbon-14 (^{14}C) dating and microfaunal analysis. Nineteen boreholes were



sunk at locations between Tilbury and the Isle of Sheppey. In addition to proving the bedrock at each site, penetrating the base of the Holocene sequence was essential for correlating key strata — particularly the organic (peat-rich) units that will be subject to ^{14}C dating.

Integrated Ocean Drilling Program (IODP)

The BGS-led European Consortium for Ocean Research Drilling (ECORD) implemented the Integrated Ocean Drilling Program (IODP) Tahiti Sea Level Expedition that aimed to establish an improved global sea-level curve for post-glacial time as well as identifying environmental changes during that interval. The expedition in the autumn of 2005 successfully cored Holocene reefal limestones in shallow water, obtaining excellent samples that were studied in detail during a meeting at the University of Bremen in early 2006. Drilling services were contracted to Seacore Ltd who used a piggy-back drilling system for obtaining high-quality core. It is anticipated that the objectives of the expedition will be fully met once detailed analyses on the cores have been completed.

Indian Ocean Tsunami research

The Indian Ocean earthquake and tsunami of December 2004 continued to be a focus of interest throughout 2005/06 resulting in our scientists giving numerous lectures explaining the event. We also continued to play a leading role in research into the disaster with participation in two marine research expeditions to the area of the earthquake rupture. In May we led a marine survey funded by the BBC and the Discovery Channel that searched for evidence of seabed movement associated with the earthquake and resulted in the BBC programme *The Unstoppable Wave* broadcast in December 2005. In January we participated in the expedition funded by the German Federal Institute for Geosciences and Natural Resources (BGR) that acquired over 5000 line-kilometres of multichannel seismic data over the region surveyed by HMS *Scott* in early 2005. The Indian Ocean event has also led to a raised awareness of tsunamis nearer to home and research continued into the regional impact in the Atlantic Ocean due to the possibility of collapse of the Canary Islands volcanoes.

Publications and students

This year saw the publication of an entire issue of Marine and Petroleum Geology devoted to the results of the Stratagem project, which studied the Neogene development of the north-east Atlantic Margin. All twelve papers feature BGS authors.

BGS staff contributed to the convening of a Petroleum Group conference on post-break-up inversion tectonics on passive margins. The Marine, Coastal and Hydrocarbons Programme now has four Ph.D. students jointly with Edinburgh and St Andrew's universities and Imperial College studying Palaeogene and Neogene tectonics on the Atlantic Margin, submarine landslides, Quaternary of the Central North Sea, and evidence for Quaternary climate change in the Rockall Trough.

IODP: *(below) DP Hunter* IODP drilling platform and *(bottom)* studying Holocene reef limestones at the Onshore Science Party, Bremen.

I Pheasant © IODP

E Gillespie © IODP

Estuaries and the open coast: drilling cored boreholes on the banks of the Thames estuary.

Economic Minerals

Programme overview

The Economic Minerals programme covers a range of topics that relate to the sustainable development of the nation's mineral resources. Its monitoring and research activities deliver up-to-date spatial and statistical information, as well as new approaches to mineral exploration, resource evaluation and management. The programme includes projects investigating mineral deposit models, the compilation and analysis of mineral production statistics to underpin policy, development of methodologies to assist in maintaining security of supply, and geographical information systems to support land-use planning decisions. The programme is supported by a major commission from the Department for Communities and Local Government (DCLG) and operates internationally as well as in the UK.

Understanding the formation of metallic mineral deposits

Against a backdrop of burgeoning global demand for raw materials and escalating metal prices, there has been a major upturn in mineral exploration activity worldwide in the past two years. This in turn has led to increased interest in the development of improved models for the genesis of metallic mineral deposits, and in new methods for identifying prospective terrains and for locating new resources, especially beneath cover. The BGS continues to develop its scientific capability in these fields through research in the UK and the supervision of post-graduate research projects overseas, for example in Mongolia, Cyprus and the Solomon Islands.

In line with current commercial interest in gold and base-metals in the UK, mainly in Scotland and northern England, we have undertaken research on the genesis of stratabound lead–zinc–barium–fluoride deposits in the Alston Block of the Northern Pennine Orefield. We have developed a new model for these potentially economic deposits which envisages the development of enhanced porosity related to carbonate alteration, followed by mixing of fluids of contrasting salinity giving rise to the main fluorite-sulphide mineralisation. In Aberdeenshire we are studying magmatic nickel–copper–platinum group element mineralisation in the Ordovician mafic–ultramafic intrusions, while in the Lake District research on pre-tectonic gold-bearing copper–iron–arsenic veins is aimed at understanding their origin in terms of the tectonic and magmatic development of the region.

Web-based digital maps for more sustainable mineral development

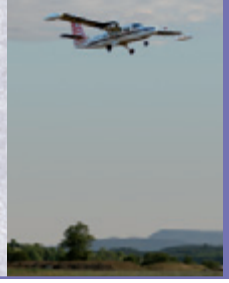
Effective planning for the sustainable development of the UK's mineral resources requires a wide range of up-to-date and impartial information. This year has seen the completion of our flagship Minerals Information Online system for England. This web-based geographical information system (GIS) is designed to provide access to a range of spatial, text-based and statistical minerals information and allows it to be related to other forms of land use such as urban areas, nature conservation areas, and transport infrastructure. It can also be used to identify areas where mineral extraction may conflict with other land-use and conservation interests.

The system was developed and populated in collaboration with the Department for Communities and Local Government. It is primarily intended as a tool for all national, regional and local decision makers planning the sustainable supply of minerals essential to maintain our economy and lifestyle. Minerals Information Online is provided on a regional basis and covers all of England except central London.

Strategic overview of environmental sensitivity in England

This year has seen us meet our objective to map environmental sensitivity in England. This provides a simplified strategic overview of the environmental and cultural assets that have been designated by government

Strategic overview of environmental sensitivity: detail from the environmental sensitivity map of England showing the Isle of Wight and surrounding areas. Deeper colours indicate more sensitive areas.



and statutory bodies, and integrates numerous datasets into a single composite layer in a geographical information system (GIS). A transparent methodology provides an easily understood visual overview of these assets. Mapping is carried out using a grid system and is available at one hectare and one square kilometre resolution. Environmental sensitivity mapping represents a rapid, objective and straightforward method of identifying areas that may be particularly sensitive to development.

Environmental sensitivity mapping has a number of applications in land-use planning for minerals and other forms of development. It may be used both to aid and explain decision-making. It can form part of the Strategic Environmental Assessment process and, more specifically, can be used in the environmental appraisal of plans and policies for aggregates provision.

Safeguarding our mineral resources

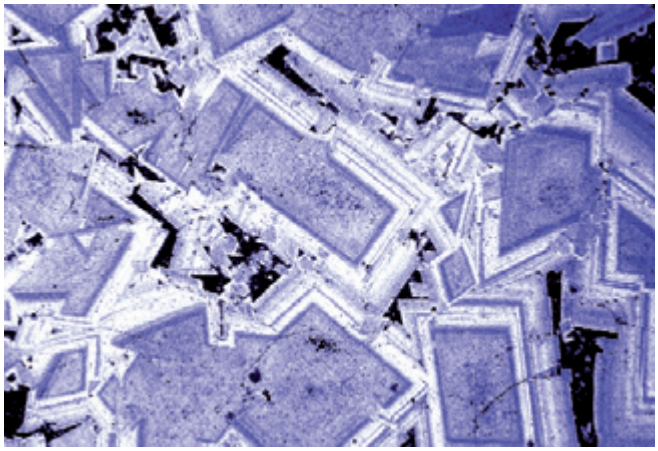
A key aspect of sustainable development is the conservation and safeguarding of non-renewable resources, such as aggregate minerals, for future generations. Safeguarding minerals from sterilisation by other types of development will ensure that there is a greater choice when identifying sites for extraction and provides greater flexibility in selecting sites with least environmental impact. Unlike other resources, such as landscapes, biodiversity and built heritage, there is no statutory protection for our mineral wealth; as a result, some resources have been wasted or sterilised indefinitely by inappropriate forms of development. With funding from the Aggregates Levy Sustainability Fund, research is being undertaken to assess and advise government on the effectiveness of current guidance and mechanisms, and the magnitude of the current mineral sterilisation problem. Focus is given to measures that could be employed now to prevent unnecessary sterilisation of mineral resources in the future.

Towards a better informed mineral planning process

The UK is a major economy and, despite significant imports from around the world, still depends heavily on supplies of minerals from indigenous sources. Balancing the need to maintain domestic mineral supply with the need to protect our environment in the UK is the task of the mineral planning system. With the support of the Department for Communities and Local Government, the Scottish Executive and the Welsh Assembly Government, we have produced a series of 'Mineral Planning Factsheets' that provide succinct, up-to-date and impartial information on individual mineral commodities. They are primarily intended to inform stakeholders in the land-use planning for minerals at national, regional and local level, but will be of value to all those interested in the extraction of minerals in the UK. The factsheets provide a wealth of information, under a standard set of headings, on the supply of specific minerals (from ball clay to silica sand) that are of economic importance to Britain. They are available from our website and will be updated on a regular basis.

Safeguarding our mineral resources: sand and gravel for concrete manufacture being produced from the Trent Valley in Nottinghamshire. A sustainable supply of high-quality construction minerals is essential for our national economy.

Sustainable mineral development: scanning electron microscope image showing well-developed compositional zoning in wall-rock replacive dolomite. Dolomitisation generated porosity within the wall rocks that was exploited by subsequent mineralisation. The compositional variations record increasing iron contents in the fluids during the early stages of mineralisation (Small Cleugh Mine, Nenthead: field of view 3 mm).

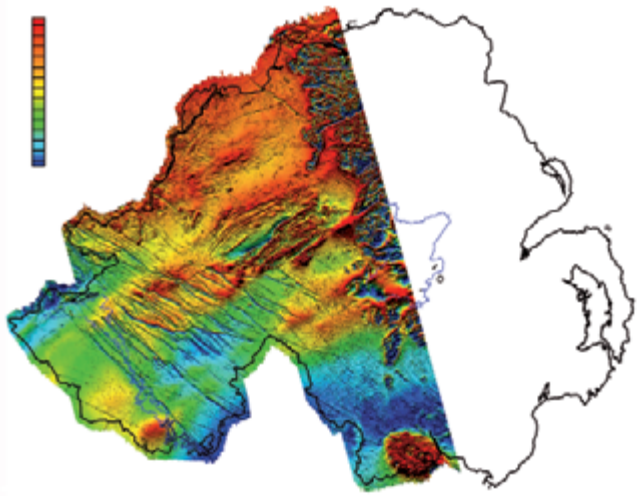


Geological Survey of Northern Ireland

Programme overview

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 avail itself of expertise from within other parts of the BGS. GSNI carries work out for other Northern Ireland government departments and collaborates closely with the Geological Survey of Ireland (GSI) on cross-border projects.

Minerals and energy resources: site development at the Omagh Gold Mine.



Tellus: the new aeromagnetic image of western Northern Ireland showing the contrast between more magnetised Dalradian rocks (red) in the north and less magnetised sediments in the south (greens and blues). Prominent features include the textured western edge of the Antrim basalts, north-westerly-trending dyke swarms and isolated intrusions, such as the Slieve Gullion Ring Complex in the south-east.

Tellus Project

The new geophysical and geochemical surveys of Northern Ireland were significantly advanced during the year. A total of 47 600 kilometres of low-level airborne geophysical surveying was flown over western Northern Ireland by the Joint Airborne-geoscience Capability (JAC) operated by the BGS and the Geological Survey of Finland (GTK). The preliminary magnetic, electromagnetic and radiometric data comprise a wealth of new information. Geochemical sampling teams collected 12 600 stream sediment, water and soil samples which have been analysed for more than 60 elements and compounds.

Initial results from Tellus reveal significant anomalies likely to be of interest to natural resource companies and environmental bodies. The new data, in association with existing information will provide Northern Ireland with a unique database that will be used by government, private sector and academia. Tellus surveys have been accompanied by a major public information campaign. This has significantly raised levels of interest in geology within Northern Ireland.

Mapping and publications

The major effort during the year was directed towards completing 1:50 000 scale geological remapping of Northern Ireland. Cross border cooperation with GSI saw the publication of both Bedrock, and Bedrock and Superficial editions of the geological maps of the Lisnaskea area, thus finishing modern remapping of the hydrocarbon-prospective Carboniferous rocks of County Fermanagh.

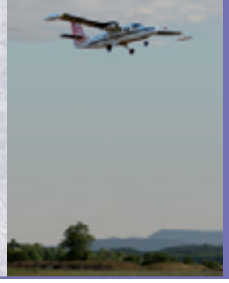
The acquisition of new, high-quality geophysical data by the Tellus project provided a vast amount of new information to aid interpretation of the concealed geology in areas where new geological maps were scheduled for publication, including in the Maghera, Dungiven and Newtownstewart districts.

Minerals and energy resources

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

Northern Ireland has continued to attract attention from natural resource exploration companies. In addition to the thirteen current mineral prospecting licence holders, five applications for mineral prospecting licences and one for a mining licence have been received. Development at the Omagh gold mine is nearing completion and the operation is expected to be in production later in the year.

Exploration programmes were carried out by licensees over the four current petroleum licences in the North-west Irish Carboniferous Basin, and the concealed Rathlin and Larne sedimentary basins. GSNI provided vital data and advice towards the licensees' seismic reprocessing, gravity and basin modelling studies, which may lead to exploration drilling next year.



Environment

Phase 1 of the Belfast Geoscientific Information System (BGIS) was completed and involved capture of available datasets, refinement of the existing geographical information system and construction of a preliminary three-dimensional geological model of the central Belfast area. Future work will enhance the GSNI's ability to meet the growing demand for essential geoscientific information and help underpin the infrastructure renewal projects planned for the Belfast Metropolitan Area.

Demand for GSNI information and advice services continued to increase with planning applications for wind farms a particular growth area. GSNI has been active in ensuring that potential instability hazards associated with disturbance of peat in upland environments have been highlighted and taken into consideration during the Environmental Impact Assessments for these projects.

Peat slides were one of several landslide geohazard types considered by the Landslides Working Group chaired by GSI and involving GSNI. *Landslides in Ireland*, which provides guidance for planners and developers, was published.

The GSNI, on behalf of the DETI, continued to discharge its responsibility to ensure the safety of abandoned mines throughout Northern Ireland. A database of 2400 mine shafts and adits in Northern Ireland was completed and developed into a geographical information system.

The large surface void created by the collapse of the Maidenmount Salt Mine near Carrickfergus in 2001 was successfully filled and a number of open adits in the environmentally sensitive north Antrim coast area were closed. Advice was provided on significant engineering projects within Belfast, including the large-scale dewatering programme associated with the Victoria Square redevelopment.

A comprehensive review of groundwater monitoring across Northern Ireland was initiated with recommendations to be made for a new regional strategic network that will report groundwater quality and resource status for the coming years.

Mapping and publications: Bedrock and Superficial edition of the geological map of the Lisnaskea area at 1:50 000 scale.

Landscape heritage and public awareness of science

The cross-border Briefne project was completed with the publication of state-of-the-art guidebooks and high definition DVDs. The GSNI continues to work closely with Fermanagh District Council at Marble Arch Caves European Geopark, which was awarded the status of Northern Ireland's top tourist attraction. Work continued organising the Geoparks Conference to be held in Belfast in September 2006. Public awareness of science activities included gold panning, school debates and workshops and lectures organised in association with the Museums and Galleries of Northern Ireland.

Landscape heritage and public awareness of science: gold panning in the Mourne Mountains.
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Environment and Hazards Directorate

The **Environment and Hazards Directorate** delivers a wide range of applied geoscience research and information through seven programmes, each focusing on a particular aspect of environmental geology. The Directorate is principally concerned with the interaction between the solid earth (and the fluids it contains) and the human environment.

The **Electrical Tomography** programme utilises a range of electrical resistivity geophysical techniques to investigate and monitor the shallow sub-surface non-destructively. The techniques can be used to monitor the movement of contaminants, to assist the management of waste sites, to locate potential geohazards and to contribute to the sustainable use of soils and groundwater.

The **Groundwater Management** programme provides research and information on groundwater processes, diffuse pollution and resources to the benefit of the hydrogeological community. A multidisciplinary approach dramatically increases the understanding of how aquifer systems work and how they interact with surface water bodies, for example in relation to groundwater flooding.

The **Seismology and Geomagnetism** programme continues to monitor and disseminate valuable information on seismic events and variations in the Earth's magnetic field. It is concerned with long-term monitoring of natural earthquakes and man-made seismic disturbances. Objectives include provision of data for research into planetary processes and support to UK national interests and industry.

The **Physical Hazards** programme provides the user community with information on, and understanding of, ground conditions and land quality relevant to development and regeneration, particularly in urban areas. Important issues include the likely occurrence of geological hazards, such as landslides, dissolution of karstic rocks and ground movements associated with compressible and collapsible soils and swelling and shrinking clay soils. The programme provides information on the geotechnical and engineering characteristics of UK rock and soil formations and the physical and mechanical properties of geomaterials.

The **Chemical and Biological Hazards** programme delivers information, expertise, advice and research on environment and health, contaminated land, point source groundwater contamination, environmental geochemical baseline surveys, geomicrobiology, mathematical modelling, and waste disposal impacts through its geosphere containment research. These activities are undertaken on local, regional, and national scales within the UK and throughout the world.

Soils form an interface between the atmosphere and geosphere through which nutrients and pollutants circulate. The **Sustainable Soils** programme has been set up to provide data on the sustainability of soil use and its management to UK government, regulatory agencies and industry (including agriculture) in response to recent and currently developing legislation.

The **Sustainable and Renewable Energy** programme supports the development of sustainable energy options through research into carbon dioxide sequestration/avoidance, providing information on the UK's onshore energy resources, defining reservoir characteristics and researching into underground fuel storage and geothermal energy. To mitigate the threat of global warming and acidification of the oceans we have pioneered research into underground geological storage of carbon dioxide.

(Opposite) Landslide at Lochearnhead, August 2004, one of the biggest in the UK in recent years. The BGS has analysed the variables that contribute to landslides and published a ground stability model for Great Britain as part of the GeoSure data suite, developed to meet an increasing demand for information about ground conditions and geohazards.

Groundwater Management

Programme overview

The Groundwater Management programme carries out surveys, monitoring and applied research to allow improved management of groundwater in the UK and internationally. The programme contains many new features including issue-led thematic research on diffuse pollution, climate change and extreme events, and groundwater and health. As the NERC Lowland Catchment Research (LOCAR) thematic programme draws to a close we are contributing to major reports and papers including a Journal of Hydrology Special Edition. The new programme is moving towards web-based working, communication and delivery of science, information, and data.

Scotland nitrate project

The effective monitoring and management of nitrate concentrations in groundwater is essential to the protection of water resources. Most European countries expend considerable resources collecting and reporting nitrate data from national groundwater quality monitoring networks. Less consideration is given to assessing the effectiveness of the networks. Funded by the Scottish Executive, we undertook a detailed assessment of Scotland's groundwater monitoring network to focus a five-year plan for investment to meet the requirements of current European Directives. Scotland has had a national network since 2000, comprising springs, shallow wells, and boreholes. A fundamental element of the project was finding ways to assess the quality of each monitoring site, taking into consideration the diversity of sites, geology, and land use. An interdisciplinary team was assembled including soil specialists from the Macaulay Institute in Aberdeen.

Field data collected from surveys at each site were combined with national datasets and nitrogen leaching models to give an accurate assessment of the network. We are now working with the Scottish Executive and the Scottish Environment Protection Agency to help implement the recommendations from the study.

Developing groundwater

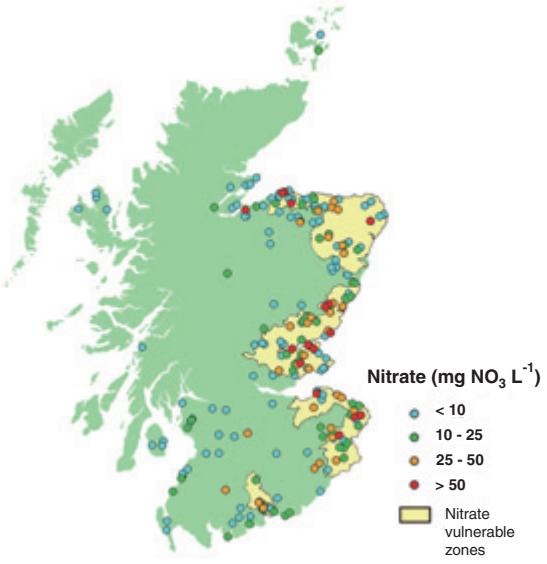
There are at least 1.1 billion people across the world who do not have access to safe drinking water. Most of these people live in rural areas and are among the poorest and most vulnerable to be found anywhere in the world. Meeting this need relies on finding and developing local water resources close to communities. In most locations the only viable option is to develop groundwater.

In 2005, we published a manual, called *Developing Groundwater*, which brought together for the first time the wide range of techniques required to develop groundwater for community water supply. Its main aim was to be a practical and user-friendly guide. All techniques described in the manual had to be both easy to carry out and effective. The technical aspects of rural water supply were also set firmly in their socio-economic context, so that readers could take proper account of community concerns as well as engineering and water resource issues.

Developing Groundwater has sold 400 copies in its first year, and a further 200 have been distributed free to key workers throughout Africa. The manual has been used to develop an extended training course for 30 UNICEF community water supply staff in Nigeria, and more training courses are planned.

Groundwater Portal

A Groundwater Portal has been developed to provide easy and intuitive access to the work of the Groundwater Management Programme. It provides access to data, information, dynamic web-based tools, and resources related to groundwater in the UK and overseas. The structure of the site is based on the Groundwater Management programme of work for the period 2005–10. Initially, it is intended for use by BGS staff on the intranet. With time, selected pages and mini-sites will be migrated from the intranet to



Scotland nitrate project: measured nitrate concentrations in Scottish groundwater in 2003. The EC maximum permissible concentration of nitrate in drinking water is 50 milligrams per litre.

BGS extranet sites so that our partners and customers can access them. Eventually pages and resources will be moved to the external BGS website.

Examples of resources developed for the Groundwater Portal include: online access to our groundwater database (WellMaster); a range of regional hydrogeological studies supported by dynamic hydrogeology maps; a range of groundwater themed pages (such as groundwater and extreme events, and groundwater modelling); downloadable groundwater modelling codes and spreadsheets with supporting documentation; and a wide range of research resources, such as searchable lists of downloadable groundwater reports, publications, presentations and bibliographies.

AISUWRS

The EC-supported research project Assessing and Improving Sustainability of Urban Water Resources and Systems (AISUWRS) was designed to integrate knowledge on urban water supply and drainage systems with hydrogeological expertise on urban groundwater resources by means of a set of modelling tools. The tools comprise a chain of interconnected flow and water-quality models that link urban water supply, urban drainage, and urban groundwater resources. The model suite can schedule urban water flows, estimate sewer and stormwater pipe leakage, assess contaminant attenuation capacity through the unsaturated zone, and then demonstrate the effects on the underlying aquifer using proprietary groundwater flow and transport models.

Detailed field investigations were undertaken to help quantify model parameters and the methodology applied in case studies in urban areas overlying productive aquifers in the UK, Germany, Slovenia, and Australia. The models can be used as a predictive tool to manage increasingly scarce water resources, help avoid future problems like groundwater flooding of urban infrastructure, or mitigate deterioration of groundwater quality.

Hydrogeology reports

Three Research Reports in the BGS Hydrogeology Series have been published:

- The Dumfries Basin aquifer. RR/06/02
- The Chalk aquifer system of Lincolnshire. RR/06/03
- The Chalk aquifer of Yorkshire. RR/06/04

They are the latest output from the National Groundwater Survey and describe and quantify the occurrence of groundwater, its movement and natural quality as well as contamination, and how the resource is managed. They have been compiled in collaboration with the Environment Agency, the Scottish Environment Protection Agency, and water companies. The reports comprise reviews of published and unpublished material, analysis of existing data, collection and interpretation of new water quality data, research through drilling, logging and tracer testing, and, in the case of Dumfries, development of a groundwater flow model. The reports provide a comprehensive statement on the aquifers studied and how they are managed, as well as providing a pathway to the detailed information on which they are based. All data collected are stored in BGS corporate databases with future aim for online information delivery.

Hydrogeology reports: National Groundwater Survey reports published in 2005/06.

Developing groundwater: evaluating the yield of a borehole at a BGS-run training course in Nigeria.

Sustainable Soil Management

Programme overview

The Sustainable Soil Management programme is a new developmental Science Budget programme aimed at providing:

- High-quality geological information on the UK's near-surface environment customised to meet the needs of end users in soil science, environmental science, and associated regulatory communities.
- An improved understanding of how structural relationships, and interactive processes, that occur between soils and their underlying geological environment impact on soil sustainability and the management of soil function.

Parent material mapping: screen capture of version 0.1 of the BGS Soil Parent Material Map. The spatial framework for this map is based on that of DigMap50GB with additional property specific information added to assist in the development of digital soil maps.

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 project aims to produce a detailed spatial model and associated database containing information on the geological classification and physico-chemical properties of weathered and unweathered parent material for any given location within the UK. This will greatly facilitate the spatial mapping of UK soils and 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 major 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 (DiGMapGB-50, *see page 42*). This has been achieved and Version 0.1 of the Parent Material Map was launched as a development version in December 2005. This product will be further developed over the next four years by assimilating additional information derived from a wide variety of BGS data sources including scanned field data slips, mineralogical, geochemical, and geotechnical information.

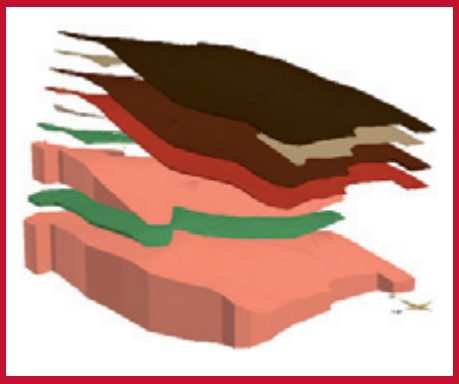
Three-dimensional soil modelling

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 science, 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 national level this has resulted in significant knowledge gaps and uncertainties that hinder our ability to successfully model the environmental processes that traverse the transition zone (groundwater recharge and pollutant transport). We aim to investigate and spatially model the zone of uncertainty through multidisciplinary field surveys and geospatial modelling in representative landscapes across the UK.

We have, with the National Soil Resources Institute, carried out an integrated survey of the shallow subsurface at the Brackenhurst campus of Nottingham Trent University. Several remote sensing, geological, geophysical, hydrogeological, and geochemical survey techniques were used. All data were converted to common classifications and reference systems and were subsequently viewed and analysed in one software package. The result of the work has been UK's first integrated 3D soil-geological model showing A, B, E and BC soil horizons overlying a sequence of mudstones and siltstones of the Mercia Mudstone Formation.

Subsoil properties and processes

With increased 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. There is very little understanding of the properties and processes at the interface between the parent material and subsoil (transition zone). Scientists



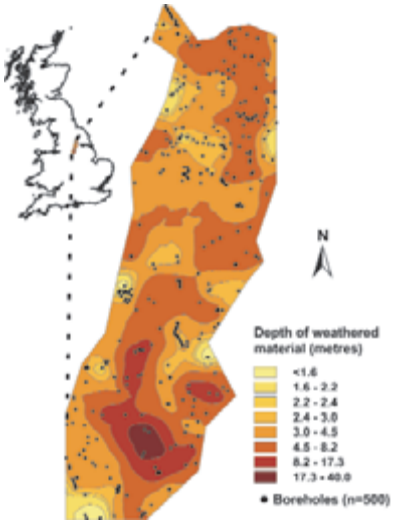
3D soil modelling: three-dimensional image from GSI3D showing an integrated 3D model of soil horizons (A, B, E and BC) and geological formations (mudstones and siltstones of the Mercia Mudstone Formation) at the Brackenhurst site near Southwell, Nottinghamshire.

increasingly view the soil as a continuous system, and the functions it supports need to be assessed in this context. For example, the function of 'filtering' water as it percolates through the ground involves both the soil and near-surface environment.

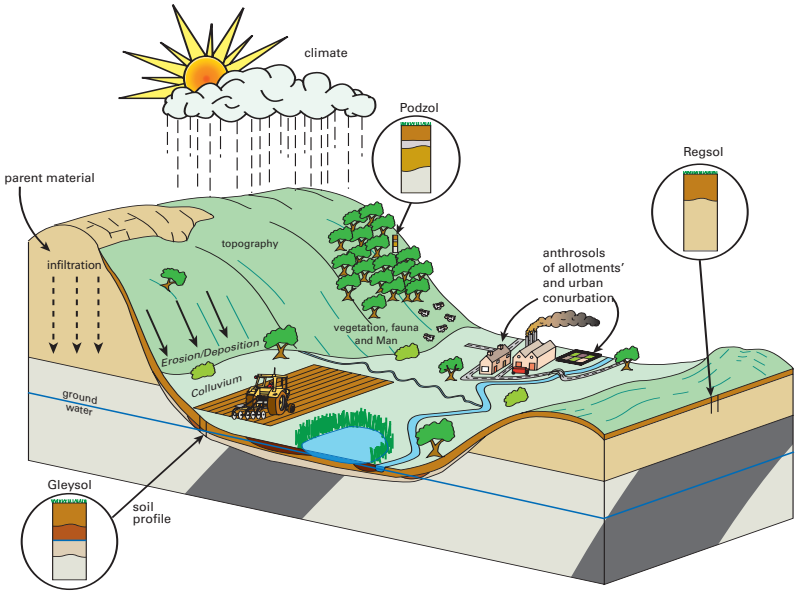
One project has examined in 3D the cation-exchange capacity of the soil and weathered parent material above the Sherwood Sandstone Group outcrop, an important aquifer in the East Midlands. In this particular transition zone, two factors are likely to have a dominant control on the ability of the soil and underlying weathered material to 'filter' contaminants. Firstly, different types of land use, which potentially influence the organic matter content and the cation-exchange capacity of the transition zone. And, secondly, the total depth of the transition zone through which water infiltrates. The depth of transition zone has been estimated using BGS borehole information. We are currently investigating whether the thickness of the weathered material is related to landscape features such as slope and slope length. The next stage will be to examine the geochemical and physical attributes of the transition zone (such as organic carbon content) that control the magnitude and depth dependence of its cation-exchange capacity and its ability to attenuate pollutants. Our investigations on this relatively simplistic transition-zone will help us develop methodologies that can be applied to more complex systems.

We are also studying the effects of long-term management and changing land use on clay minerals. Clays represent some of the most reactive surfaces in soils and are important in filtering, nutrient sustainability, and maintaining soil structure. A collaborative project with Rothamsted Research uses archived samples from their 'Classical Experiments' to investigate possible effects on the properties of clay minerals.

Subsoil properties and processes: image indicating the depth of the weathered zone overlying the Triassic sandstone outcrops north of Nottingham (calculated from an analysis of BGS borehole records).



Sustainable soil management: the soil forms the interface between the , biosphere, hydrosphere and atmosphere and is characterised by horizons that have developed through pedological processes. Apart from the parent material, the main soil forming factors are climate, organisms, topography, time and people.



Chemical and Biological Hazards

Programme overview

The aim of the Chemical and Biological Hazards programme is to position itself, through its research portfolio, in order to enable a response to ongoing and emerging national and international issues related to anthropogenic and geogenic contamination, and waste disposal in its broadest sense. The objective is to address the interlinked themes of geosphere containment, anthropogenic and natural contamination of soils and groundwater, and environment and health through a programme of process-related research, and both direct and remotely sensed environmental monitoring.

Pollution, migration and mitigation

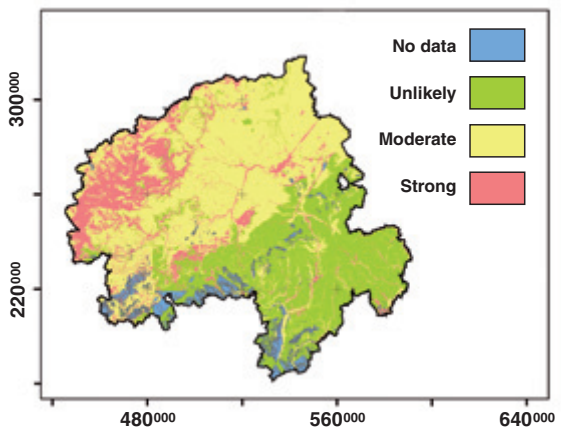
Environmental protection and sustainable use of land and groundwater is threatened by pollution from a diverse range of industrial and commercial activities. Where pollutants make land 'unsuitable for use' remedial work is undertaken, typically requiring a detailed understanding of the subsurface. Describing and predicting pollutant behaviour is, however, influenced by our ability to characterise the subsurface. Heterogeneities, which are inherent in all geological systems, can result in variable data quality, which leads to uncertainty in predictions. We are exploring methods to understand and quantify uncertainty in predictive modelling at polluted sites. Firstly, a software programme, combining expert rules with a 'fuzzy logic' framework, is being developed to assess and score the quality of data input to numerical models that simulate petroleum hydrocarbon fate and transport in groundwater. Secondly, a methodology is being developed to reduce the uncertainty in quantifying the spatial distribution of contaminants in the subsurface.

Environment and health

This research theme studies the potential risk to human health from both the natural geological environment and the UK's industrial heritage. Efforts are concentrated on the exposure to, and the impact of, potentially hazardous substances in solid materials, predominantly soil. The contaminants investigated include anthropogenic and geogenic contaminants, which can be both inorganic (for instance, arsenic, cadmium, chromium, lead, nickel) and organic (such as polyaromatic hydrocarbons). Members of the team are working with a wide range of collaborators to help us achieve the project aims. We currently hold positions as chair, secretary, and ordinary members of the Bioaccessibility Research Group of Europe (www.bgs.ac.uk/barge). In addition to our international links, we are working with a number of UK agencies including the Health Protection Agency, the Environment Agency and the Small Area Health Statistics Unit to look at ways of validating the estimated human exposure derived from risk models with site-specific data.

Environmental impacts of abandoned mining

The focus of this research theme is on developing scientific understanding that will allow us to create rapid and robust predictive tools for mapping and characterising the nature of contamination and dispersal from past mining in the context of the EU Mine Waste Directive (2006/21/EC). Building on earlier work focused on site-specific impacts, the project has been expanded to catchment-scale studies to enable assessment of both diffuse and point source contamination from abandoned mines. The project has been successful in the continued development of the capability to measure and map mine waste using hyperspectral remote sensing techniques. Additionally, a more detailed process understanding of leaching, weathering sequences, and pollutant loading from mine waste has been developed. The methodology will be applied to mapping contamination through a study of vegetation stress and adaptation. As a result of this work, we have developed methodologies for field and laboratory measurements of unsaturated flow in mine tailings. This has contributed to the development of the catchment scale conceptual model for use in source-pathway-receptor analysis.



Geochemical baseline sampling: a map showing the likelihood of soils exceeding the arsenic soil guideline value for the proposed growth area of Milton Keynes–South Midlands and London–Stanstead–Cambridge. This is based on G-BASE baseline geochemical data for soils. Frame coordinates are the British National Grid in 40 kilometre intervals.

Geochemical baseline mapping

The Geochemical Baseline Survey of the Environment (G-BASE) project has now made available high-density geochemical information about the surface environment of UK for an area north of a line from the Thames estuary to the Bristol Channel. This includes up to 50 chemical elements on soils, stream sediments, and waters. The baseline geochemical data continue to be used by government departments and agencies in order to establish guideline values for chemical elements in the environment and for the purpose of strategic planning for development areas. An example of this is a report commissioned to appraise the soil geochemistry for two growth areas in the south of England. There is increasing legislatively-driven demand for the results of the baseline mapping that can quantitatively demonstrate how urbanisation and industrialisation modifies the environment. Technical reports presenting results for the systematic surveying of seven urban centres in the Humber–Trent region have been published (Doncaster, Hull, Lincoln, Mansfield, Scunthorpe, Sheffield, and York).

Environmental impacts of abandoned mining: classification of mine tailings from Frongoch Mine, Mid Wales, overlaid on hyperspectral image data.

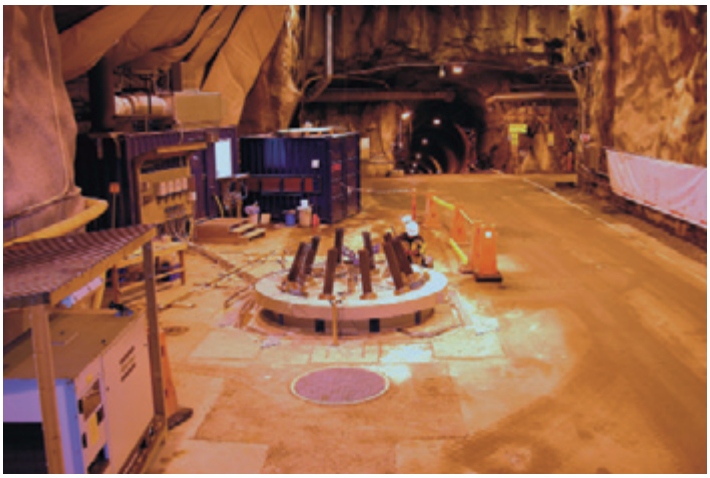
Bio Tran

Landfill and radioactive waste disposal risk assessments are principally concerned with understanding the movement of gas, water and solutes, and transport of contaminants through engineered barriers and natural groundwater systems. Microbes can have an important impact on transport but at present, little effort is made to model the movement of micro-organisms (including pathogens), or the impact of microbes on transport properties. The Bio Tran project was initiated to examine microbial affects on transport processes. In the first year, a detailed review has identified many gaps in the required data for microbial transport models and recommended an experimental programme to assess a wide range of parameters. Additionally, potential methodologies, including organic biomarkers which can be used in laboratory and field situations, have been identified.

Gas flow in compact bentonite

Our current understanding of the movement of gas in a compact buffer bentonite is based on small-scale laboratory studies that are designed to address specific issues relating to gas migration and its long-term effect on the clay. Recent laboratory work has highlighted a number of uncertainties, notably the sensitivity of the gas migration process to experimental boundary conditions and possible scale-dependency of the measured responses. To address these issues we were commissioned by the Swedish waste management company SKB to perform a large-scale gas injection test (Lasgit). Lasgit is the first demonstration project designed to study gas migration in bentonite under full-scale repository conditions. The experimental system has been operational for more than 500 days and has provided detailed information on the development of swelling pressure in the system, the resultant movements of the canister and lid, and conditions under which hydraulic piping occurs. Numerical data from the experiment will be used to develop and validate process models aimed at assessing the performance of the repository.

Gas flow in compact bentonite: large-scale gas injection test (Lasgit) 420 metres below ground at the Äspö Hard Rock Laboratory in Sweden. A BGS scientist works next to the large steel lid anchored over the deposition hole.

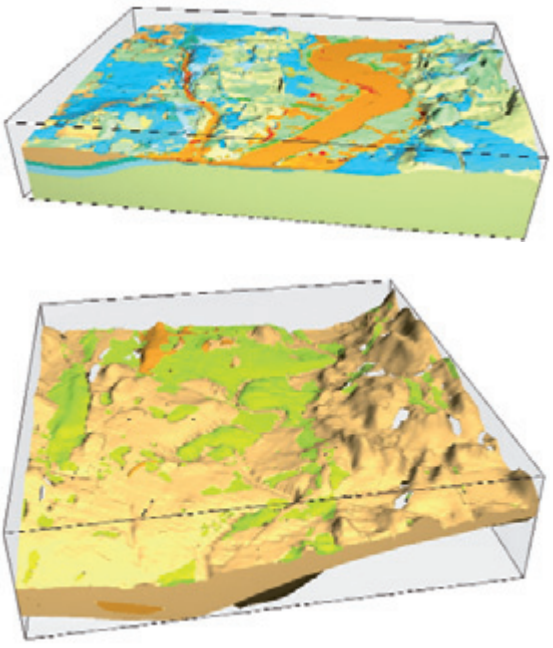


Physical Hazards

Programme overview

The aim of the Physical Hazards programme is to provide the user community with information on, understanding of, and solutions to problems with ground conditions and land quality, particularly in urban areas. This is achieved by:

- Modelling and visualising the shallow subsurface in 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.
- Measuring, monitoring and interpreting the chemical, physical and mechanical properties of subsurface materials and masses.



Urban engineering geology: *(top)* 3D geological model of part of the London Gateway project area attributed for basic engineering geological characteristics. And *(above)* 'running sand hazard' model of Quaternary deposits in part of the Clyde Basin/Glasgow area showing which deposits are most likely to 'run' during boring and excavation (orange-brown: moderate hazard; light brown: low hazard; green: no hazard).

Urban engineering geology

As part of its aim to make geological information more accessible and relevant to sustainable construction, the BGS has embarked on a programme of 3D modelling in three major development areas:

- the London/Thames Gateway;
- the Manchester/Lower Mersey Corridor; and
- the Clyde Basin.

High-quality site investigation boreholes form the framework of the models, which are depth limited to show maximum geological detail in the near-surface 'development zone'. By attributing the models with geotechnical data, the models can offer insights into the likely engineering behaviour of the near-surface deposits with respect to loading, ease of excavation, ground stability, and geological hazards.

The ground models are not intended to replace site investigation studies but should assist competent practitioners to identify where construction is likely to be more difficult, and potentially more costly, and lead to more focused site investigations. Although there is increasing recognition among users of the value of acquiring information in 3D, the challenge is to make the models accessible at an early stage in the urban regeneration process so that they may better inform strategic planning options, ground investigation, and reclamation strategies.

Engineering geology of the Lias and Lambeth Groups

We have produced two reports detailing the engineering properties of the Lias and Lambeth groups. These reports aim to provide baseline information to assist ground engineers and planners in undertaking feasibility studies and site investigation design for engineering projects and land-use planning for regional development.

The Lias report includes an assessment of regional trends in engineering properties for the principal clay-rich formations. For example, trends in plasticity, density, strength, and compressibility data reflect the inferred burial history of the Lias Group in areas subjected to glaciation.

Lithological variability within the Lambeth Group has caused problems for engineering works since the early nineteenth century. Based on high-quality data from recent construction projects, the Lambeth report examines this lithological variability using 3D modelling software to produce cross-sections to highlight where particular engineering problems are most likely to occur and where difficulties in predicting engineering behaviour are most pronounced.

Landslide hazard in Scotland

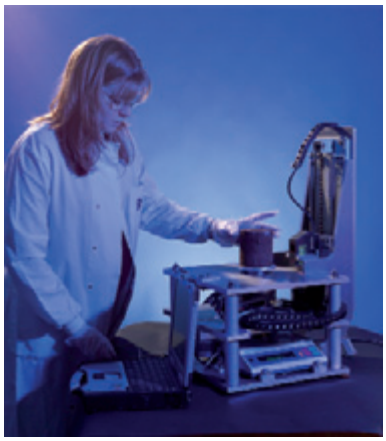
Geohazard and risk experts at the BGS have been working with other specialists, led by the Transport Research Laboratory, to

develop a strategic GIS-based tool to identify areas of potential debris flow landslide hazard affecting the Scottish road network. This cross-disciplinary team approach is proving highly beneficial, enabling focused application of BGS data holdings, and expertise in geohazard analysis and GIS development. The project has required the analysis of multiple data sources including high-quality topographic data (NEXTMap), a specially modified version of our digital geological maps (DiGMapGB-50), and satellite-derived land-use data. The truly novel aspect of this work has been the validation of the model inputs and outputs, with BGS specialists working closely alongside experts with extensive experience of landslides and landslide management on the Scottish road network.

SHRINKiT technology

We have invented a new laser system to help engineers identify how rocks and soils change shape under different weather conditions. Much of the UK is covered in clay soils that shrink and swell due to seasonal changes in moisture. Every year these movements cause hundreds of millions of pounds of damage to houses, water pipes, and sewers. Until now, scientists could only assess the reduction in volume of soil samples using liquid mercury — a dangerous and expensive procedure. Our invention is a robotic system that uses a laser to model the tiny changes in the shape of soil samples that occur as a sample is soaked, dried or squeezed. The new system, called 'SHRINKiT', means that researchers can now model changes in soils in safety and at a reduced cost. Results from SHRINKiT have already been integrated into the GeoSure geohazard information system, providing homeowners with information on the shrinkage potential of the ground beneath them.

SHRINKiT technology: SHRINKiT laser measurement system.



Monitoring and maintaining an efficient railway infrastructure

The efficient running of the existing rail network and the upgrading of operational and abandoned infrastructure are high on the government agenda. Efficient rail performance requires that constant and level rail-track geometry be maintained. The geotechnical properties of the track subgrade exert a major control over the performance of the railway network. We are actively involved in developing new techniques to measure and assess subgrade properties.

We are collaborating with the Great Central Railway and the Railway Research Centre at Birmingham University in the management of railway research sites where new methods are evaluated. Successes at Leominster and East Leake have provided high-quality datasets that demonstrate new application and improved integration of geotechnical and geophysical techniques in enhanced assessments of subgrade properties. Developments for the future include satellite methods to assess embankment heave and investigating the role of mineralogy on subgrade performance.

Monitoring and maintaining an efficient railway infrastructure: geotechnical and geophysical surveys being undertaken on a Great Central Railway embankment, at a research site near East Leake, Nottinghamshire.

Electrical Tomography

Programme overview

The Electrical Tomography programme (ETP) provides leading-edge technology for the non-invasive electrical imaging of the shallow subsurface. The techniques developed by ETP are being used to underpin studies in waste management, contaminated land remediation, the sustainable use of groundwater and soils, as well as the detection and mitigation of natural hazards. This cross-cutting research is undertaken in close collaboration with universities, industry, and a range of public sector clients.

Electrical Resistivity Tomography

A field-scale test pit facility has been designed and constructed at Keyworth to simulate leachate generation and migration within landfills. The pit has been instrumented with simulated boreholes, pressure transducers, multi-level samplers and permanent in situ 3D Electrical Resistivity Tomography (ERT) electrode arrays. The hydraulic system and ERT data capture is fully automated. Pumping rates can be finely adjusted to simulate fluid-level fluctuations over a range of timescales or to maintain a constant hydraulic gradient between the injection and abstraction wells. This allows us to simulate pumping-induced flow in a landfill site. The hydraulic pumping experiments confirm that automated time-lapse ERT imaging can track temporal changes in fluid distribution, hydrochemistry, and saturation levels. This result has important implications for the sustainable management of commercial landfills. A landfill instrumented with ERT sensors could be monitored remotely without invasive sampling. The images could then be used to optimise leachate recirculation within the waste mass and enhance the supply of landfill gas for the generation of electricity. Once installed, ERT could also provide early warning of leakage or plume migration off-site. This work was commissioned by the Onyx Environmental Trust and English Partnerships.

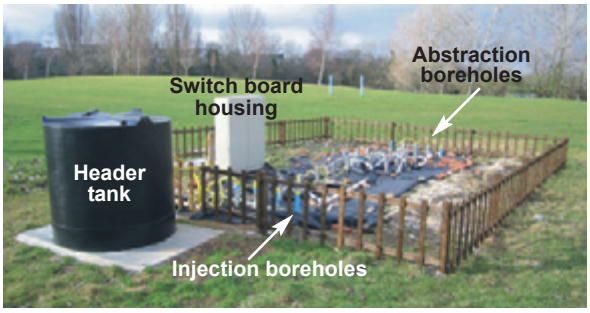
Capacitive Resistivity Imaging

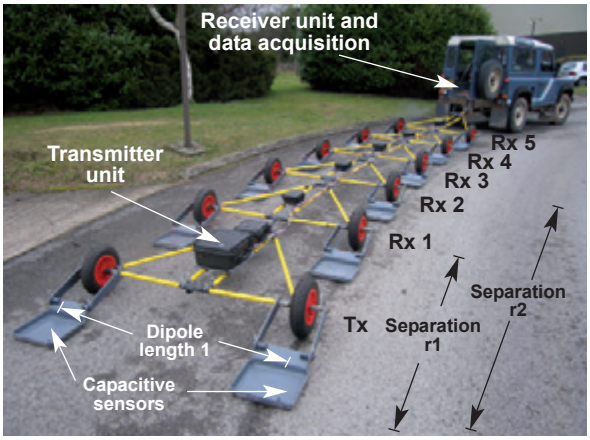
A new wheel-based platform has been designed for Capacitive Resistivity Imaging (CRI). Unlike ERT, non-contacting capacitive electrodes permit continuous data acquisition on highly resistive engineered surfaces (such as roads or pavement) where invasive direct current (DC) coupling is both difficult and undesirable. The system has been used to detect shallow voids and to investigate the geotechnical properties of road subgrade. This BGS-designed system is a major improvement in CRI technology as it is capable of measuring the full complex transfer impedance (in-phase and out-phase) across pairs of capacitive sensors without the need for a fixed reference potential.

Theoretical model studies and field experiments have been undertaken to establish the operational range of the CRI system. It has been shown that there is an optimum range of capacitive electrode separations where the measurements obtained are equivalent to those measured by conventional four-point DC resistivity arrays. Further, it has been demonstrated that electromagnetic induction effects can invalidate existing DC resistivity formulations in zones of high conductivity. We have derived a quasi-static formulation of apparent resistivity specific to the CRI case for use in all environments. As this technology has significant potential for commercialisation, a NERC patent has been filed in the USA and the UK.

Self-Potential Tomography

Research into Self-Potential Tomography (SPT) is continuing with support from an ongoing Ph.D. studentship (funded by the BGS) at the University of Nottingham. The aim of the project is to understand the fundamental causative mechanisms that give rise to self-potential anomalies. These mechanisms are complex





Electrical Resistivity Tomography: *(top)* ERT test pit facility to simulate landfill hydrogeology.
Capacitive Resistivity Imaging: *(above)* prototype system with wheel-based platform.

and include changes in electric potential caused by diffusion, electrofiltration, bioelectric, mineral, thermal, and geochemical redox effects. Without this basic understanding, SP surveys will continue to be under-utilised or misinterpreted. The research involves modelling, controlled laboratory experiments, and field studies.

Automated time-Lapse Electrical Resistivity

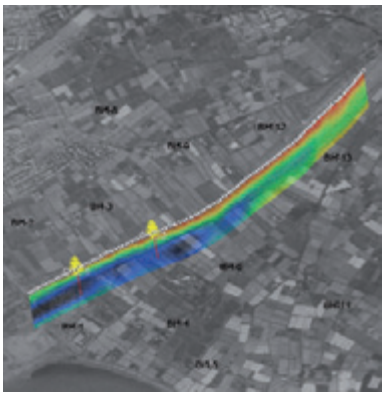
Work has continued on the development of Automated time-Lapse Electrical Resistivity (ALERT) technology to remotely monitor temporal changes in subsurface electrical properties. Such changes may be related to changes in fluid flow, hydrochemistry, or saturation levels. A customised ALERT system has been developed to assist the sustainable management of coastal aquifers that may be under threat from over-exploitation, anthropogenic pollutants and sea-water intrusion. A new 10-channel prototype ALERT system with 288 electrodes has been designed that measures DC resistivity, induced polarisation, and self-potential parameters using permanently installed instrumentation and buried electrode arrays. Sites may be interrogated from the office by GSM telemetric and/or satellite links to provide volumetric images of the subsurface at regular intervals, thereby obviating the need for expensive repeat surveys and manual intervention.

This work is funded by the European Commission Framework Programme (FP6) and is led by the BGS. The consortium comprises nine EU partners and an International Cooperation partner, the University of Marrakech, Morocco. This generic technology has cross-cutting applications for other market sectors, including the remote monitoring of contaminated land remediation, incipient physical hazards (such as landslides, cavity development), and the understanding of extreme events such as flooding or drought. Scientists and engineers can now study transient earth processes at unprecedented sampling rates without manual intervention. An integrated scheme has been developed for data capture, processing, modelling, visualisation and databasing using a centrally managed BGS network server and web-portal. ALERT has been identified as a candidate technology for commercialisation through a NERC spin-out company.

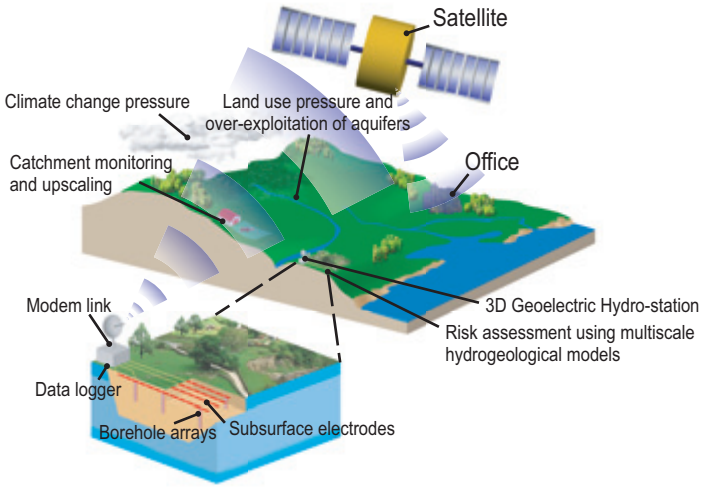
Cross-hole Electromagnetic Tomography

Work commenced in 2005 to develop a cross-hole Electromagnetic Tomography (EMT) capability for geotechnical rock mass characterisation studies. Transmission and reception of electrical fields provides sensitivity to even moderate variations in electrical conductivity. Operating in the radio band (50 kHz to 2 MHz) provides shorter wavelengths than ERT techniques while providing imaging over greater distances than radar techniques. The frequency band also provides sensitivity to both electrical permittivity and magnetic susceptibility variations. No such capability exists within Europe. The basic modules comprise a signal generator, lock-in amplifier, and slim-line borehole antenna. It is anticipated that cross-hole EMT surveys could assist the future characterisation of host rocks for the disposal of radioactive waste in deep underground repositories.

Automated time-Lapse Electrical Resistivity: aerial photograph with two-dimensional ERT image overlay. The image shows conductive saline water (in blue) and resistive fresh water (in red) at a test site in Spain. Photograph © Sara Jorreto Zaguirre of University of Almería, Spain.



Automated time-Lapse Electrical Resistivity: schematic ALERT concept showing buried ERT arrays and remote data transmission.



Seismology and Geomagnetism

Programme overview

The Seismology and Geomagnetism programme is responsible for monitoring seismicity and geomagnetic field variations, and operating the UK seismic network and magnetic observatories. It provides a responsive, rapid-access data and information service for government, industry, academia, the media, and the public. This is particularly important following significant UK and global earthquakes, and during adverse space weather and magnetic storms. Extensive datasets are used for seismic hazard evaluation and accurate geomagnetic field models for navigation. Techniques derived from diverse studies of multi-component seismology and seismic anisotropy allow oil reservoirs to be better imaged and characterised for fluid content and fracture distribution.

Buncefield explosion

A massive explosion on 11 December 2005 at the Buncefield fuel depot near Hemel Hempstead started a fire lasting for about two days. Seismic and acoustic waves generated by the explosion were detected on the BGS seismograph network. Accurate timing of the explosion was established from the seismograph recordings in a report commissioned by the Health and Safety Laboratory. A macroseismic survey confirmed that the explosion was felt throughout a large part of England, with the most distant reports coming from as far north as Lancashire, West Yorkshire, and Humberside, and as far west as Powys, Mid Glamorgan, and Somerset.

National earthquake monitoring

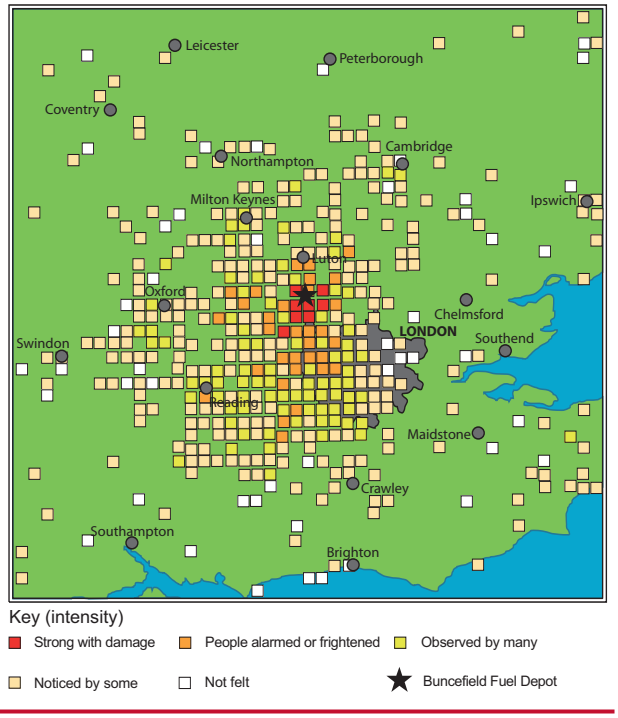
We are currently upgrading the seismic monitoring network by installing broadband seismograph stations across the UK with near real-time data transfer to Edinburgh. So far, we have installed nine broadband sensors at stations across the UK. These stations improve the quality of the data by extending the dynamic range and frequency bandwidth of recordings. This will improve the scientific value of the data and improve the services provided to customers. Recent studies have demonstrated that precise relative earthquake locations can be obtained by using a double difference location algorithm with a combination of catalogue and cross-correlated phase readings. Such studies are generally undertaken in areas of high seismicity. We have investigated how these techniques can be applied to the UK, a low seismicity area, and found that significant improvements can be achieved. Improvements in relative earthquake locations were achieved for the Manchester earthquake swarm in 2002, which allows us to identify single causative faults.

Edinburgh anisotropy project

We are developing and applying innovative data processing and analysis techniques for multi-component seismology and seismic anisotropy in order to solve various problems that the oil industry encounters when investigating hydrocarbon reservoirs. A recent example is the application of shear-wave analysis to determine which parts of a reservoir contain unrecovered oil and which parts contain injected water, without resorting to expensive drilling operations. Shear-waves split into two differently polarised waves when travelling through anisotropic rock (rock in which cracks and pores are aligned in a preferential direction) with each wave travelling at a different velocity. Cracks and pores containing oil or water give rise to slightly different changes in time delay between the two shear waves due to differences in pore pressure. Mapping these changes allows the water-injected region to be identified.

National geomagnetic service

We monitor variations in the Earth's magnetic field by operating magnetic observatories both in the UK and overseas. Observatory data are used to support



Buncefield explosion: strength of shaking from the Buncefield fuel depot explosion, determined for five-kilometre grid squares.

mathematical modelling of the geomagnetic field and to provide geomagnetic data to a number of academic and private sector interests. Funding from a variety of organisations, including mapping agencies and the hydrocarbons sector, support this project. We play a leading role in INTERMAGNET (the international programme for the rapid exchange of geomagnetic data) and operate a World Data Centre for geomagnetism. Near real-time data from our observatories are used to support directional drilling operations in the North Sea. The installation of a back-up generator and uninterruptible power supplies in Murchison House this year enable computer systems to continue operating during power outages. This has helped improve the reliability and robustness of the real time services to the oil and gas companies. We also maintain two observatories established by the hydrocarbons industry in Alaska and Nova Scotia to support local directional drilling operations.

Space weather

We have produced a geomagnetically induced current (GIC) monitoring and analysis software package for the Scottish Power grid. This project, with near real-time data delivery, was partly supported by the European Space Agency (ESA) in order to help them ascertain the wider market potential for space weather services. Our GIC and other space weather data, such as solar and geomagnetic activity indices, are now also regularly provided to ESA's Space Weather European Network (SWENET) data server. We also undertook a preliminary study into the potential of the Eskdalemuir observatory site for high frequency magnetic field measurements, in association with the University of Bath. Long-term continuous monitoring of the magnetic field in the ultra-low and extremely low frequency bands should provide new data on atmospheric and climate variability and the link to space weather.

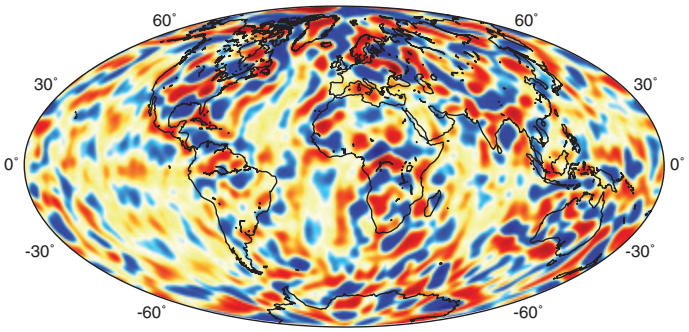
Geomagnetic field modelling

Drilling for oil with magnetic survey tools or navigating by compass requires estimates of the Earth's magnetic field derived from mathematical models. These models are on a variety of scales depending on the accuracy required. They range from global, where the magnetic field from the Earth's core is parameterised, to local, where the field from magnetic minerals in the underlying crust is estimated from airborne and shipborne surveys. The global model used for directional drilling in the hydrocarbons industry, the BGS Global Geomagnetic Model, was revised in 2005 using the latest data from the Ørsted and CHAMP satellites and from observatories around the world. The BGS supplies the magnetic north information portrayed on Ordnance Survey maps, derived from an annually revised UK model.

Using sophisticated data selection techniques and local basis functions like band-limited wavelets, long wavelength features of the crustal field can now be modelled robustly from satellite data. We are collaborating with Edinburgh, Liverpool, and Leeds universities in a project that aims to separate out the core, the crust, and external field signals in magnetic field observations and to better understand their source mechanisms.

National geomagnetic service: undertaking absolute observations of the Earth's magnetic field at Ascension Island observatory.

Geomagnetic field modelling: the vertical component of the crustal magnetic field at 400 km altitude derived from satellite measurements. The data were selected to minimise the rapidly varying external fields and modelled using spherical harmonics in both Earth-fixed and Sun-fixed coordinate systems in order to isolate the crustal magnetic field signal. Range is –18 to +18 nT.



Sustainable and Renewable Energy

Programme overview

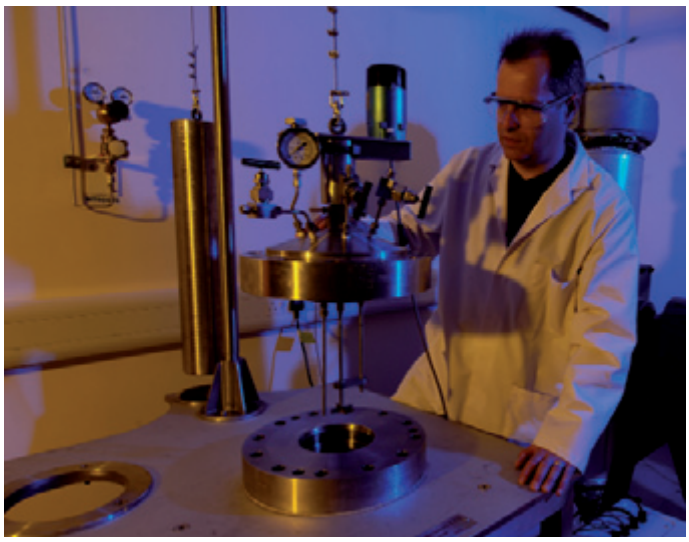
The focus of the Sustainable and Renewable Energy programme is on clean fossil fuel technologies, underground energy storage, and the interface between renewable energy infrastructure and geology. The programme aims to deliver core science to UK strategic energy priorities (Energy White Paper), and the newly formed Research Council's Energy Programme (RCEP). We have a significant international profile and are heavily involved in Europe's Framework 6 Project. Much of our activity is in collaboration with governments, intergovernmental organisations, and industry. We also provide research and technical advise on carbon dioxide storage operations for policymakers and regulators.

CO_2 GeoNet

We coordinate the European Research Network of Excellence on the geological storage of carbon dioxide (www.co2geonet.com) captured from fossil fuels. This Framework 6 Project initiative comprises thirteen partners including national geological surveys, research laboratories, and universities. This brings together expertise from the earth sciences, engineering, and biosciences. The aim is to form a durable alignment of research efforts, and infrastructure, targeted at helping enable large-scale underground carbon dioxide storage become reality.

The network has just completed its second year in which it implemented its joint research activities and initiated its postgraduate training programme. The network uniquely addresses issues surrounding potential carbon dioxide leakage from underground storage. This includes testing, comparing, and developing monitoring technologies, through to learning about the effect of leakage on organisms and ecosystems. Highlights in year include: airborne surveys over natural carbon dioxide leakage sites in Italy; and deploying a benthic chamber in a Norwegian fjord to expose the sea bed, contained in the chamber, to raised carbon dioxide levels. This experiment provides important information for marine protection if carbon dioxide storage is to be conducted beneath the seabed of the North Sea.

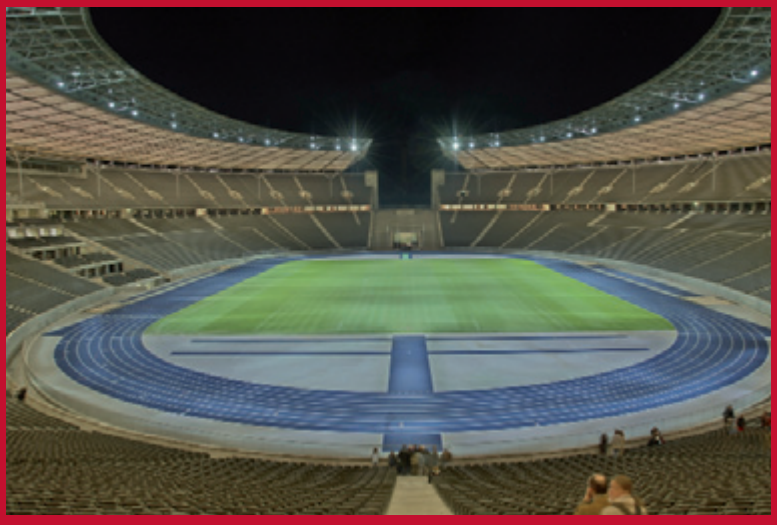
The BGS, and its network partner, the Federal Institute for Geosciences and Natural Resources (BGR), ran the underground carbon dioxide storage session at the G8+5 Energy Research workshop, hosted by the UK Energy Research Centre (UKERC). CO_2 GeoNet also gained endorsement by the USA-led Carbon Sequestration Leadership Forum (www.cslf.org). International collaboration on carbon dioxide storage was also conducted with the Petroleum Technology Reseach Centre (Canada), the Siberian Branch of the Russian Academy of Sciences (Tomsk) and the Chinese Academy of Sciences.



CO_2 GeoNet: the BGS's hydrothermal laboratory conducts long-term experiments on rock/water reactions so as to understand how rocks will immobilise carbon dioxide permanently via carbonation reactions.

UK Carbon Capture and Storage Consortium (UKCCSC)

This consortium (www.ukccsc.co.uk/UKCCSC/), coordinated by Imperial College, was launched in July and funded through the NERC 'Toward a Sustainable Energy Programme'. BGS is a major partner. The UK Carbon Capture and Storage Consortium (UKCCSC) is a consortium of engineering, technological, natural, environmental, social, and economic scientists from twelve UK universities and two NERC-affiliated institutes (Plymouth Marine Labs and the UK Energy Research Centre). The consortium is a way to rapidly expand the research capacity in the area of carbon capture and storage, commensurate with the large potential contributions to national energy targets. Our mission is to promote an understanding of how options for carbon capture and storage from fossil fuels could be used to assist the UK in achieving an energy system that is



Stefan Baum

CO_2 GeoNet: underground natural gas storage is common in Europe, but so far poorly developed in the UK. It is an extremely safe technology and is essential to maintain safe operation of gas grids and meet demand swings. Natural gas is stored in an aquifer 800 m beneath Berlin's World Cup football stadium.

environmentally sustainable, socially acceptable, and meets energy needs securely and affordably.

Underground gas storage

The sustained rise in gas prices and concerns over security of supply heightened interest in this project, which was initiated several years ago in anticipation of the present squeeze on UK gas supplies. We have been busily involved in assisting and giving geotechnical advice to planning enquiries and regional government during the year. We were also involved in advising the Department of Trade and Industry about UK salt distribution, which has resulted in a change in legislation that will allow liquid natural gas storage schemes in salt caverns. With the recent concerns over surface storage of fuels arising from the Buncefield disaster the project is now extending its remit to underground storage of refined fuels.

Renewable energy

We have been promoting low enthalpy ground source heat technologies, which so far are poorly taken up in the UK. We have also studied underground compressed air storage — a technology that could be deployed to help address the inability of wind power to load-follow electricity demand and its intermittency. Compressed air storage can also improve the efficiency and responsiveness to peaks in the demand for conventional gas turbine electricity generation.

CO_2 GeoNet: a carbon dioxide injector at the BP InSalah carbon dioxide storage site. The BGS, with its CO_2 GeoNet partners, is assisting BP in shallow subsurface monitoring to ensure security of carbon dioxide storage.

CO_2 GeoNet: the NERC ARP Dornier conducted airborne surveys over natural carbon dioxide seeps in Italy (Latera) in collaboration with CO_2 GeoNet partners. These airborne data are being compared with detailed ground observations in order to appraise ground based and airborne carbon dioxide monitoring techniques.


Burnhead
Course of
Wall Mill

Information Directorate

The BGS continued to invest substantial resources in the evolution and development of our corporate, asset-based system for information management and delivery. It is an approach that attracts interest from geological surveys around the world and during the year we have hosted senior representatives from Canada, Australia, the United States, the Czech Republic and Denmark.

The new Information Products programme was successfully initiated in 2005 along with the delivery of a new version of our national high-resolution geological hazard dataset, GeoSure, and a groundwater flooding database. We introduced new GeoReports for ground source heat pumps and building-stone assessments and there has been a huge demand for the GeoReports water borehole prognosis in southern England due to the expected drought. The BGS website attracted a record number of visitors, reaching 1.26 million in the year to April and we retained our accreditation for data access under the Information Fair Trader Scheme of the Office of Public Sector Information.

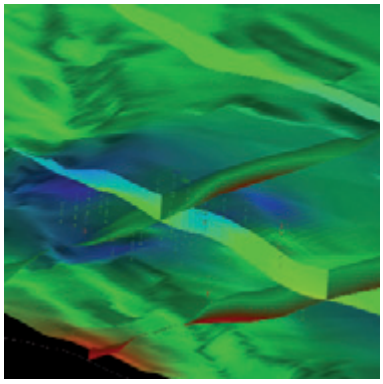
Our close collaboration with the Coal Authority, at both managerial and technical levels, culminated in the signing of an agreement on the provision of a ground stability report for the property sector and in particular for the Home Information Pack. The Regulations for the latter were laid before Parliament in June and we are pleased to note that they specifically refer to ground stability, contamination and flooding as information that is authorised to be included in the Packs.

Providing effective information systems to underpin the move to operational three-dimensional modelling and digital field data capture has been a priority and significant progress has been made, an aspect of our work that has generated considerable interest amongst our fellow geological surveys.

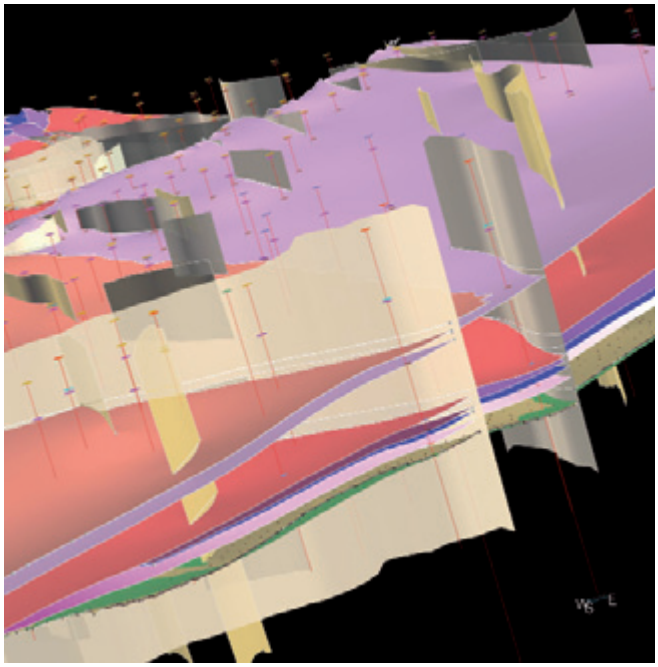
Substantial effort has been invested in monitoring and providing input to the shape and content of the upcoming EC INSPIRE Directive (a Directive to create a spatial data infrastructure for Europe, which will encompass geological data). In a similar, standards and interoperability, context the BGS is playing a leading role in an International Union of Geological Sciences initiative to develop a global geoscientific data model and Geoscience Mark-up Language.

Finally, during the year we set up a BGS 'Information Futures' team, comprising staff drawn from across the organisation, to look over the horizon at the future needs and drivers for geoscientific information. The pace of evolution of information technology and systems continues unabated and we are trying to ensure that the BGS is as well prepared as it can be for a world where flexible and dynamic access to information, driven by the user, rather than the provider, is likely to be the norm.

Model showing 3D variations in an engineering property of till in Manchester.



GOCAD™ model of key bedrock horizons, faults and boreholes in an area between Nottingham and Doncaster.

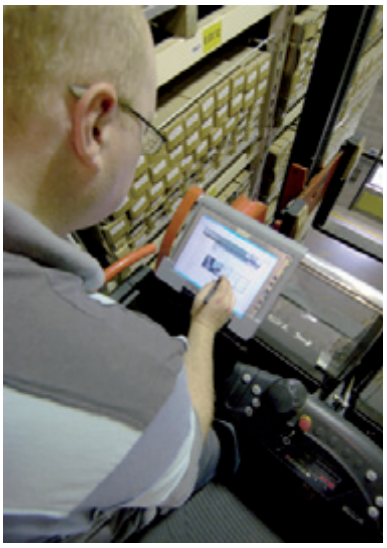


(Opposite) A fully immersive three-dimensional visualisation suite has been installed at Murchison House in Edinburgh. This new facility is invaluable as an aid to understanding geological structures in three dimensions, planning fieldwork and demonstrating geological models.

Information Management

Programme overview

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 collections: with the help of the BGS Systems and Network Support team *(see page 58)* wireless technology has been installed in the BGS core store. Staff can scan barcodes on core boxes and interrogate a remote database that returns information via a tablet PC at the top of the forklift.

Enabling access — BGS collections on the Internet

Additional funding from the NERC has allowed us to provide Internet access to our main collections databases. The British onshore borehole collection database and the mineralogy and petrology collection database are now available and the palaeontological collection database will follow shortly. This initiative means that access to the most comprehensive British geoscientific collection is now even easier, benefiting commercial organisations, academia and the public alike.

The mineralogy and petrology collection contains over a million samples, housed in Keyworth and Edinburgh, and systematically covering Britain, complete with approximately 200 000 microscope thin sections. International material is also included, as well as historical material collected by Darwin and others. The onshore borehole collection contains material from over 15 000 boreholes and the palaeontological collection of over 3 000 000 samples covers most British fossil localities from the past 175 years, including many no longer available. The collection also includes over 30 000 type figured and cited specimens, as well as comprehensive micropalaeontological material.

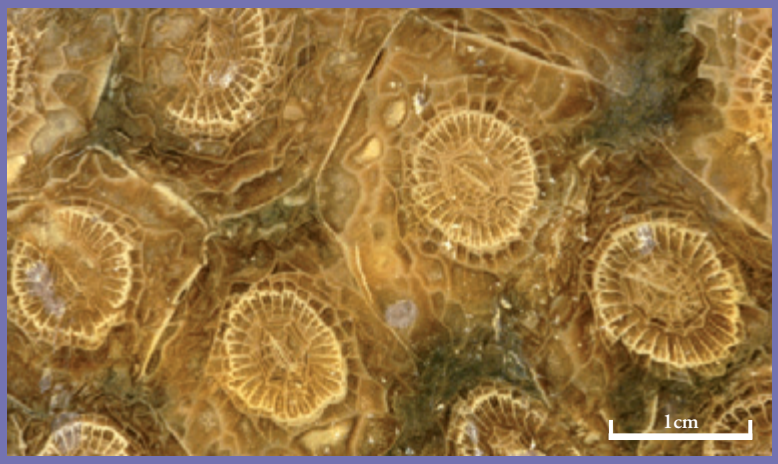
Consolidation of UK hydrocarbon sample archives

The steady decline in output from the North Sea means that the UK is now a net oil importer. As a result the provision of easily accessible data to underpin new exploration has become increasingly important. To facilitate this, the operation of the Gilmerton Core Store has been transferred from the Department of Trade and Industry to the BGS, ensuring coherent management of, and easier access to, all UK hydrocarbon sample archives. The Gilmerton Core Store has now become a constituent part of the National Geoscience Data Centre and will support the commercial sector, the academic community and the NERC's own research.

The transfer was marked by a formal ceremony on 12 October 2005, when Nigel Griffiths, MP for Edinburgh South and then a Minister at the Department of Trade and Industry, opened the National Geoscience Data Centre Gilmerton Core Store. The exploitation of the UK's remaining reserves is being further assisted by the work of the National Hydrocarbons Data Archive.

Improving the quality of corporate databases

Our corporate databases are key to our success in information management. Substantial effort is devoted to ensuring that the databases are designed, documented, implemented and managed to a professional standard. During the past year three developments of the database system have been completed. The first is the production of improved guidelines for database developers to ensure that they follow corporate standards. Secondly, the BGS has invested in a new database-modelling tool, which will allow us to clearly and fully document all aspects of our corporate data model and ensure that new developments are fully integrated with the existing database tables. This data model repository will be available to all BGS developers helping to share knowledge and best practice. Finally, we have upgraded our system to Oracle® 10g. This will allow us to exploit the wealth of new functionality built into this version of the database software and to continue the development and evolution of our information management and delivery.



BGS collections: a specimen of the fossil coral *Lonsdaleia caledonica* Smith from Boghead near Lesmahagow, Lanarkshire, Scotland. (GSE 1366).

Consolidation of UK hydrocarbon sample archives: Mr Derek Davis (BGS Board Chairman) and Dr David Falvey (Executive Director) present Mr Nigel Griffiths, MP for Edinburgh South with a geological map of his constituency at the opening of the Gilmerton Core Store.

Redesign of Coastal and Marine Database

The first stage in the redesign of the Coastal and Marine Database was completed successfully during the year. This involved the development, testing and initial population of the Marine Surveys Module. This holds information associated with the geological and geophysical surveys conducted on the UK continental shelf and surrounding deep-water areas. As an example, the BGS currently holds some 300 000 line kilometres of survey information and new survey data is gathered every year. The new system is ISO compliant and better integrated with other corporate databases, delivery systems and with the internal coastal and marine geographical information system. The system allows a much richer set of information to be stored and queried than previously. Existing data are being validated during migration and additional parameters are being captured. Loaders have been developed to capture information from new surveys.

BGS corporate dictionaries online

A range of digital dictionaries underpins the BGS's databases, applying constraints to the terms that are entered into the individual database fields. These dictionaries cover a wide range of fundamental geoscientific terms. We are progressively publishing these dictionaries on the Internet to allow users to incorporate these controlled vocabularies into their own systems. The first two such dictionaries to be published are the BGS Lithostratigraphical Lexicon and the BGS rock classification schemes. Both can be downloaded as Microsoft Excel spreadsheet files. These first two dictionaries to be published are arguably the most fundamental in geoscience and are of relevance to the widest audience.

Consolidation of UK hydrocarbon sample archives: one of the core storage aisles at BGS Gilmerton — showing just a fraction of the 300 km of core and 5 million cuttings samples.

Information Delivery

Programme overview

The Information Delivery programme carries out all activities related to the internal and external delivery of the BGS's data and information products. These include internal and external web delivery of our science and commercial products, the Enquiry Service, Sales, the BGS Library, Science and Society, and Copyright and Data Licensing.

Web delivery

The main BGS website (www.bgs.ac.uk) continues to grow in popularity, with over 1.26 million visitors in the year to April 2006. The continually updated website provides a wealth of information and free reference materials — over a thousand reports can now be downloaded free of charge. The strong growth of the BGS e-commerce site (www.geologyshop.com) continues. The online bookshop now accounts for 15% of all sales, and there was a 64% increase in online GeoReports orders over the previous year. Further online services, including enhancements to GeoRecords, are due for release in the coming year.

The Intranet is a core element of our internal scientific and administrative operation. It now has over 60 000 static pages, images and documents, and over 5000 scripts (ColdFusion™, Perl). The requirement for greater robustness and resilience to cope with ever increasing demands was achieved this year through the implementation of cluster technology.

Enquiry Service

The BGS Enquiry Service responded to 21 000 enquiries during 2005/06. Of these, some 8000 were from members of the public seeking advice on a wide range of geological matters, including questions from school pupils and students via the online '*Ask-about-Geology*' service. The commercial side of the service also performed very strongly, with over 8000 GeoReports provided to customers, including the newly released Building Stone Assessment and Ground Source Heat Pump reports. The GeoRecords service dealt with 5000 enquiries for copies of archive material held in the National GeoScience Record Centre. Many customers, including visitors, were able to take advantage of the increasing availability of digital scans of the Records Centre archives.

Sales

The Sales Desk network disseminates publications and related products to the BGS's wide range of customers. The network also provides an important route through which feedback on our publications is channelled back into the organisation. A catalogue of geological maps, publications and data is published annually, and for the first time this year an index map was also produced. In addition to the main series map publications and reports, new popular publications and 'Classical areas of British geology' (for instance, *Glencoe caldera volcano, Scotland*) were released.

There was a marked shift from traditional postal and telephone sales to orders via the online bookshop (www.geologyshop.com), which accounted for 15% of all sales, including a growing proportion from outside the UK. The 1:10 000 scale geological map series and the BGS collecion of '6-inch' scale Historic Ordnance Survey maps are now available for online purchase in analogue and digital formats.

Enquiry Service: a GeoReports Building Stone Assessment was used in the major redevelopment at London King's Cross–St Pancras.

Library

This year has seen a major refurbishment project at the Keyworth Library. The main serials shelves have been replaced with rolling stacks, creating room for expansion and allowing the integration of stock into a single logical sequence. Access to electronic information has been improved through greater access to online journals and scanning of BGS reports, along with scanning and metadata entry for photographs by a corps of volunteers. A major upgrade to GEOLIB (the online public access catalogue) has improved searching and download facilities. Collection descriptions were added to the Cornucopia database and our serials holdings were downloaded into Suncat — a union catalogue for serials.

Participation in events such as the National Archives Awareness Campaign, the Geological Society's Careers Day and providing numerous tours for external groups and visitors have greatly increased awareness of the Library collections and services. The BBC visited the Library to view rare archive documents during research for their documentary dramatisation on Krakatoa.

Science and Society

The Science and Society project supports the BGS's aims of improving the public understanding of science, specifically geoscience. It does this principally through publications such as *Earthwise*, the BGS website, public events, and a programme of activities for schools. Issues of *Earthwise* were published on the themes of *Aid and co-operation around the world* and *The geoscience challenges of oceans, seas and coasts*. The Popular Geology and Education section of the BGS website saw a 70% increase in visitor sessions over the previous year, and was nominated by Yahoo! as one of their 2005 educational 'Finds of the Year'. A major new interactive application, the *Geological Timeline*, was launched along with an improved version of the popular *Make-a-Map* tool.

BGS support for schools is mainly delivered via the Department for Trade and Industry's Science and Engineering Ambassadors initiative. During the year, the number of accredited Science and Engineering Ambassadors at BGS increased from 24 to 37 and they helped to deliver an expanded programme of hands-on science and enterprise activities in schools. Several events for National Science Week were held at both our Keyworth and Wallingford offices, and the Murchison House Open Day in September attracted a record number of visitors.

Intellectual property rights

The Intellectual Property Rights section provides guidance on intellectual property matters and advises staff and external parties on the terms and conditions relating to the use of BGS materials. Demand for our digital data continues to grow, and income from digital data licences, copyright fees and royalties increased by 6% over the previous year. Private sector Value Added Resellers continue to use our information products in an ever-increasing range of environmental search products. The user base and market penetration for these information products is widened through a network of Licensed Data Suppliers, and there was marked growth in income from this sector during the year.

Science and society: detail from the *Geological Timeline*, a major new interactive application launched on the Popular Geology and Education section of the BGS website in 2005.

Sales: the BGS catalogue of geological maps, publications and data and the *Glencoe Caldera Volcano, Scotland* booklet from the 'Classical areas of British geology' series, published in 2005/06.

Information Products

Programme overview

Information Products is a new programme. Its role is to design and prepare the national digital datasets that are fundamental to geoscientific research and ensure the availability of relevant information for use by society, commerce and government. Products include digital bedrock and superficial geology at a variety of scales and new data products derived from integrating geological data with other geoscientific and environmental data; for example; engineering, chemical, mining and hydrological hazards. The programme remit covers the development of both onshore and offshore datasets.

DiGMapGB and National Borehole Information Capture

We have made considerable progress in creating the Digital Geological Map of Great Britain (DiGMapGB) — a national digital geological spatial database at scales of 1:625 000, 1:250 000, 1:50 000 and 1:10 000. Standardised geological map databases provide the core data, which can be tailored to meet the particular needs of both external customers and NERC scientists. DiGMapGB-50, a full GIS dataset, is now the prime reference for British digital geological map data and means that Great Britain now has the most detailed national coverage of digital geological map data in the world.

The programme also extends into the third dimension and a project (the National Borehole Information Capture project) to create a single BGS interpretation of boreholes within its data holdings has been initiated. Boreholes will be selected according to their geological and spatial significance. The project will create a dataset that will underpin the 3D Lithoframe modelling programme and meets external demand for a single authoritative interpretation. The work involves recording borehole log information, classifying the information in terms of the lithostratigraphy and progressively building a thesaurus for local terms.

DiGMapGB-50 and existing borehole data have been combined to create the first models of the thickness of superficial deposits and rockhead surface for Great Britain. These are critical to a number of areas of work, such as civil engineering (the planning and building of roads, pipelines and major structures), the evaluation of groundwater resources and their potential for pollution, and as a key input to the prediction of surface hazards, such as landslides and the collapse of underlying rocks.

Geohazard Products

GeoSure

GeoSure is a national dataset that identifies the potential for natural ground instability, a major cause of subsidence (and insured losses) in the UK. GeoSure incorporates landslides, swell-shrink clays, running sands, soluble rocks, and collapsible and compressible deposits. Subsidence can be a serious problem for homeowners, insurers, planners and surveyors. A familiar consequence of ground stability, and in particular swelling clays, is cracks in the walls of houses. But more dramatic and less common problems also include damage to roads and pipelines from landslides, or building collapse into cavities caused by dissolving rocks (such as gypsum).

Mining activity

Voids caused by past mining activity can also lead to ground movement and are a hazard in their own right. More than 35 different raw materials have been extracted in Britain, ranging from precious metals such as gold and silver, to bulk materials such as sandstone and gypsum. Coal mining areas are relatively well known, but fewer people are aware of other forms of mining. Understanding the extent of past mining activity is extremely important in ensuring health and

Groundwater flooding: roads in Berkshire had to be closed during the exceptionally wet winter of 2000/01 due to groundwater flooding.

safety and the stability of property. The Information Products programme is building a dataset that identifies ground likely to be affected by past mining activity for commodities other than coal.

Potentially harmful elements

Chemical elements occur in the environment, which, under certain circumstances, can be harmful to plants, animals, or people. Relatively high concentrations of potentially harmful elements (PHEs) such as arsenic, chromium, or nickel may be found in soils, stream sediments, surface waters, groundwater or dust. The sources of PHEs may be natural, such as rocks containing veins of metals, or artificial, for example sewage sludge. Spatial datasets are being developed which delimit areas of potentially high PHEs, and which can provide information important for planning and land management. Radon, a naturally occurring radioactive gas of geological origin, is a nationally recognised health risk, estimated to cause 2000 to 3300 deaths per annum in the UK. The BGS is working with the Health Protection Agency's Radiation Protection Division to improve the resolution and quality and update the currently available radon information.

Groundwater flooding

Unlike flooding by rivers, groundwater flooding is little reported and not widely appreciated. However, it can cause significant social and economic disruption to affected areas. For example, during the exceptionally wet winter of 2000/01 groundwater levels were high throughout much of southern England. One of the more serious incidents took place near Brighton where groundwater flooding affected over two dozen properties including a petrol station, flushed sewage into the streets from surcharged sewers, and disrupted the mainline London to Brighton rail link and the A23 road route. Groundwater flooding events tend to be longer lasting than surface water or fluvial flooding and subsequently more costly per property. A national groundwater-flooding product has been developed, which builds on the BGS's research in groundwater management.

Seabed sediment

Seabed sediment information is being used to identify the variety and distribution of possible hazards that may pose problems for new developments, such as oil rig, pipeline and wind farm construction. We are collating seabed records and developing an offshore linear route system to enable us to better answer queries related to offshore renewable energy, oil and gas development, aggregate extraction, fisheries, environmental monitoring, marine and coastal planning and legislation.

In partnership with the BGS Business Development team we continue to research potential markets and evaluate potential new products with the aim of exploiting and adding value to BGS data and knowledge. In doing so the focus will be on creating national datasets that are needed by our external customers.

GeoSure: subsidence hollow over 10 m across and 5 m deep, Ripon. The subsidence was caused by a cave system formed by the dissolution of gypsum and the collapse occurred in April 1997.

GeoSure: landslip on the A9 trunk road approximately 2 miles north of Dunkeld.

Information Systems Development

Programme overview

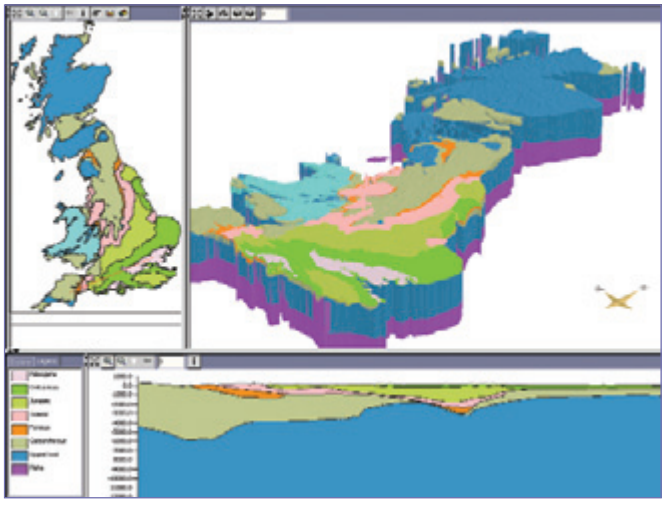
The programme is responsible for information systems developments that enhance geoscientific knowledge delivery. It works at the interface of geoscience and information technology. A priority is providing underpinning systems for three-dimensional modelling and visualisation and digital field capture systems. The programme is also taking forward development of secure web delivery, geographical information systems and digital publication systems. The programme provides a coordinated and controlled approach to new system developments within BGS IT systems, through the role of the Applications Architect.

Three-dimensional geoscience

The BGS continues to lead in the application and development of operational, multi-dimensional, geoscientific spatial modelling systems. This year we have advanced capability in this field and promoted the ongoing development and support of several key geospatial systems for the BGS science programme. A major element of this project is to continue to develop and support the IT infrastructure developed by the Digital Geoscience Spatial Model (DGSM). The programme works closely with the National Geoscience Framework programme (*see pages 12–13*). Substantial upgrades were made to the DGSM infrastructure, with development of the model storage, retrieval and archiving within the three-dimensional geoscience (3DG) portal. Such underpinning infrastructure has allowed the BGS to develop and improve its 3D visualisation systems, and we have added a second fully immersive visualisation suite at Murchison House and procured two portable immersive visualisation systems.

The programme works with and customises state-of-the art commercial systems such as: the virtual geo-landscape software by Virtalis Ltd; three-dimensional modelling systems such as GOCAD (Earth Decision Systems) and GSI3D from Insight GmBH; and ESRI's ArcGIS suite. We were an early adopter of the Itronix field tablet — 55 new tablet PCs are now deployed — and integrated data collection for the Geoscience Spatial Database is under way.

The 3DG project continued its international collaboration with the development of the conceptual data model, which underpins Geoscience Markup language (GeoSciML), We also contributed to the development of a Multi-Lingual Thesaurus (MLT) for the geosciences, and the development of a geographical thesaurus incorporating spatial 'footprints' for use in applications such as the GeoIndex. A small but important part of the project investigates new spatial technologies that may be of relevance to the BGS in the medium term.



Three-dimensional geoscience: the GSI3D Subsurface Viewer (Insight GmBH) displaying the UK Regional 1 million scale Lithoframe model.

Geoscientific computing

Information systems need to provide geoscientists with platforms that are able not only to process data but also aid their interpretation and turn those data into knowledge. This project promotes and supports the development of capability in technical computing. Specifically it is developing a confidence modelling system that will help to promote the BGS's position as a provider of quality assured geoscientific data products. The project uses a collaborative approach to systems development and spans areas such as eScience, GRID and the development of coupled IT systems, which will allow improved integration with other scientific centres and deliver our own products more effectively.

Publication systems development

The project has focused on developing publication and graphics presentation systems that are aligned with evolving science program workflows. For example

outputs from three-dimensional modelling of landscapes and surfaces were converted into professional quality fly-throughs and animations, and immersive stereo clips with advanced 3D film effects were produced. These have been used to demonstrate and market BGS capabilities through dynamic and realistic displays of geological models and processes. The project has also supported the prototype development of a commercial photo library, which will be completed during 2006/07.

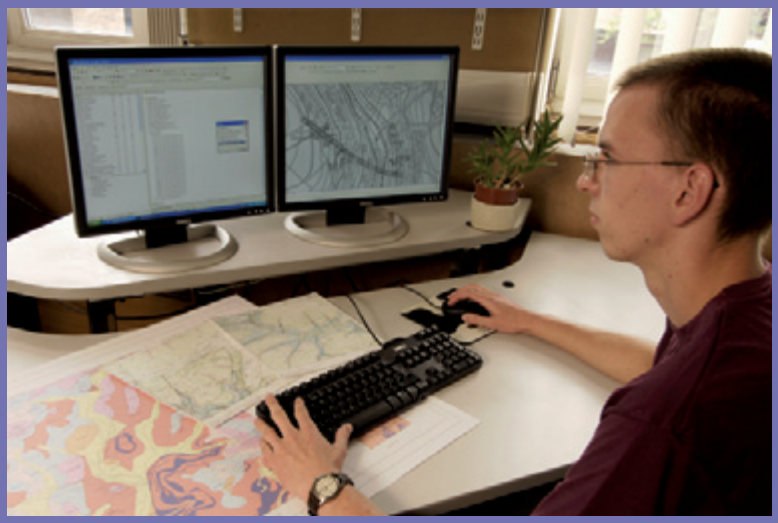
Research Centre Infrastructure Fund projects

Digital field mapping

Research Centre Infrastructure Fund (RCIF) support has enabled us to purchase 55 rugged tablet PCs that are running bespoke, cutting-edge software for capturing digital geological field data. The software was developed within the BGS. This technology is enabling our staff to capture observations and interpretations in the field and make it readily available for use in modelling and visualisation systems. Training courses are under way and the equipment has been deployed in mapping projects as part of our developing integrated digital workflow.

Cartographic production system development

RCIF funding also allowed continued development of the AEGIS project, now in the second of three years. The BGS have been operating digital cartographic production systems since the 1980s, and this project is developing new cartographic workflows using ESRI software. These workflows will be fully integrated with the digital field capture systems. The development has produced customised data capture and cartographic systems, and has workflows to handle data generated by both traditional and modern digital field surveys.



Cartographic production system development: the AEGIS digital cartography system in operation. This system can handle data generated by both traditional and modern digital field surveys.

Digital field mapping: field staff have received training in new technologies.

Digital field mapping: rugged tablet PCs enable mapping in all weather conditions.

Geoscientific Skills and Facilities Directorate

Role overview

The role of the Geoscientific Skills and Facilities Directorate (GSFD) is to ensure that adequate human and physical resources are available to deliver the scientific programme, and to develop scientific capacity in order to ensure that our capabilities remain in line with both our present and future requirements. Scientific staff are managed and deployed by four Heads of Discipline (HoDs), divided into groupings of: Geology, Geotechnics and Palaeontology; Geophysics and Marine Geoscience; Geochemistry, Mineralogy and Hydrogeology; and Information Systems. A separate HoD is responsible for staff in Administration and Finance. GSFD also manages the full range of BGS's scientific infrastructure including laboratories, information technology facilities, and publication services: these areas are all headed by a manager responsible for strategy and operational matters. We take staff training and development very seriously and GSFD runs an extremely active training section headed by a training manager responsible for meeting the development needs of all staff.

University collaboration

The GSFD acts as a focal point for collaboration between universities and the BGS. There are currently two collaborative schemes operating: the School of Field Geology (described on pages 58 and 59) and the University Collaboration Advisory Committee (UCAC). UCAC funds research students at M.Sc., B.Sc., and Ph.D. levels as well as post-doctoral research fellows and specific research projects between collaborating scientists at the BGS and a specific university. To date UCAC has supported over 50 Ph.D. projects, 8 M.Sc. projects, 13 specific research topics and a small number of post-doctoral projects. The projects are spread across over 20 universities involving over 60 academic scientists. 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, and remote sensing. UCAC 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.

Optimising BGS resources and encouraging staff development

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: 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 and/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 coordinates a wide range of activities such as conference attendance, secondments, publication of key Commissioned Research data and results; involvement in learned societies and professional bodies and taking up a range of leadership positions within the wider community.

Mobile Environmental Laboratory: this new facility has already proved its worth on several projects, for instance it was used to carry out soil gas, portable XRFS and microbial analysis at a natural analogue site for underground storage of carbon dioxide in Latera, Italy.

(Opposite) The new MC-ICP-MS (multi-collector inductively coupled plasma mass spectrometer), acquired autumn 2005. It can be used for the high-precision analysis of a number of isotope systems and is predominantly being used currently for laser ablation uranium–lead geochronology.

Publications

Programme overview

The Publications programme publishes the BGS's formal output of maps, books and reports. It is a major contributor to our digital databases, in particular the Digital Geological Map of Great Britain (DiGMapGB) and the National Archive of Geological Photographs. We also design and produce marketing and promotional materials, and this year has seen a remarkable growth in demand for multimedia products, for example, web pages, and animated visualisations of geological processes or history.

We use geographical information systems (GIS) to capture geoscientific information to build digital map databases (DiGMapGB) and produce cartographically enhanced hardcopy. The year has seen a significant increase in survey-scale data (1:10 000 scale) provided to us through SIGMA (*see page 49*) for us to develop into cartographic standard datasets for licensing and print-on-demand maps.

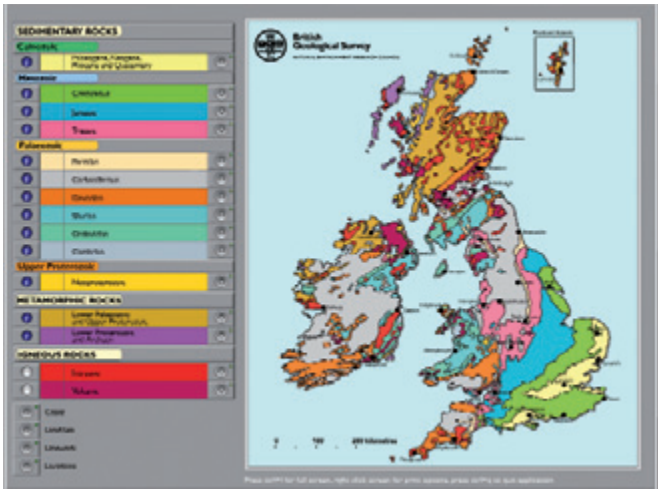
Graphic design and publishing

A range of high quality books has been published. Notably, these include Sheet Explanations that accompany the 1:50 000 scale maps, a British Regional Geology guide to the Palaeogene Volcanic district of Scotland, a seismic atlas of Southern Britain, and a memoir describing the structure and evolution of the south-west Pennine Basin. Other reports are converted to digital documents (in PDF) and made available as free Internet downloads.

Demand for the graphic design service has grown considerably for multimedia products, including the *Make-a-Map* interactive geological map of Great Britain; website design for the Afghan geological survey; and a redesign of the website for the Association of Geoscientists for International Development (AGID).

Reprographic and Photographic Services

Investment in digital studio equipment has enabled large-format photographic image capture and large-format reprographic scanning. Recruitment of a professional photographer with commercial and teaching experience boosted the service capabilities and effectiveness. A broader range of work is possible to further enhance the National Archive of Geological Photographs. Digitisation of the Northern Ireland photographic collection is now complete and available online.



Publications output in 2005/06: *(left, below, and opposite)* publications included technical reports, brochures, geological maps and sheet explanations, and web and multimedia products for internal and external customers.

Output in 2005/06

Digital map and book data and printed media include:

- Additions to the 1:50 000, 1:25 000 and 1:10 000 scale map databases. At 1:10 000 scale, map data covers 7% of Great Britain (820 5 × 5 km tiles).
- At 1:10 000 or 1:25 000 scale 132 maps were approved for print-on-demand.
- Fourteen new maps were litho-printed and published at 1:25 000 and 1:50 000 scale.
- Folded editions of 29 maps were published.
- Ten maps approved for print-on-demand at smaller scales.
- Additions to the horizontal sections to the LithoFrame models *(see page 12)*.
- Geological Memoir: Structure and evolution of the south-west Pennine Basin and adjacent area.
- Southern Britain Seismic Atlas.
- British Regional Geology: Palaeogene Volcanic District of Scotland.
- Sheet Description: Geology of the Huddersfield district.
- Sheet Explanations: Geology of the Beaconsfield district, Geology of the Brecon district, Geology of the Huddersfield district, Geology of the Kettering district.
- Annuals: UK Minerals Yearbook 2004, Annual Report 2004/05, Directory of Mines and Quarries 2005, World Mineral Production 2000–2004, Map Catalogue 2006.
- Thirteen 'special' publications, including Strategic Science Programme 2005–2010, DGSM Final Report.
- Earthwise 22, Earthwise 23.
- Twelve multimedia CD and original website designs, including Make-a-Map, Afghan Geological Survey Website.
- A total of 127 'projects' in the posters and brochures series, including Corporate Brochure 2006.

Laboratory Operations

Programme overview

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.

Scientific infrastructure: Niton Handheld X-Ray Fluorescence Spectrometer being used for metal contaminant determination in waste soil.

New XRD: PANalytical X'Pert Pro X-ray tube, goniometer and sample changer.

BGS Mobile Environmental Laboratory

A Mobile Environmental Laboratory (MEL), the first of its kind in the UK, has been developed and equipped with state-of-the-art screening and laboratory based analytical tools. The facility allows the rapid, on-site analysis of soil, water and gas samples for a wide suite of analytical determinands. Operational and scientific decisions can be taken instantly, resulting in cost benefit savings through more focused identification of samples for laboratory testing while still increasing coverage of the site. The laboratory has proved its worth at a number of sites around the UK since its launch and has been used, for instance, to determine the organic toxicity of drill core in southern England and the microbiological activity of soil in the East Midlands. The MEL has recently returned from Italy where it was an integral part of a collaborative research project on underground carbon dioxide storage.

X-ray fluorescence spectrometry

The X-ray Fluorescence Spectrometry (XRFS) laboratory has been enhanced by the delivery of its second PANalytical Epsilon-5 energy dispersive, polarised XRF spectrometer and a new PANalytical Axios Advanced 4 kW sequential wavelength dispersive XRF spectrometer. The laboratory now houses five fully automatic spectrometers that are used to deliver high quality geochemical data to its main customers, the G-BASE and TELLUS projects. The laboratory has also led the way in mobile analytical XRFS methods. Three Niton handheld XRF spectrometers and a PANalytical MiniPAL4 bench-top XRF spectrometer are available for the determination of metals in soils, sediments and environmental materials in support of the mobile environmental laboratory.

X-ray diffraction and thermal analysis

To retain our position at the forefront of analytical mineralogy, we have invested in new state-of-the-art X-ray diffraction and thermal analysis systems. The versatile PANalytical X'Pert Pro diffractometer offers superb resolution for the identification and quantification of mineral phases. Using the X'Celerator detector, diffraction traces can now be obtained 100 times faster than with previous instruments. The Mettler-Toledo SDTA851^e simultaneous thermogravimetric and differential thermal analysis system offers complementary mineralogical information by monitoring sample response to a controlled heating programme. Both instruments are in great demand for projects across the BGS programme, particularly in the study of poorly ordered minerals in soils, contaminated sites and Quaternary deposits.

Hydro mechanical behaviour of clay-shale

The Transport Properties Research Laboratory (TPRL) is a specialist facility undertaking applied experimental research on the movement of gas, water and solutes in natural and engineered materials. This year the TPRL completed a detailed experimental study on behalf of the Mont Terri Consortium examining the deformation behaviour of Opalinus Clay in response to a change in boundary stress (simulating burial and subsequent exhumation of the clay). This complex experimental history, supported by numerical modelling, provided information on the consolidation, creep and rebound behaviour of the clay that will be used to help assess the long-term evolution of the Opalinus Clay as a potential geological barrier for the disposal of radioactive waste.

Maintenance and Development of Capability

Programme overview

The Geoscientific Skills and Facilities Directorate carries out strategic scientific research to underpin BGS's core strategic and commissioned programmes. The Maintenance and Development of Capability programme comprises many small-scale initiatives covering a diverse range of scientific disciplines, including laboratory operations, remote sensing, geophysical equipment and software maintenance and palaeontological applications. The main objective is to assimilate new scientific ideas and technological developments across a wide range of our present and future activities. The programme is used to maintain our cutting-edge capability through introduction of new methodologies, enhancement of existing capabilities and formal accreditation of our scientific services.

Taxonomy Online

The Taxonomy Online project uses the Internet as a forum to illustrate fossil specimens held in the collections of the BGS and collaborating institutes, and to outline their taxonomic, biostratigraphical and palaeogeographical importance. The project captures data relating to fossil taxa in a way that is readily accessible through information technology, to facilitate their identification and promote their use in stratigraphical studies. Data are presented as BGS Research Reports and as web-based packages, so that amateur, student and professional palaeontologists have easy access to the information. Several 'monographs' have been completed, including those on Wenlock graptolites and Palaeozoic spores, and several are nearing publication, including Cenomanian ammonites and Kimmeridgian ostracods. New starts during 2005/06 included Callovian ammonites, Hettangian ammonites, Early Palaeozoic acritarchs and Late Palaeozoic conodonts.

Dating and tracing recent groundwaters

Chlorofluorocarbons (CFCs) have been building up in the atmosphere at a known rate since the late 1930s. The dissolved concentrations of CFCs in rainfall provide a unique signature of the atmosphere at that particular time and can prove invaluable in groundwater studies concerned with water flow paths and residence time. However, atmospheric CFCs are starting to decline as a result of the Montreal Protocol, and in a few years there will no longer be a 'unique' date to fit the measurements made. In response, the laboratories at BGS Wallingford have developed the capability to measure sulphur hexafluoride (SF_6) in groundwater. This chemical behaves in a similar manner to CFCs, but its atmospheric concentration is increasing since it is not subject to the Montreal Protocol. It should therefore serve as a good groundwater tracer for many years to come. Concentrations of sulphur hexafluoride in groundwater are very low, with measurements made in units of femtomoles per litre (10^{-15} moles). This capability is unique within the UK and has been used by the BGS, consultants and water companies in a number of applications.

Assessing the fine-scale structure of rocks and soils

The BGS geotechnical and geophysical laboratories have developed a methodology for assessing the fine-scale structure of rock and soil cores using electrical resistivity measurements. The technique uses a bench-top robot to acquire very closely spaced resistivity point data systematically across the face of core samples. The data are processed to create a resistivity image that highlights fine-scale sedimentary and discontinuity structures across the core, allowing millimetre-scale variability to be assessed. Recognition and assessment of these fine scale structures are important in understanding the flow paths of fluids, such as water and oil, in reservoir rocks. For example, thin sedimentary layers often present barriers to the flow of fluids and are reflected as low resistivity 'zones' due to the presence of clay, or high resistivity 'zones' due to more pervasive cementation around individual grains. The assessment of fine-scale structures in sedimentary rocks and soils is also assuming ever more importance as their sensitivity to past climatic change becomes recognised.

Dating groundwaters: groundwater sampling in Bishkek, Kyrgyzstan, where CFCs and sulphur hexafluoride have been used by the BGS to determine water movement beneath the city.

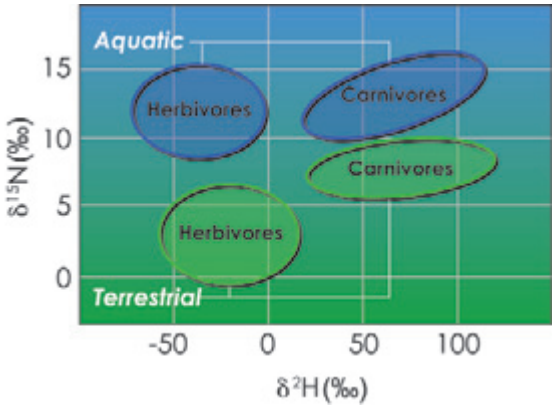
NERC Isotope Geosciences Laboratory

Programme overview

The NERC Isotope Geosciences Laboratory (NIGL) is a comprehensive facility for the analysis of stable and radiogenic isotopes 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.

NASA Imagery

The role of weathering on global cooling: weathering of the Himalayas and Tibet is an important sink for carbon dioxide levels.



Dietary effects on hydrogen in animal bones: isotope differences due to diet within animal bones.

Dietary effects on hydrogen in animal bones

Special facilities for analysis of non-exchangeable $^{2}H/^{1}H$ ratios were used in a pioneering study of hydrogen isotopes in animal bones with the Department of Archaeology, University of Cambridge, and published in Birchall et al. (2005), *Journal of Animal Ecology*, 74, 877–881. Analysis of a wide variety of modern terrestrial and aquatic animals revealed that there was a substantial increase in the δD value of carnivores compared to herbivores. Of particular significance was the fact that, compared with nitrogen isotopes, this trophic level increase for hydrogen was more consistent, and irrespective of terrestrial versus aquatic environments.

Sources of nitrate in UK upland waters

The first $^{15}N/^{14}N + {}^{18}O/^{16}O$ study of nitrate in UK rainfall and stream waters has demonstrated the ability of this technique to discriminate nitrate sources, and provided some surprising results. Working with researchers from University College London, we have found that $\delta^{18}O$ values of nitrate allow clear distinction between atmospheric (rainfall) and bacterial (soil-derived) sources. Contrary to expectations, moreover, results from samples from the UK Acid Waters Monitoring Network indicate that streams draining upland areas contain hardly any nitrate from rainfall. Almost all of the nitrate has been leached from the soils, with important implications for modelling ecosystem response to future changes in acid deposition.

The role of weathering on global cooling

Weathering of rock involves absorption of atmospheric carbon dioxide, and may have played an important role in cooling of the Earth's climate during erosion of the Himalayas and Tibet during the past 40 million years. A joint study with the Open University used radiogenic isotope tracing techniques (uranium–lead geochronology, strontium, neodymium, hafnium) to determine the relative importance of the western and eastern Himalaya in this process, and the results are published in Richards et al. (2005), *Earth and Planetary Science Letters*, 236, 773–796, and Richards et al. (2006), *Geology*, 34(5), 341–344.

North Atlantic region atmospheric circulation dynamics

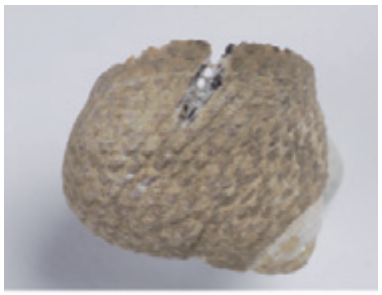
Using the isotope composition of authigenic carbonate in a Swedish lake (Lake Tibetanus), we have determined the characteristics of regional precipitation and shown that oxygen isotope ($\delta^{18}O$) minima occurred at about 150, 500, 700, 1200, 1400, 1600 and 2900 calibrated years BP and these all coincided with major peaks in North Atlantic ice-rafted debris deposition. It is suggested that these patterns from northern Swedish lakes are caused by the same climatic shifts as those noted in the North Atlantic marine records. The lakes therefore provide a high-resolution archive of regional information about Northern Hemisphere climate and help in the reconstruction of weather patterns to a higher resolution than is available through the marine isotope record.

Marine resources in the Mesolithic and Neolithic of Sicily

Shell carbonate samples from marine rocky shore intertidal gastropods were investigated in both modern and archaeological

North Atlantic region atmospheric circulation dynamics: Lake Tibetanus in northern Swedish Lapland. (Photography courtesy of Gunhild Rosqvist, Stockholm University.)

Marine resources in the Mesolithic and Neolithic of Sicily: sampling strategies on shells of *Monodonta turbinata* for isotope analysis. (Shells courtesy of Ken Thomas, University College London.)



specimens to evaluate their use in determining the time of year of food consumption in past cultures. Variations in shell edge values of $\delta^{18}O$ in living specimens show that the species can be used for palaeo-seasonality studies and provide information on the season of collection. The study also shows that the human exploitation of marine resources increased in the later Mesolithic to early Neolithic periods.

Earthtime

Knowledge of the timing of events in the geological record is crucial to our understanding of mass extinctions and other globally significant episodes. However, the development of a highly resolved, accurate timescale using $^{40}Ar/^{39}Ar$ and uranium–thorium–lead (U–Th–Pb) geochronology is hindered by problems of inter-laboratory calibration and standardisation. The NIGL is playing a leading role in addressing these issues through its accurate synthesis and calibration of new U–Th–Pb tracers and reference solutions. The work is being undertaken in collaboration with the Massachusetts Institute of Technology. The distribution of our solutions to world laboratories via the EARTHTIME project hub (www.earthtime.org) will play a vital part in underpinning high precision dating of earth events.

Sources of nitrate in UK upland waters: Lochnagar, one of the nitrate monitoring sites.

Staff Development and Infrastructure

School of Field Geology: BGS course tutor Dr Colin Waters *(right)* instructing a postgraduate student and BGS recruit working as a pair on the geological mapping course.

Training and staff development

During 2005/06 all staff received training in the use of the new electronic records management system. Courses were also provided covering a range of personal and workplace skills, with particular emphasis on communication and presentation skills training. Senior staff attended a series of NERC-organised leadership workshops and 72 new recruits attended induction courses.

Scientific training included field-based courses in clastic sedimentology, modern glacial landscapes, mapping in high-grade gneiss terranes, sequence stratigraphy, geological feature mapping, structural geological mapping, an introduction to landslides and both lowland and highland Quaternary geology, some of these courses being run in conjunction with the BGS School of Field Geology (SFG). The SFG initiative was a success with 11 postgraduate students attending courses in core field skills. The students are trained alongside BGS staff, mostly new recruits. External attendance is funded by the BGS and by the NERC for their sponsored students. Feedback has shown that these field skills are highly valued both by the students and by future employers.

In the IT sector, training was provided in a number of specialist areas, as well as further training in web technologies to support geoscientific modelling and information delivery activities. Courses in 3D visualisation and geological modelling software were held, as well as in-house training in the corporate software applications used widely by staff. New in-house courses in modelling uncertainty, an overview of the Digital Geoscience Spatial Model and the use of the new 3D visualisation suites were developed and presented.

A variety of health and safety training courses were run, primarily for staff working in hazardous environments or with potentially hazardous materials and equipment. Training in first aid and fire awareness was provided as well as in specialist areas such as minibus driving, gas safety awareness and the use of high voltages in the marine environment. Fifty staff were trained in quarry safety and a programme of safety responsibilities and risk management training for all staff was concluded.

New recruits and those undertaking major job changes received workplace coaching and support was provided for 44 staff working towards further education qualifications. Seven staff successfully completed further education courses during the year with BGS sponsorship.

Training and staff development: BGS staff on the Modern Glacial Landscapes course in Iceland.

IT infrastructure

IT infrastructure support services are provided by the Systems and Network Support (SNS) team. In addition to day-to-day support SNS is also responsible for the planning and implementation of new and upgraded IT services. The IT Infrastructure Manager liaises with the BGS Computer Advisory Group. The key areas of activity during 2005/06 have been in data storage and IT security. Storage Area Network (SAN) disk subsystems have been high maintenance and changes have been made. In Edinburgh a Linux high availability service went live for serving Unix data in the SAN. Key datasets are replicated between sites

and Wallingford users now have greater integration with other BGS sites. New security tools have been installed to combat spyware and wireless network systems installed. Developments have also taken place with Citrix and remote access systems and IP Telephony studies have taken place. Local Area Network systems have been upgraded to support virtual networking and improved video-conferencing systems installed. Access Grid is now supported between the large BGS sites and JANET access has been installed at the Gilmerton office.

Scientific collaboration

Scientific collaboration with the British Antarctic Survey and Leeds University was taken forward with participation by a BGS palaeontologist on an Antarctic expedition to study past climate change in the Late Cretaceous Period. BGS research capability was extended through the purchase and operation of a portable Dando drilling rig, which is being used to investigate rocks and soils as part of our multidisciplinary 3D characterisation of the UK landmass.

BGS observatories

The BGS geophysical observatories at Eskdalemuir in the Borders, and Hartland in Devon have recorded variations in the Earth's magnetic field continuously from 1907 and 1957, respectively. They are also regional recording stations for the BGS's seismic monitoring network and provide facilities and host experiments for national and overseas agencies and universities. At Eskdalemuir, we host a Meteorological Office station, in a reciprocal arrangement involving Lerwick Observatory, and a recording station of the US IRIS global broadband seismometer network. University experiments include the continuous monitoring of atmospheric electricity (University of Reading). Hartland Observatory provides facilities for manufacturers to test and calibrate magnetometers, and for our staff to train observers operating from Antarctic survey ships in geomagnetic surveying methods.

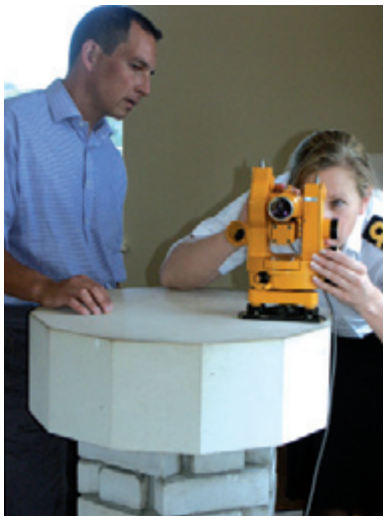
Remote sensing activities

BGS Remote Sensing moved to a newly refurbished laboratory in Keyworth, and replaced ageing computer hardware in both Keyworth and Murchison House to ensure we remain a world-class facility. Existing ImageStation photogrammetry systems were rejuvenated, while the Research Council Infrastructure Fund supported the setting up of SOCET SET, which will further integrate photogrammetry into the SIGMA digital mapping workflow. Linked to this, we invested in digital national aerial photographic coverage to ensure quick and efficient access for geoscientists to an informative dataset.

Support Services

The Support Services discipline provides essential backup to colleagues working across many areas including the administrative functions of Personnel, Finance and Estates. This year has seen the implementation of secretarial team working in order to ensure fully effective cover throughout all sites, and support staff have undertaken personal development through formal and informal training, including obtaining accountancy qualifications. The discipline has new challenges to meet as the Research Councils move towards the centralisation and sharing of services.

BGS observatories: BGS experts training Antarctic survey ship officers in geomagnetic surveying methods at Hartland Observatory.



Scientific collaboration: BGS palaeontologist Dr Jim Riding with a collection of Late Cretaceous ammonites, Seymour Island, Antarctica.

Business Development and Strategy Directorate

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

In its marketing role, BDSD works closely with all BGS programmes to promote capabilities, understand market needs, engage with clients and stakeholders, and prepare bids and tenders. Marketing activities are supported by weekly bulletins of new opportunities, prepared in-house, and by a small team who produce and manage exhibition and promotional materials. The UK Business Development (UKBD) team comprises a team leader and seven sector marketing staff, who are based at each of the principal BGS sites. The team has devoted a large amount of effort to marketing data products to current and new clients, including those in the insurance sector. This has led to an increase in revenue for 2005/06 within this sector. Two new Value Added Resellers and two Reseller Agreements have been established. A variety of exhibitions and seminars was organised across a wide range of sectors including oil and gas, water, minerals, environment and information services. There has been further engagement with both devolved and regional government that has secured new externally funded commissions and heightened the BGS's profile, and stronger links have been built with the Environment Agency.

There are four regional managers for overseas work, whose responsibilities are based around language skills especially necessary in francophone and lusophone Africa. International activities included several large, long-term projects in the UAE, Madagascar, Ethiopia, Afghanistan, Mozambique, Montserrat and elsewhere, which are concerned with geological mapping, natural resource exploration, natural hazard mitigation and data management, but which all place a great emphasis on training and knowledge transfer.

Staff working on Directorate projects presented several papers at important international conferences and managed exhibition stands at various trade exhibitions in the UK and overseas, including the Indaba Conference in South Africa.

Since 2005, BGS and the US Geological Survey have been jointly engaged in a major geological mapping survey of northern and central Madagascar.

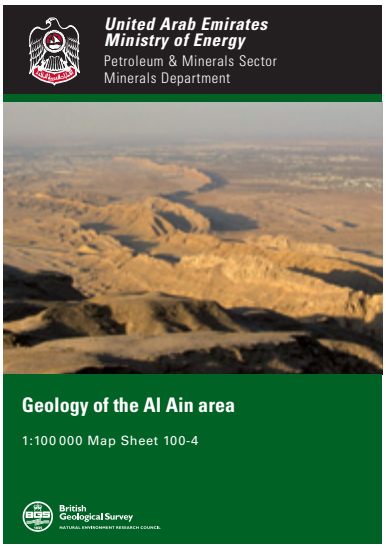
Our activities in the remoter parts of Madagascar invariably attract a great deal of local interest. Here, the head of the rafting expedition on the Mangoro River of central Madagascar entertains some local villagers.

(Opposite) Madagascan student collecting a stream sediment sample for the geochemical sampling programme, central Madagascar.

International

Programme overview

Our International programme coordinates overseas activities and manages directly certain large, multidisciplinary projects, mainly in the developing world. The sustainable development of minerals, water and the greater understanding of geohazards in these countries is often key to their economic and social development, as is the associated training, technology transfer and institutional strengthening of their national geoscience organisations. Most of the funding for this work comes from the World Bank, African Development Bank, the European Union, DFID and the host governments themselves.



United Arab Emirates: sheet explanation for new 1:100 000 scale geological map of the Al Ain area.

New project aims to bring economic growth to Niger

Situated on the edge of the Sahara Desert, Niger has few natural resources to enable it to launch economic development projects. Since the 1970s, exports of uranium have been one of the main sources of income, but the value of these exports has declined following a depression in the world market. Mineral-based exports are now focusing on gold, mined in the south-west of the country. In 2003 the European Union signed a financing agreement with the government of Niger to execute a programme aimed at diversifying the mining sector. This goal will be achieved by strengthening the capacity of state administration to promote Niger's mining potential with national and international private investors and to regulate the mining sector.

In February 2006 the BGS signed a contract with the government of Niger (won through competitive tendering under the EDF-SYSMIN funding arrangement) to conduct a geological mapping and mineral prospecting survey over the Aïr massif of north-central Niger. This region, located north of Agadez, is known to contain deposits of tin, niobium, tantalum, gold and copper. We will undertake systematic geological mapping and geochemical exploration of 48 map sheets at 1:100 000 scale, covering an area of 110 000 square kilometres. The data will be presented within the framework of a geographic information system and we will also conduct a programme to promote the country's mineral resource potential to investors.

Mapping the mineral prospectivity of the PNG Highlands

Although the mining industry contributes significantly to the economic wealth of Papua New Guinea, the country is still considered to be under-explored yet highly prospective for the discovery of new mineral deposits. However, an overall decline in exploration activity over the past ten years is causing concern for the long-term future of the industry. One way to reverse this trend is by creating and releasing attractive multidisciplinary geological information that will reduce exploration costs and risks for mining investors. The European Development Fund, under its SYSMIN funding arrangement, is proposing to remedy the situation by financing several large projects including a systematic geological and geochemical mapping programme over the PNG Highlands, covering an area of about 72 000 square kilometres. The BGS in partnership with Deutsche Montan Technologie (DMT) and the South African Council for Geoscience (CGS) was awarded the contract to undertake this work in December 2005. The project has an overall budget of €13.8 million and will take five years to complete, starting in April 2006.

Supporting airborne geophysics in Ghana

The mineral sector in Ghana represents 37% of the country's total export value and employs more than 36 000 people. The success of this sector is now under threat because of the rapid depletion of known resources and a requirement for institutional strengthening. Under present conditions private sector mining activity cannot be sustained unless government regulatory institutions improve their operations, provide up-to-date geological and geophysical information to assist in the discovery of new resources, and formulate and implement new policies. The European Development Fund (EDF) is currently financing a Mining Sector Support programme aimed at sustaining the country's mining sector economic performance, alleviating poverty through employment, and mitigating the negative environmental impacts of mining. One component of the programme includes an airborne geophysical survey of the Volta and Keta river basins, covering an area of 98 000 square kilometres, or more than one third of the country. This undertaking

has been awarded to Fugro Airborne Surveys in partnership with the BGS and has been running since October 2005. Fugro is flying the geophysics, while the BGS is conducting a satellite imagery study and field mapping, as well as providing training to Ghanaian counterparts at the Geological Survey Department.

High-quality geological maps of north-eastern United Arab Emirates

In 2002 we were contracted by the government of the United Arab Emirates to undertake a detailed geological mapping programme in the mountainous north-eastern region of the country overlooking the Gulf of Oman. The project finished in March 2006, and over the next few months we will be publishing thirteen high-quality geological maps at various scales detailing an area of 13 000 square kilometres, together with accompanying explanatory booklets. Other products include a geohazards map of the entire country at a scale of 1:500 000 and a project report in five volumes describing the regional geology, mineral and groundwater resources, geological hazards and environmental geology. All outputs will be available both in hard copy and digital formats.

The project area includes a portion of the world's largest and best preserved ophiolite thrust sheet (a rarely exposed fragment of oceanic crust and mantle) which extends into neighbouring Oman. The UAE section of this ophiolite had not previously been well studied. However, the new mapping combined with data derived from seismic and airborne geophysical surveys (undertaken by commercial contractors on our behalf) have given us a much greater understanding of the evolutionary history of the UAE–Oman ophiolite. We can now say that it was initially formed at a mid-ocean ridge, was then moved sideways by powerful earth movements until it came to occupy a position above an oceanic subduction zone, and was finally thrust up on to the continental surface where it now rests.

Planning for the establishment of a Geological Survey of Kosovo

In 2004 we were awarded a contract by the Directorate of Mines and Minerals (now the Independent Commission for Mines and Minerals in Kosovo) to advise on the structure, financing and staffing of a proposed Geological Survey of Kosovo. Kosovo is currently an autonomous province within Serbia and Montenegro, and since 1999 has been under UN interim administration pending a settlement on its future status. Whatever the outcome, it is clear that a significant level of self-government will prevail. One essential feature of such autonomy is the establishment of a geological survey organisation to collect and curate all geoscientific data for Kosovo, and to provide impartial advice to government, the general public and industry.

We submitted our final report in September 2005 with recommendations for establishing such a Survey over a five-year period modelled on the European norm. We also suggested that a geochemical or geophysical survey would aid the metalliferous mining sector — one of the main instruments for future economic growth in Kosovo — and this is now being commissioned. Furthermore, an urgent need was identified for the establishment of a construction materials testing laboratory. The BGS has recommended that this facility be placed in the University of Prishtina.

Economic growth in Niger: Dr David Falvey presenting a small gift to His Excellency the Minister for Mines and Energy at Niamey, March 2006. This followed the successful negotiation by BGS of a €2 million contract to geologically survey the Aïr massif in Niger.

Supporting airborne geophysics in Ghana: geologists from the Ghana Geological Survey Department undergoing training in the use of a high-resolution differential global positioning system (GPS) to test the elevation model derived from Shuttle Radar Topography Mission data (SRTM). Ground-truthing of the data is a necessary prerequisite for producing reliable contoured topographical base maps of the region.

Finance

BGS summary of income and expenditure 2005/06

Income	£ million
Science Budget	29.050
Other income	27.934
Total	**56.984**
Expenditure	
Salaries	30.850
Capital	4.318
Other expenditure	20.235
Total	**55.403**
Excess	1.581

BGS funding

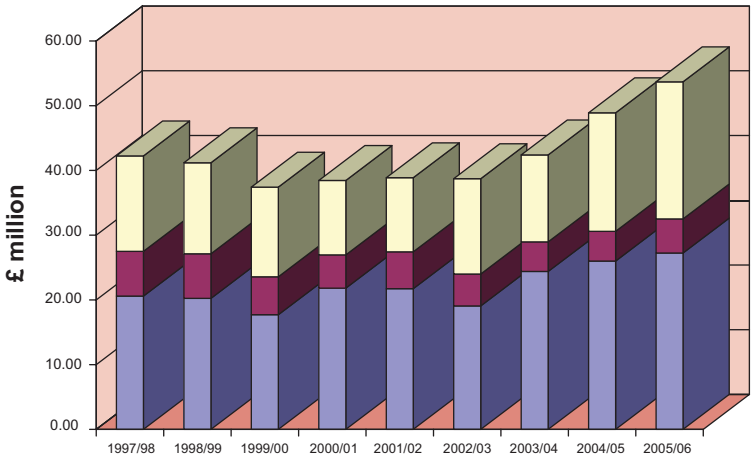
The BGS receives funding from our parent organisation, the NERC, to carry out our Core Strategic programme. Funding under a new five-year Science Programme began in 2005/06; the core resource funding increased from £21.864 million to £23.91 million (both final allocated figures).

The NERC also provide a baseline capital allocation of £1.5 million per annum plus additional allocations for continuing schemes funded through the Research Councils Infrastructure Fund (RCIF); for example, the Mobile Field Laboratory and the Accelerated Evolution of Geoscience Information System (AEGIS). From 2005/06 the NERC have also provided capital funding towards the rebuilding of six office blocks, an ongoing capital project over the next three years.

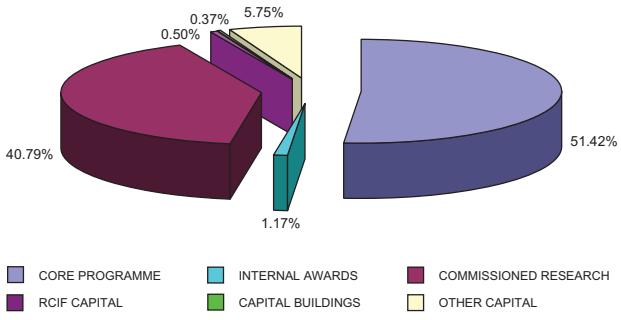
The BGS earns approximately 50% of our non-capital budget from research commissioned by external partners and customers, chargeable services, products and data licensing. The commissioned research programme enhances the Core Strategic programme through funding, ideas, data and review as well as making a vital contribution to our infrastructure. In 2005/06 the total operating income received from these sources amounted to £27.93 million. This included significant commercial projects such as the Tahiti drilling project, Afghanistan minerals project and mapping in Madagascar.

In 2005/06 there was investment in scientific assets including aerial photography, 3D modelling software and hardware, NEXTMap phase 2 and Terrestrial Laser scanners.

There was also continued investment in the fabric of the buildings including refurbishment of the Rotunda building, high density storage racking and CCTV equipment. The development of the site was funded partly from a Science Budget contribution towards infrastructure and partly from infrastructure contributions from the commercial programme.

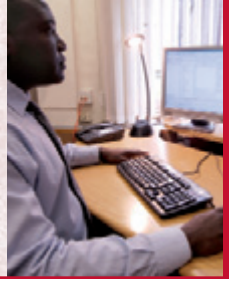


Sources of BGS income 1997/98 to 2005/06 (at 2005/06 prices).



BGS expenditure during the financial year 2005/06.

Personnel



Personnel

Recruitment was a continuous process during 2005/06 with new starters accounting for 9% of our total complement. We have maintained a policy of encouraging applications from people with disabilities and from minority groups. New appointees included staff transferring in under TUPE terms. Staff leaving our employment accounted for 7% of the complement. Nineteen staff were expected to retire during the year but five of that number opted to remain beyond age 60 as we move towards a change in retirement age to 65. We expect that with impending changes in legislation staff will increasingly opt to remain beyond the age at which they can draw their company pension. The Survey will reap the benefits of a strong skills base remaining in employment for a longer period.

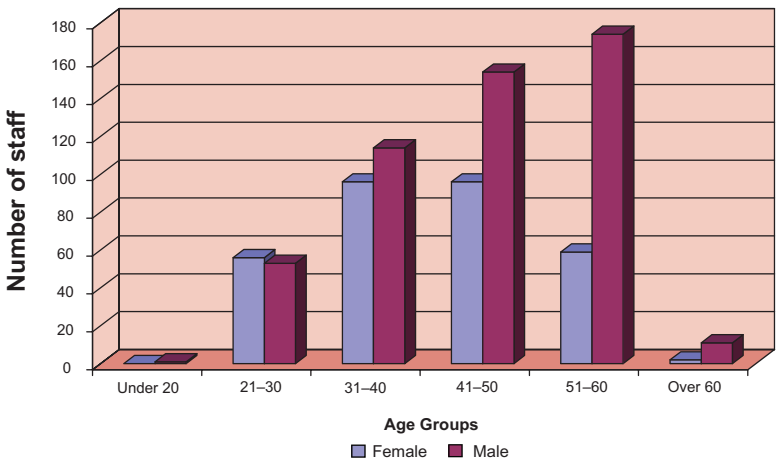
We continue to provide a work experience programme, attracting mostly 15-year-old students from locally based schools. We have also been involved in arranging placements for voluntary workers who undertake important tasks for various parts of the organisation as 'Friends of BGS'.

Personnel section has an important role in supporting staff and management. In addition, the Head of Personnel has now taken on responsibility as Head of Discipline for Support Services, building closer links with that group of staff.

Formal training in diversity has been established for new starters and further work carried out relating to equal opportunities. A paper was produced looking at career development opportunities within the organisation, with an emphasis on female staff, to ensure best practices are in place.

The Personnel section continues to procure occupational health services for staff serving in the UK and overseas. The Survey is committed to ensure medical support is provided. There has been a fall in absence due to ill health with an average of 5.9 days being recorded during the year. Personnel have produced a draft paper reviewing stress management within the Survey. The document will be the basis for producing action plans and a toolkit for managers that will ensure good practice and adherence to the recommendations of the Health and Safety Executive management standards. The BGS is participating in an external research project looking at the impact of management on stress, which aims to provide a competency framework for managers. Personnel staff have also been proactively working with the NERC Welfare Advisor to produce a Pressure Management Strategy for the NERC.

Towards the end of the year it was announced that a Research Council's Support Services Centre would be established in Swindon. This change in the management of some of our administrative functions will have a major impact on several areas within Support Services, and Personnel will have a close involvement in this review.



Age profile of BGS staff at March 2006.

Estates

Estates: the newly refurbished first floor of the Rotunda building at Keyworth, modelled on the 'house style' established during other recent refurbishments.

Estates

The past year saw the continuation of an ongoing upgrading programme for the BGS estate. Two major projects were undertaken: firstly, the first floor of the Rotunda building at Keyworth was refurbished to provide accommodation for the Heads of Discipline and Service Managers together with their support staff. This was modelled on the 'house style' established during recent refurbishments at Keyworth. Secondly, uninterruptible power supplies and standby electrical generation were installed to serve the main computer installations at both Keyworth and Murchison House. The resulting installations will guarantee a high level of resilience for our main infrastructure computing hardware in the event of any interruption in the mains electrical supply.

Another highlight was the completion of a major programme to upgrade the heating installation in Murchison House. This work, together with a general refurbishment of rooms which was carried out at the same time, has resulted in much improved conditions for staff together with a reduction in energy costs.

Funding was secured to carry out a major redevelopment of part of the Keyworth site. We intend to replace six blocks with a purpose-built, environmentally friendly, building which will meet our needs over the next fifty to sixty years. Preparatory work has been carried out with a view to starting the final design process during 2006/07 and work should commence on site early in the 2007/08 financial year.

We have seen further improvement in the underlying condition of the BGS estate. With improved levels of funding and with works based on the Maintenance Plan, this upgrading work will continue with tangible benefits to the whole organisation. In parallel with these major initiatives work has continued across our sites to operate the maintenance regimes already in place and to meet ad hoc requests for a wide variety of works in support of our science.

Quality and Environmental Management

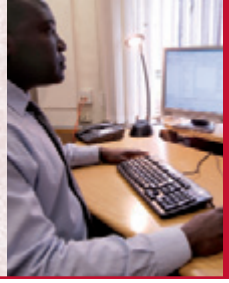
Management systems have continued to be rolled out throughout the Survey. The driving forces behind this initiative have been our business needs and the requirement of the Quality Standard ISO19001-2000 for systems to be in place that encourage a climate of continuing improvement and for the organisation to be able to demonstrate this to its customers. Systems continue to be implemented which reflect the way that we work and it has been possible to operate these without a significant increase in bureaucracy.

In 2005 the BGS also gained registration to ISO14001 for environmental performance. This was another landmark for us as, again, we were amongst the first scientific research establishments in the country to achieve this.

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 personnel continues to give confidence that our structure and existing operational organisation will allow compliance with the Standards by fine-tuning the way we work rather than requiring radical widespread change.

Estates: the newly installed standby electrical generator serving the main computer infrastructure installation at Keyworth.

Health and Safety



Health and safety procedures and guidance

Work has continued both to produce and update procedures and guidance at NERC and BGS levels. This has allowed the organisation to ensure that best practice is followed and that the requirements of new legislation are met. The NERC procedures are drafted by the Safety Management Group, of which the BGS Health and Safety Adviser is a member, and then ratified by the NERC Safety Management Team which then releases the documents for use.

Occupational health

The contacts that the Survey has with the Queens Medical Centre in Nottingham and the Institute of Occupational Health in Edinburgh continue to ensure that we can offer a high level of occupational health advice to our managers and staff. This programme is now well established and allows for referrals either by managers or directly from staff themselves.

Accidents, incidents and near misses

During the year staff working at all sites and in the field have been encouraged to report any 'near miss' they witness, that is a situation that, on the occasion in question, did not result in damage or injury but which, in other circumstances, may have. This is carried out within a 'no blame culture' to ensure that, as an organisation, we learn from our experience.

Office health and safety

Offices continue to be inspected to ensure that staff are not exposed to uncontrolled risks. This regime has two main benefits: it ensures that fire regulations are not breached, and that basic standards of housekeeping are maintained. In general, the standards are good and any minor issues that are identified can be dealt with quickly and effectively.

Project health and safety

As a project-based organisation, many of the most significant health and safety risks to which staff are exposed present themselves during the course of those projects. Work in the offices and laboratories is generally well controlled but the most significant risks may well manifest themselves during fieldwork. Project managers are responsible for assessing these risks and then putting in place appropriate safe systems of work. The BGS Health and Safety Adviser has become more actively involved in both aiding managers in the drafting of suitable systems and also in ensuring that such systems are implemented in the field. This work will again be a priority in the year ahead.

Health and safety training

All new members of staff continue to receive an induction on their first day of service, this is then followed by a formal two-day induction course where health and safety is again covered. NERC funded training has been taking place covering health and safety responsibilities for all staff, and risk assessments for staff with duties and responsibilities that require this. In addition to these courses others are delivered on an ad-hoc basis as needs are identified.

Health and safety: a new Dando drilling rig has been purchased to replace older equipment now considered hazardous for staff to use.

Health and safety: a programme of training for staff visiting quarries in the course of their work has been implemented to ensure health and safety standards are met.

British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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