

# 2003-04 Annual Report



**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL



**Natural Environment  
Research Council,  
Polaris House,  
North Star Avenue, Swindon  
SN2 1EU, UK.**

01793 411500

[www.nerc.ac.uk](http://www.nerc.ac.uk)

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##### **British Antarctic Survey**

☎ 01223 221400

[www.antarctica.ac.uk](http://www.antarctica.ac.uk)

##### **British Geological Survey**

☎ 0115 936 3100

[www.bgs.ac.uk](http://www.bgs.ac.uk)

##### **Centre for Ecology and Hydrology**

☎ 01793 442524

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In addition, the NERC funds a number of collaborative centres in partnership with other organisations. For the full list of NERC Centres see the web site at: [www.nerc.ac.uk](http://www.nerc.ac.uk)

#### *Bibliographical reference*

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The British Geological Survey (BGS) is a component body of the Natural Environment Research Council (NERC) — one of the seven research councils that fund and manage scientific research and training in the UK. The NERC uses a budget of just over £270 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 is the research council that carries out earth system science with the aim of advancing knowledge of planet Earth as a complex, interacting system. Its work covers the full range of atmospheric, earth, terrestrial and aquatic sciences, from the depth of the oceans to the upper atmosphere. The NERC's mission is to gather and apply knowledge, create understanding and predict the behaviour of the natural environment and its resources.

The NERC's current strategic priorities are: to prioritise and deliver world-class environmental science to understand the Earth system; to use NERC-funded science to identify and provide sustainable solutions to environmental problems; to train and develop skilled individuals to meet national needs; and to provide effective national and international leadership for the environmental sciences.

*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.

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## FUNDING BGS SCIENCE

The BGS is a public-good, not-for-profit organisation. Our funding is derived from government-funded strategic geoscience, distributed through the NERC's allocation of the Science Budget, and income from external sources for delivery of commissions, sales, and services. 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.

## THE CORE STRATEGIC PROGRAMME

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).

## THE COMMISSIONED RESEARCH PROGRAMME

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.

## Principal offices of the BGS

Kingsley Dunham  
Centre, Keyworth,  
Nottingham, NG12 5GG  
☎ 0115-936 3100

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

Macleans Building,  
Crowmarsh Gifford, Wallingford,  
Oxfordshire OX10 8BB  
☎ 01491-838800

London Information Office  
at the Natural History Museum  
Earth Galleries,  
Exhibition Road,  
London SW7 2DE  
☎ 020-7589 4090

Forde House,  
Park Five Business Centre,  
Harrier Way, Sowton,  
Exeter EX2 7HU  
☎ 01392-445271

Geological Survey of  
Northern Ireland,  
20 College Gardens,  
Belfast BT9 6BS  
☎ 028-9066 6595

Sophia House,  
28 Cathedral Road,  
Cardiff CF11 9LJ  
☎ 029-2066 0147

# Foreword



Dr. Geoffrey W. Robinson, CBE, F.R.Eng.  
Chairman of the BGS Board

It seems no time since I wrote my first Chairman's Foreword, and now it's time to write my last — my term of office comes to an end at the end of 2004.

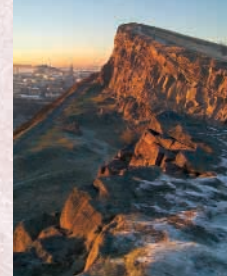
It has been my pleasure and privilege to watch the Survey make great strides over the last three years. The NERC Science and Management Audit, conducted at the end of 2003, gave a very strong vote of confidence in the Survey, its science and its management. A wide range of public and private sector organisations — both in this country and overseas — continue to back their confidence in the Survey and its activities with their funding of an equally wide range of programme activities. And not least, the internal management and staff development programmes continue to bear fruit both in terms of efficiency and morale.

My association with the BGS may be drawing to a close, but the Survey itself looks set to go from strength to strength. The publication of the study on *The economic benefit of the BGS* has provided evidence of the critically important economic contribution that the BGS makes to the UK. More recently, the geological atlas *Britain beneath our feet* (conceived and published within the space of a few short months) has received wide acclaim for the way that it makes geological information much more relevant to the lay person.

And, after all, it is this relevance — economically, socially, culturally and scientifically — that, in the end justifies the BGS's existence, funding and work. This relevance will undoubtedly continue to influence the Survey's future programme; if anything, it looks set to grow. As the Survey considers the next five years, economic and social considerations play a large part in influencing the shape of its new research programme. Issues such as sustainable development, environmental hazards, water and soil quality, mineral discovery and recovery and so on are not only increasingly important to society, they provide the BGS with many intellectual challenges.

But despite the seriousness of many of the issues that the BGS tackles, I would like to say that my lasting memory of my association with the Survey is that it has been great fun: fun because of the fascination of the subject and fun because of the friendliness and dedication of the people. To them all, thank you and best wishes for a successful future.

# The BGS Board during 2003/04



## Membership of the BGS Board

Board members are appointed by the NERC Chief Executive from nominations made by the Director and others, and approved by Council. Membership comprises: a non-executive, part-time Chairman; the BGS Executive Director, **Dr D A Falvey**; Council's Chief Executive or his nominee (in 2003/04 this was the NERC Science and Innovation Director **Dr D Lynn**); the BGS Executive Committee; and up to ten non-executive members. The latter are appointed by reason of their qualifications and experience and represent a broad cross-section of the BGS user community. They include senior representatives of industry, government agencies and the academic community, as listed below. Members may be appointed for up to four years in the first instance and may be reappointed for up to a further four years. **Dr B R Marker** of the Office of the Deputy Prime Minister sits on the Board as an observer.

## Board Members: non-executive

Dr G Robinson	(Chairman), former Director General of the Ordnance Survey.
Dr M J Carter	Managing Director, M J Carter Associates.
Dr O Bavinton	Senior Vice-President, Exploration, Anglo American PLC.
Mr J Smith	Managing Partner, Wardell Armstrong.
Mrs R Johnson-Sabine	ChevronTexaco.
Dr D Lynn	Director Science & Innovation, NERC.
Professor A Rogers	Former MP for Rhondda, and External Professor, University of Glamorgan.
Dr R Scrutton	School of Geosciences, Edinburgh University.
Professor P Styles	Head of the School of Earth Sciences and Geography, Keele University.
Dr M Tricker	Director, NERC Partnerships and Exploitation Policy.
Dr B R Marker	Office of the Deputy Prime Minister (Observer).

## BGS Executive Committee

Dr D A Falvey	Executive Director.
Mr F G Curry	Head of Administration and Finance.
Mr D C Ovidia	Director of Marketing, International and Corporate Development.
Mr D C Holmes	Director of Environment and Hazards.
Mr I Jackson,	Director of Information Services and Management.
Dr M K Lee	Director of Lands and Resources.
Professor J A Plant	Chief Scientist.
Dr D J Morgan	Acting Head of Geoscience Resources and Facilities.

## Secretariat

Miss K A Booth of the BGS.

## Remit

As required in the Management Statement and Financial Memorandum agreed between the NERC and the BGS during 1997, the NERC has established the BGS Board to support the management and strategic direction of the Survey, taking into account the recommendations of Director, BGS. The Board was inaugurated in January 1998 as the successor body to the Programme Board after it was dissolved in December 1997. Whereas the Programme Board's remit was to determine the overall objectives and to set the priorities for the BGS Core Programme, the BGS Board has a much wider remit encompassing all the activities of the BGS. The Board currently meets four times a year.

**The BGS Board:** 8 June 2004 at the BGS Wallingford office. Left to right: Dr Roger Scrutton, Dr D A Falvey, Mr I Jackson, Mrs R Johnson-Sabine, Dr B R Marker, Dr G Robinson, Mr D C Ovidia, Dr Owen Bavinton, Mr David Bloomer, Professor A Rogers, Dr M K Lee, Mr F G Curry, Dr D J Morgan, Mr Derek Davis and Mr Jeff Smith.



# Director's introduction



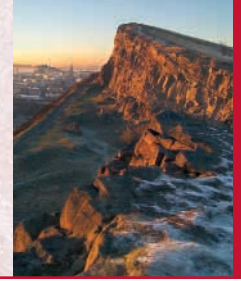
David A Falvey, B.Sc., Ph.D., FGS, C.Geol.  
Executive Director

I am delighted to introduce the BGS Annual Report for 2003/2004, a year in which we have continued to deliver world-leading science through many exciting initiatives, some of which I would like to take the opportunity to highlight below. It was a year of organisational stability that allowed the science programme, commenced in 2000, to start delivering its promise in terms of digital products, a move from two-dimensional to three-dimensional survey and increased relevance to the nation. The year has also seen two major activities in which the whole organisation has enthusiastically participated. The first, the Science and Management Audit (SMA), looked back over the previous five years. The second, the planning and development of the new BGS Science Programme, looks forward five years. A significant effort was also devoted to preparing the organisation for assessment against ISO 9001:2000, the internationally recognised standard for quality management. I am pleased to be able to announce that we subsequently achieved registration to this standard from the British Standards Institute in August 2004. The BGS is the first of the Natural Environment Research Council's (NERC) research centres, and one of the very few public sector research establishments to achieve this.

Every five years we undergo an external review of our activities, the SMA. I am extremely proud to report that the latest SMA found the organisation to be successful and well managed, with the large majority of our work receiving the top rating and the remainder being very highly regarded. The SMA panel also expressed the view that the BGS is a world leader in geoscience information delivery. They also recognised that the organisation actively develops staff through training and mentoring. As with any review, some issues were identified. We welcome such constructive criticism and are working closely with our parent organisation, the NERC, to address the points raised by the panel and continue to improve.

The current five-year science programme is due to end in 2005. Planning for the 2005 to 2010 programme started in December 2003 with a period of consultation with customers, stakeholders and staff prior to the drafting of a programme proposal document. This is now with the NERC. We will contribute to the NERC mission through the scientific understanding of the environmental conditions, natural resources and hazards of the UK landmass and continental margin. We will support UK competitiveness, effectiveness of public services and policy, improved quality of life, and provide forward-looking solutions for sustainable development.

We have been responsible to government for surveying the subsurface of the UK since 1835 and have gathered an extensive range of information that is probably unrivalled anywhere in the world. Much of this information, carefully stored, maintained and interpreted, is not yet used to its full potential to benefit the nation we serve. In February this year, we took a major step towards remedying this situation with the publication of *Britain beneath our feet*. This is an atlas of some of the data that we hold, in easily available digital format, in areas of geology, land quality, groundwater, hazards, resources, and offshore and



coastal geoscience. This atlas demonstrates the relevance of such information to people's daily lives. It is also a valuable educational resource.

The GeoHazarD project has built on the seamless digital geological map of Britain to compile a series of national geological hazard datasets that show where one can find soluble rocks, shrink-swell clays, landslides and unstable slopes. The service was launched at the Globe Theatre in March 2004 and now provides access to invaluable information for a wide variety of customers, ranging from individual home owners and buyers to national, regional and local policy makers.

We can be rightly proud of our achievements. I feel confident that better is yet to come. Our new science programme, intended to ensure that the UK gains maximum benefit from our world-leading capabilities, begins in April 2005. Even before that, the summer of 2004 has seen BGS scientists working in a thousand metres of ice-covered water in the Arctic Ocean, within 250 kilometres of the North Pole, to recover the first continuous deep sediment core samples from the Lomonosov Ridge. This operation is the first contribution from the European Consortium of Ocean Research Drilling to the Integrated Ocean Drilling Programme. The core is showing how the climate has changed over the past 50 million years and is contributing towards a better understanding and prediction of climate change in this previously unexplored area.

This report includes many more examples of our activities in both the UK and overseas. This work undoubtedly reinforces the relevance of the Survey to the prosperity and sustainability of the UK and global society. I hope that you, after reading further, will agree that the BGS, the oldest geological survey in the world with its origins in the early nineteenth century, has a vital part to play in the twenty-first century.

The BGS's work programme is organised around three Programme Directorates: 'Land and Resources'; 'Environment and Hazards'; and 'Information Services and Management'. These are responsible for the management and delivery of the operational science programmes (coherent packages of related projects).

The resources (staff, facilities and infrastructure) necessary for this work programme to be carried out are managed by a fourth Directorate, 'Geoscience Resources and Facilities'.

Essential cross-Directorate support is also provided by the 'Marketing, International and Corporate Development Directorate' and the 'Administration and Finance Directorate'.

Executive Director			
Marketing, International and Corporate Development Directorate			
BGS International®	UK Business Development	Central Directorate Support	Parliamentary and Media Liaison Office
Environment and Hazards Directorate			Chief Scientist
Coastal Geoscience and Global Change	Urban Geoscience and Geological Hazards	Groundwater Systems and Water Quality	Geoscience Resources and Facilities Directorate
Environmental Protection	Seismology and Geomagnetism	Electrical Tomography Service	Geochemistry, Mineralogy and Hydrogeology
Lands and Resources Directorate			NERC Isotope Geosciences Laboratory
Continental Shelf and Margins	Integrated Geoscience Surveys (Southern Britain)	Integrated Geoscience Surveys (Northern Britain)	Geophysics and Marine Geoscience
Geological Survey of Northern Ireland	Economic Minerals and Geochemical Baseline	Sustainable Energy and Geophysical Surveys	Geology, Geotechnics and Palaeontology
Information Services and Management Directorate			
Information Management	National Geoscience Information Service	Publications Production	Information Systems
GeoHazarD	Digital Geoscience Spatial Model	Training and Career Management	
Administration and Finance Directorate			
Personnel and Administration	Facilities and Infrastructure	Finance, Accounts and Contracts	





# Lands and Resources



The **Lands and Resources Directorate (LRD)** operates through six multidisciplinary programmes designed to define the 2D and 3D geology (onshore and offshore), provide information on energy and mineral resources, and carry out research on the sustainable use of the land, seabed and natural resources. A major part of the work is concerned with strategic survey, modelling and research in the UK, supported by a mixture of BGS funding, commissions from government and its agencies, and industry-sponsored research consortia. The programmes also operate in Europe and worldwide through international research projects and commissioned contracts. LRD projects directly underpin the work of the Environment and Hazards Directorate and generate many of the publications and digital products delivered through the Information Services and Management Directorate.

The **Integrated Geoscience Survey** programmes (Northern and Southern Britain) had a most productive field season and generated a record output of maps and related publications. The recent focus on providing better maps and new 3D models of the shallow geology continued during the year. Our role in landscape tourism activities also grew markedly, through a series of co-funded projects, and has greatly increased our profile in the geodiversity and landscape heritage sectors. In particular, a BGS-designed Local Geodiversity Action Plan helped to win Geopark status for North Pennines, a similar project in Leicestershire produced interpretation boards at key geological sites, and a new walkers' map and guide to the Assynt area was released to wide acclaim.

The **Sustainable Energy and Geophysical Surveys** programme further expanded its external funding base and international reputation in the fields of clean energy and carbon dioxide (CO<sub>2</sub>) sequestration. The team continued to monitor CO<sub>2</sub> injection at the Sleipner gasfield as part of the EU/industry-funded CO<sub>2</sub>Store project. They also completed a major new project in collaboration with the Carbon Trust to provide online information to assist the design of ground source heat pump installations.

The **Continental Shelf and Margins** programme saw the successful completion of surveys across the Hatton margin and Lousy Bank, providing data across the continent–ocean boundary and helping to define the inversion history of the area. Further advances were made in the use of 3D seismic first returns to image down-slope and along-slope sedimentary processes, and in understanding controls on the formation of coldwater coral reefs.

The **Economic Minerals and Geochemical Baseline** programme continued to develop the 'sustainable minerals' approach in the UK and internationally and is creating a broad range of products and services. These include novel GIS techniques to provide more objective methods for defining the environmental impact of potential mineral extraction sites, and high profile products such as the *Minerals in the National Economy* report, *Mineral Planning* fact-sheets and the *Foundations of the Peak* interactive website.

The **Geological Survey of Northern Ireland** (operated by the BGS for the NI Department of Enterprise Trade and Investment) continued to develop its activities across all sectors in response to increasing demand for geological information and advice. A notable achievement was the release of a new-style regional guide, *The Geology of Northern Ireland*, which received extremely positive reviews.

## New mapping techniques and digital methodologies

In parallel with the six main programmes, LRD has two special projects to develop new techniques and digital methodologies for onshore survey activities. The aim of the **SIGMA** project (System for Integrated Geospatial Mapping) is to implement integrated digital methodologies for the revision of geological maps. These methodologies employ a mixture of analysis of landscape and legacy data, based on geographical information systems (GIS), and targeted fieldwork. The **Quaternary Methodologies and Training Programme** has developed new survey protocols and skills to meet the increasing need for better information on Quaternary deposits. Both projects have completed their initial phases and are being progressively rolled out and further developed in active projects.

Executive Director	
Marketing, International & Corporate Development	
Environment & Hazards	Geoscience Resources & Facilities
Lands & Resources	
Information Services & Management	
Administration & Finance	

Lands & Resources <b>Dr M K Lee</b> 0115 936 3356 <a href="mailto:mklee@bgs.ac.uk">mklee@bgs.ac.uk</a>		
Continental Shelf & Margins <b>Mr R W Gatliff</b> 0131 650 0405 <a href="mailto:rwga@bgs.ac.uk">rwga@bgs.ac.uk</a>	Integrated Geoscience Surveys (Southern Britain) <b>Mr P J Strange</b> 0115 936 3171 <a href="mailto:pjst@bgs.ac.uk">pjst@bgs.ac.uk</a>	Integrated Geoscience Surveys (Northern Britain) <b>Dr M Smith</b> 0131 650 0320 <a href="mailto:msmi@bgs.ac.uk">msmi@bgs.ac.uk</a>
Geological Survey of Northern Ireland <b>Mr G Earls</b> 028 9066 6595 <a href="mailto:gearls@bgs.ac.uk">gearls@bgs.ac.uk</a>	Economic Minerals & Geochemical Baseline <b>Dr M G Petterson</b> 0115 936 3493 <a href="mailto:mgp@bgs.ac.uk">mgp@bgs.ac.uk</a>	Sustainable Energy & Geophysical Surveys <b>Dr N J Riley</b> 0115 936 3312 <a href="mailto:njr@bgs.ac.uk">njr@bgs.ac.uk</a>

(Opposite) Breedon Quarry, Breedon on the Hill, Leicestershire.

# Integrated Geoscience Surveys

## Programme overview

The Integrated Geoscience Surveys (Northern Britain) programme is responsible for providing geological and rock-mass data for northern England and Scotland. These data, delivered in both 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. Surveys were completed for Ayr, progressed in Glasgow, Assynt, Aviemore, Crianlarich, Hexham and Moffat, and a new start made in the Montrose area. Twelve 1:50 000 scale maps were delivered along with the launch of a new Assynt map, a thematic memoir, and popular booklets on landscape and mining.

## Midland Valley of Scotland and new constraints on the Carboniferous timescale

Revision mapping of the Ayr district was completed and a new start made on the Devonian bedrock and Quaternary deposits of the Strathmore district. Agriculture and groundwater abstraction are key to the latter area that is at risk from diffuse nitrate pollution. Studies of the macrofauna from 'shelly grey clay' (till) in Ayrshire indicate fluctuating boreal (subarctic) to slightly colder conditions and accord with the environmental interpretation from calcareous microfossils, which indicate shallow marine to estuarine conditions.

Historically, parts of the numerical timescale for the Carboniferous Period were established in the Midland Valley of Scotland, where fossiliferous sedimentary rocks are interleaved with lavas dated using radiometric (K/Ar) techniques. However, biostratigraphical ages obtained from high-resolution studies of fossilised pollen (palynology) do not agree with the timescale based on these radiometric dates. In collaboration with the Scottish Universities Environmental Reactor Centre, East Kilbride, the same rocks have been re-analysed using  $^{40}\text{Ar}/^{39}\text{Ar}$  dating techniques. Seventeen high-precision results, with errors of less than  $\pm 2$  million years, were obtained. For comparison, U–Pb dates were acquired on four additional rocks at the NERC Isotope Geosciences Laboratory. Though consistent with the  $^{40}\text{Ar}/^{39}\text{Ar}$  dates, the U–Pb ages confirmed the existence of a systematic bias between the two techniques. The revised, high-precision dates concur with the biostratigraphical ages and provide constraints on the international Carboniferous timescale. These results were presented at a European conference on Carboniferous and Permian stratigraphy.

## Climate, sea-level change and groundwater flow at Dounreay, Caithness

A modern stratigraphical framework and detailed environmental information for the Old Red Sandstone and the Quaternary deposits of north-east Scotland are required to resolve local environmental concerns such as landfill and hard rock extraction, and the unique problems associated with decommissioning the UKAEA site at Dounreay.

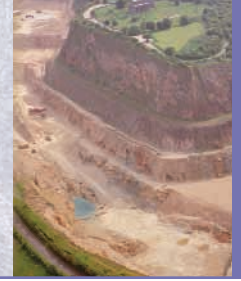
To meet these requirements, a revised 1:50 000 scale geological map (sheet number 115E, Reay) and associated geographical information system (GIS) database, co-funded by UKAEA, was released early in 2003. Work was also completed on commissioned projects investigating the framework of late Quaternary sea-level changes in northern Scotland, and palynological studies of Devonian microspores from borehole cores through the Caithness Flagstone sequence. Ongoing petrological and palynological research aims to constrain further correlations between the borehole sequences and surface exposures.

Optical luminescence dating of Quaternary raised beach sediments is being used to refine estimates of the timing and magnitude of sea-level change since the last glaciation in northern Scotland. This enables an assessment of the role played by former high sea levels in establishing ancient groundwater tables in the flagstones and, ultimately, their role in influencing present-day patterns of groundwater flow.



**Midland Valley of Scotland:** Siluro-Devonian sandstones disrupted by peperitic intrusion of basaltic andesite. Turnberry lighthouse, Ayrshire.

# Northern Britain



## Environmental data and modelling for Glasgow

The Clyde Basin Environmental Project is a cross-programme initiative with co-funding from Glasgow City Council. It aims to produce a wide range of geoscientific products and digital databases to facilitate a comprehensive geo-environmental study of the Glasgow conurbation and the Clyde catchment. This area has a long history of urban development and renewal, and of the extraction of natural resources and their consequent geohazards.

During the year, revision commenced of the environmental geology maps that were produced in the 1980s. Work involved digitisation of existing maps, the entry of thousands of borehole records into corporate databases, and the collation and digitisation of mining records. A three-dimensional model of the complex superficial deposits has been made for the area covered by sheet NS 66 SW, allowing the geometry of buried units of sand, gravel and clay to be defined explicitly for the first time. The model will be combined with shallow bedrock, geochemical, geotechnical and hydrogeological data of the River Clyde catchment and estuary to underpin decisions on key environmental issues such as contaminated land distribution, groundwater pollution and flooding.

In partnership with Glasgow City Council and with support from Scottish Environmental Protection Agency, baseline geochemical surveys of the estuarine sediments in the upper Clyde, and of drainage sediments, waters and soils were completed successfully.

## Geoparks and geodiversity

Within northern England, we have been at the forefront of developing the methods for carrying out geodiversity audits and applying the information gained to produce Local Geodiversity Action Plans (LGAPs). We were commissioned by the North Pennines Area of Outstanding Natural Beauty (AONB) Partnership and Durham County Council to prepare separate, though parallel, local geodiversity audits and action plans. The projects were funded from the Aggregates Levy Sustainability Fund: the North Pennines LGAP via English Nature and that for County Durham via the Minerals Industry Research Organisation (MIRO). Details of the geodiversity work were presented at the UKRIGS national conference in October, an English Nature seminar on LGAPs in December and the national MIRO-MIST meeting in March. LGAPs are seen as an effective way of approaching a diverse and complex need by society to use geodiversity for economic, social and environmental reasons.

The UNESCO-endorsed European Geoparks Network (EGN) was established in 2000 with the key aims of raising awareness of Europe's geological heritage and using this to promote sustainable economic development through tourism. The BGS, amongst other partners, played a significant role in helping to establish the North Pennines AONB as England's first European Geopark. Our new walkers' map and guide to Assynt and Inverpolly produced by the Moine Thrust Project amply demonstrate that area's potential for geotourism. Community interest in geotourism is increasing and we are currently involved in other initiatives with partners in Skye, Lochaber, Caithness and Northumberland.

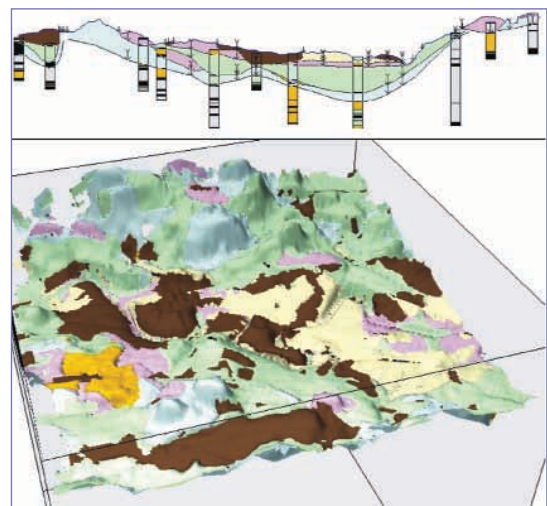
**Caithness:** late-glacial raised shoreline on the western side of Armadale Bay provides compelling evidence for relative sea levels in the Dounreay area at the end of the last glaciation.



**Geoparks and geodiversity:** crags of columnar jointed Whin Sill, Holwick Scar, North Pennines feature on the front cover of the Geodiversity Audit and Action Plan for the UK's first Geopark.



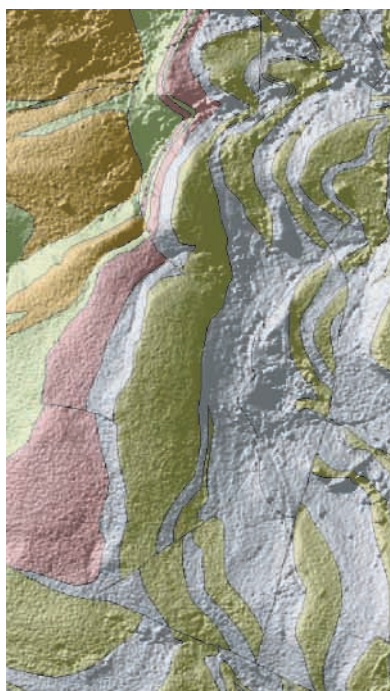
**Environmental data and modelling:** interpreted cross-section and 3D model of superficial deposits in eastern Glasgow based on borehole data. Artificial ground in brown.



# Integrated Geoscience Surveys

## Programme overview

The Integrated Geoscience Surveys (Southern Britain) programme undertakes high quality multidisciplinary geological surveys of southern Britain. The information gathered enhances our understanding of the three dimensional geology of the UK landmass, and provides the geological framework for onshore England and Wales which satisfies user needs. The surveys also underpin research and development undertaken in other BGS programmes, and the regional mapping projects ensure the local geological knowledge base is maintained. During the year, a total of 3775 square kilometres were surveyed at the 1:10 000 or 1:25 000 scale, and eight 1:50 000 scale geological maps were completed together with four Sheet Explanations.



**Sheffield:** bedrock geology draped over a shaded-relief digital surface model, illustrating the close correspondence between bedrock geology and landform features in the vicinity of Totley, Sheffield. Image includes data from NEXTMap Britain.

## Resurvey of the Sheffield district

The Sheffield district was previously mapped in 1952. However, the good quality bedrock and superficial deposits mapping lacked any information on artificial deposits. Given the extent of industrial and urban development in the area, it was identified as being in urgent need of revision to define the areas of artificial deposits. The survey has set out to trial the use of a variety of datasets that were accessed in digital format and used in a desktop compilation exercise and creation of a geographical information system. These include several generations of historical six-inch topographical maps, dated between 1880 and 1950, which provided invaluable information on previous land use such as the extent of quarrying activity. Mine plans and information on the very extensive opencast coal mining sites, were incorporated into the database together with records of man-made ground supplied by local authorities. Borehole records in our archives were examined, together with a large number of new borehole records collected from local authorities and consultants, as part of a targeted data-gathering exercise. A major dataset was the new NEXTMap Britain digital surface models created from an accurate airborne radar imagery survey. By overlaying these digital surface models with a geology drape, it was possible to recognise the close relationship between the geology and the landforms. Fieldwork has been targeted in those areas where the landform features conflicted with the expected geological features. Fieldwork has also been concentrated on delineating the artificial deposits boundaries, particularly within the urban areas and around abandoned coal mines.

## Mapping Lancashire landslides

Recent geological surveying in the central Pennines has identified extensive landslide deposits. In east Lancashire, between Bolton, Burnley and Rochdale, over three hundred individual landslides have been mapped, whereas previous surveys in the 1920s had only recognised eight. The much-improved maps have resulted from an integrated programme of geological field mapping, aerial photograph interpretation, and research into archival material. The area affected by an individual slide can range in scale from less than five hundred square metres to over three square kilometres. Many occur close to urban areas and may have a bearing on future development. The majority of these landslides have occurred since the end of the last ice age some 13 000 years ago. While the majority have remained stable for over 10 000 years, reactivation could occur at any time. This may result naturally, for example after a period of wet weather, or may result from intervention by man, such as excavating or loading the slopes. As pressure increases on urban developments, from major transport links to new housing, it is vitally important that an understanding of the local geology is taken into account during the early stages of planning. The newly released geological maps of east Lancashire will provide a much-needed modern database on which to base these decisions.

## Advances in understanding the structure of the Chalk in east Kent

Revision of the geological map of the Chalk in east Kent, combined with three-dimensional modelling of subsurface information, has revealed a complex local geological structure. This work was commissioned by the Environment Agency, with support from three water companies, to help understand underground water movement in this area, an essential prerequisite of formulating a management plan for the local water resources. The Chalk was last geologically surveyed in east Kent around 50 years ago. It has now been subdivided using the modern

# Southern Britain



lithostratigraphical scheme, enabling a better depiction of the Chalk structure. Revision of the geological maps revealed previously unsuspected faulting forming an intersecting network that tends to separate groundwater flow into 'compartments'. Some faults control the position of local springs and swallow holes. The most striking discovery is a broad zone of faulting oriented north-east to south-west through Canterbury. This marks a dramatic change in structural style between east Kent and north Kent, where the Chalk is much less faulted.

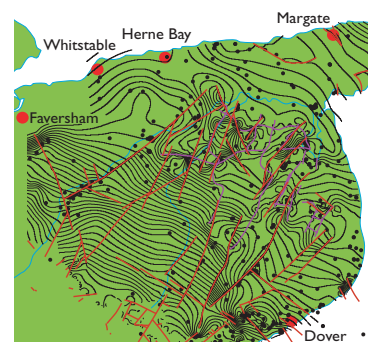
## Mapping in the East Midlands

The recently completed remapping of the Leicester 1:50 000 sheet resulted in a number of scientific advances to the geology of the East Midlands. The exposed sequence commences with Precambrian, Cambrian and Ordovician basement rocks that are overlapped by Triassic formations of the Mercia Mudstone Group. This in turn is succeeded by a full Lower Jurassic (Lias Group) sequence, in which the Marlstone Rock Formation demonstrates facies changes across the district. In the north ooidal iron grainstones predominate whereas farther south ferruginous limestones become interbedded, culminating in a sequence featuring a thin ooidal iron grainstone capping a much thicker ferruginous limestone development, as seen at the type section in the Tilton railway cutting. Around there, the Marlstone averages 3–4 metres in thickness, whereas in the south it is represented by less than a metre of ferruginous mudstone with thin, nodular beds of ferruginous limestone. Much detail has been added to the Quaternary (Anglian) glacial succession by the remapping, which has highlighted the occurrence of a 'Lias-rich' till, which was initially mapped on the Melton Mowbray sheet to the north. This till, which dies out southwards, reflects the incorporation of mainly Lower Jurassic bedrock material by ice following a different course to that which provided the overlying chalk-and-flint-rich Oadby Till and underlying Triassic-rich Thrusington Till. Provisional three-dimensional modelling based on rockhead contours generated by map and borehole data shows that the Anglian deposits veneer and partially infill a landscape characterised by valley systems that essentially replicate the modern drainage pattern.

## Geodiversity in the East Midlands

A second major project in the East Midlands has been funded by the Aggregates Levy Sustainability Fund through the Office of the Deputy Prime Minister, and administered by the Minerals Industry Research Organisation (MIRO). The project, a Local Geodiversity Action Plan for Leicestershire and Rutland, focused mainly on education at all levels, and was run in conjunction with Leicester Museum Services, Leicestershire County Council Heritage Services, the National Forest Company, Leicester University Department of Geology and the Leicestershire and Rutland Wildlife Trust. It undertook a full inventory of all geological sites in the counties, including up-to-date descriptions and photographs of exposures, and formed the basis for a website on the geology of the area. Interpretation Boards have been created and erected at 11 key geological localities in Leicestershire, and together with booklets featuring geological trails they describe the local geology and give historical information where appropriate. Two viewing areas with interpretation boards have been created at Breedon and Cloud Hill quarries, both in Dinantian limestones, in conjunction with the quarry owners, and a video of these quarries was made, aimed at A-level geology students. The project also created education packs of rocks, minerals and fossils and new specimen storage facilities have been installed at the Leicestershire Heritage Services.

**Chalk of east Kent:** a contour plot for the base of the Holywell Chalk shows a gentle north-easterly dip. Faults are shown in red. Examination of borehole records (black dots) and seismic reflection surveys (purple lines) helped to show how the structure extends to depth.



**Mapping in the East Midlands:** aerial view of Croft Quarry, working South Leicestershire Diorite with well-defined wadis infilled with red Triassic Mercia Mudstone Group sediments.



**Geodiversity in the East Midlands:** geological interpretation board at Beacon Hill, one of eleven key geological localities identified in Leicestershire.



# Continental Shelf and Margins

## Programme overview

The Continental Shelf and Margins programme is concerned with all aspects of the offshore geology of the UK, from seabed sediments to the deep crustal structure. The skills developed through the offshore mapping programme have been applied to research into marine resources, hydrocarbon exploration, site investigation and geohazards. The role of geology in marine habitats is providing the impetus for developing a new range of seabed geology maps based on swath mapping data integrated with the current BGS 1:250 000 map data. The marine geology operations capability we have developed during the past 25 years has resulted in us being awarded the co-ordinating role for science and operations for the European Consortium for Ocean Research Drilling (ECORD).

## Offshore regional mapping programme

Work is progressing on a new Offshore Report summarising the geology of the Rockall Trough and surrounding areas. This is co-funded by the Rockall Consortium of supporting oil companies. As part of the mapping programme, a geophysics mapping cruise on the RRV *Discovery* was undertaken in 2003 to collect seismic data along the northern margins of the Hatton Basin and the continental margin. Results will feed into the mapping of the Hatton area and analysis of the post-break-up tectonics and development of major folds or inversion structures along the margin.

Interpretations of BGS seismic data are being integrated with commercial data and the results of Strategic Environmental Assessments for the Møre Basin sheet, which covers the UK designated area north of 62°N. Mud diapirism can be linked to inversion structures that result in overpressuring in Neogene muds that are forced to the surface as diapirs or mud volcanoes (*see bottom left*).

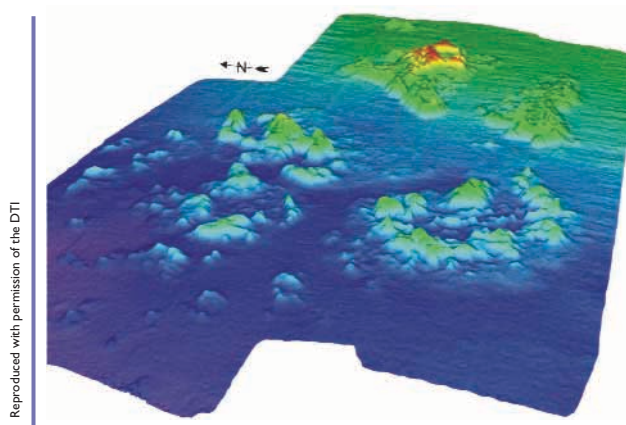
## The shallow geological model

The Western Frontiers Association continued to provide oil industry funding and data input to assess geohazards on the West Shetland margin. Studies were undertaken of features seen in the top section of 3D exploration seismic data relating to along-slope and down-slope sedimentary processes (*see top right*) linking them to sample data. Comparison of seabed images derived from 3D seismic data with swath bathymetry data and seabed samples demonstrates that the images from 3D seismic data reflect the structure of the upper 20 metres or so, and do not always reflect the current seabed sedimentary processes. We also produced a review of geohazards north of 62°N that included a geographical information system containing shallow section data. This is a new area for hydrocarbon exploration where deepwater geohazards not previously seen west of Shetland occur, including major submarine landslides originating in the Norwegian sector, and mud diapirs (*see bottom left*).

The skills we have developed in studying the regional processes and shallow geology have resulted in new site investigation and geohazards projects, both in the UK and worldwide.

## Geology and habitats

We participated with other research groups in a multidisciplinary investigation of coldwater coral reefs on the UK shelf. This was part funded by Scottish Natural Heritage and the Scottish Executive. In the primary area of survey, to the east of Mingulay, reefs formed by the cold-water coral *Lophelia pertusa* were identified. They were recognised on the multibeam bathymetry (*see bottom right*) and backscatter data records where intriguing 'trails' extend downstream from some of these mounds. The mounds are located on a series of rock ridges, locally rising more than 100 metres above the surrounding seabed. Previous seismic profiling and sampling indicate these ridges comprise both igneous and sedimentary rocks and therefore indicate no lithological control on the distribution of coral reefs. The environmental controls include an upper limit of 110 metres water depth and a close proximity to



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**Offshore regional mapping programme:** multibeam bathymetry data collected by the DTI for the Strategic Environmental Assessment project, showing the surface expression of mud diapirs that protrude up to 100 metres above the surrounding seafloor.



deep water (deeper than 180 metres). Such information will assist future mapping of cold-water coral habitats and the study has provided valuable insights into habitat mapping.

### **Petroleum geology**

We continue to work closely with the DTI and the industry-backed PILOT task force to support the government objectives of increasing production from mature fields, encouraging satellite developments and promoting new exploration. We have supported the development of a National Hydrocarbons Data Archive to ensure that key data are not lost and are made more readily available for new exploration and development. Confidential interpretations of exploration data for the DTI lead to the recognition of new prospects that are promoted to the industry in the form of CD-ROMs and presentations at scientific conferences.

### **Falkland Islands advice consultancy**

We provide geological and geophysical advice to the Falkland Islands Government on the sustainable exploration programme for offshore hydrocarbons and onshore minerals. This advice is in its twelfth year of operation.

Offshore exploration for oil and gas increased substantially during 2003/04, following some previously disappointing drilling results. Our geologists have taken a lead role in restarting exploration activity, proactively marketing the exploration opportunities to potential investors in the region. The first signs of renewed interest in the area came with the decision by one of the existing offshore licensees to invest over £4 million in a new 3D seismic survey to upgrade potential prospects ahead of a new round of offshore drilling. We helped implement, design and market the survey and its results, in an ongoing effort to bring new companies into the Falklands offshore.

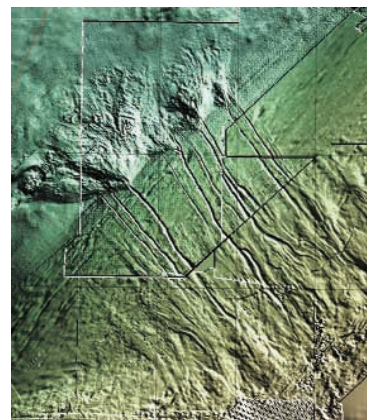
Onshore, the search for gold continues, and under guidance from our geologists, an exploration company continues to invest significant funds in seeking the source of the many gold samples that have been discovered in streams. Early 2004 saw the completion of an extensive aeromagnetic survey of the entire Islands, and it is hoped that analysis of the results will lead to a sustained onshore drilling campaign.

Data and results from all of these exploration challenges have been summarised into a new technical website designed for the Falkland Islands Government, and hosted by the BGS ([www.falklands-oil.com](http://www.falklands-oil.com)).

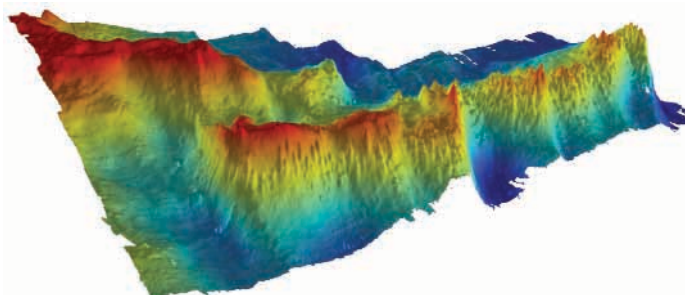
### **Ocean drilling**

ECORD Science Operator (ESO) consists of the BGS, the University of Bremen and the European Petrophysics Consortium (universities of Leicester, Montpellier, Aachen and Amsterdam). ESO will undertake a programme of drilling using non-specialist 'mission specific' drilling platforms. During 2003/04 an extensive planning operation was completed ready for the first drilling programme to be undertaken in summer 2004 in the Arctic Ocean on the Lomonosov Ridge.

**Shallow geological model:** seabed image derived from 3D exploration seismic data of probable glacial turbidite flows from bottom right to top left, leading from debris flows, via erosional channels to base of slope fans.



**Geology and habitats:** multibeam bathymetry data showing a topographic ridge covered with small mounds of coldwater coral reefs.



# Economic Minerals and Geochemical

## Programme overview

The Economic Minerals and Geochemical Baseline programme delivers information, expertise, advice and research on solid minerals (metallic, constructional, industrial, energy) and geochemical baseline surveys (for environmental and resource assessment purposes). These activities are undertaken at a range of scales from local to regional, national and international. The programme underpins a wide range of strategic sustainable development activities and policies with respect to the environment and mineral development.

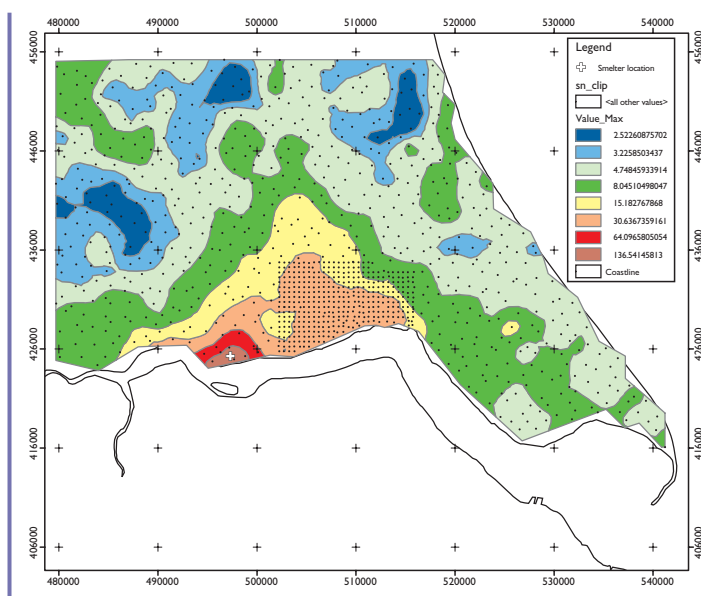
## Baseline geochemical mapping

The Geochemical Baseline Survey of the Environment project (G-BASE) has now completed sampling over eighty per cent of the land area of Great Britain, with south-east and south-west England remaining to be sampled. This multimedia survey involves the collection of drainage samples (stream waters, stream sediments and panned heavy mineral concentrates) from small streams at a density of one sample every 1.5–2 km<sup>2</sup>. Surface and deeper soils are collected at a density of one sample every 2 km<sup>2</sup>. To date, 105 000 stream sediment, 28 000 soil and 68 000 stream water samples have been collected and analysed. An improved analytical methodology for sediments and soils by energy-dispersive X-ray fluorescence spectrometry means that nearly fifty chemical elements are now routinely determined. Increasing demand for geochemical baseline data is being driven by legislation concerned with protecting and monitoring changes in our environment. We need a good understanding of the distribution of chemical elements and their behaviour in the surface environment, in which the weathering of underlying rocks and parent materials plays a very significant part. An application of G-BASE data during the past year was the provision of information to the Environment Agency of concentrations of nickel, cadmium and lead in the stream water and stream sediment defined by River Basin Districts for England and Wales for the Water Framework Directive.

## Geochemistry and health

Baseline geochemical data have important applications in the field of geochemistry and health, part of a rapidly expanding interest in 'medical geology'. The G-BASE project has one of six representatives on the International Union of Geological Science (IUGS) Medical Geology Council

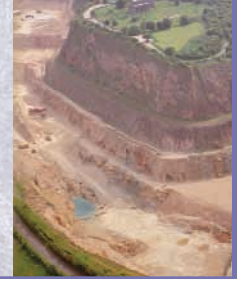
and continues to apply baseline geochemical data to many health-related issues in the UK. Historically, we have depended on our local environment for our food and water supply. Local environmental deficiencies in essential trace elements such as iodine and selenium can result in endemic diseases caused by insufficient quantities of such elements in the daily diet. Thankfully, a diet of food from a diversity of areas and non-localised water supplies has made such endemic diseases a thing of the past in the UK. However, such trace element deficiencies also afflict livestock and measures have to be taken to supplement their diet of predominantly home-grown fodder. Geochemical maps of the UK can help us to predict where such deficiencies occur and such areas can be targeted with trace element supplements. G-BASE maps can also be applied to pinpoint sources of pollution from industrial processes on a regional scale and confirm the link between anthropogenic pollutants and human health problems. An example of this is the ongoing study of the tin plume associated with the Capper Pass tin smelter on Humberside, which is clearly defined by G-BASE soil results.



**Geochemistry and health:** tin anomaly associated with a smelter location on Humberside defined in soils collected for the G-BASE project.



# Baseline



## Foundations of the Peak

In collaboration with the National Stone Centre, Derbyshire Wildlife Trust and Derbyshire County Council, we have developed a website ([www.foundationsofthepeak.com](http://www.foundationsofthepeak.com)) aimed at the general public and the education sector which shows the importance of minerals in shaping the landscape, biodiversity, industry and heritage of the Derbyshire Peak District. 'Foundations of the Peak' is a unique interactive guide to the natural and man-made landscape of the Peak District. The website shows that rocks and minerals are critical in forming the foundations of the beautiful hills and dales, the varied ecology and the rich cultural heritage in this part of central England. At the heart of the website is a three-dimensional virtual 'model' that will allow the user to 'fly' across the landscape and find out more about the links between scenery and geology, biodiversity, industry, settlement and minerals extraction in the Peak District. Development of the website was supported by the Sustainable Land Won and Marine-Dredged Aggregate Minerals Programme, managed by the Mineral Industry Research Organisation (MIRO) on behalf of the Office of the Deputy Prime Minister.

## Environmental indicators and aggregates extraction

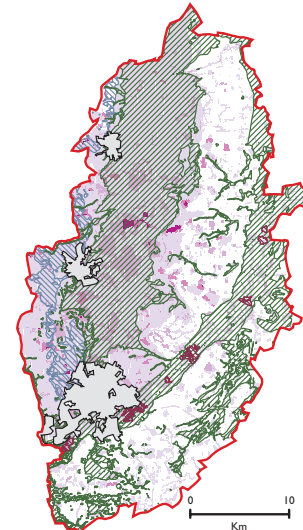
We are developing quantitative methods to measure the impact of mineral development on the environment. A true environmental indicator is something that can be measured or quantified and changes over time, for example, the number of Special Sites of Scientific Interest (SSSI). This project has used a range of environmental and cultural information (such as areas of National Park, Areas of Outstanding Natural Beauty etc.) as part of a new methodology to help indicate the most and least sensitive areas for future aggregate extraction. We were able to achieve this through the development of an environmental 'sensitivity' mapping technique using geographical information system (GIS) technology. 'Sensitivity' is based on the number of land-related 'assets' in an area that could be impacted upon by quarrying. GIS methodologies enable a wide range of information to be displayed at once or key themes to be highlighted at the click of a mouse. The database can also be interrogated. An index of all modelled information at a specified location can be quickly generated giving the user an indication of the sensitivity of that area to aggregate development.

## Reconstructing Afghanistan with minerals

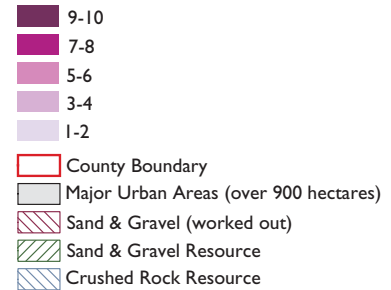
The BGS has been working with the Department for International Development to assist Afghanistan in rebuilding its minerals and mines function within government. Afghanistan is one of the world's poorest countries with a tragic recent history. To move the country towards a sustainable era of peace it is imperative that jobs are created and that a fully functioning government is reborn. We are assisting the Afghan Government in rebuilding and strengthening capacity within minerals geoscience. The aim is to rebuild important mineral databases, train staff in key mineral geoscience skills, promote Afghanistan's mineral deposits to an international audience, and develop good governance with respect to mineral development. This work will support the physical rebuilding of a war-torn country and the generation of a wide variety of jobs in the mineral industry and related areas of economic activity.

### Environmental indicators and aggregates

**extraction:** environmental sensitivity map for Nottinghamshire. The darker colours indicate areas of higher 'sensitivity'.



### Number of Assets



**Reconstructing Afghanistan with minerals:** Kabul's war-destroyed city is being rapidly redeveloped using a wide variety of minerals.



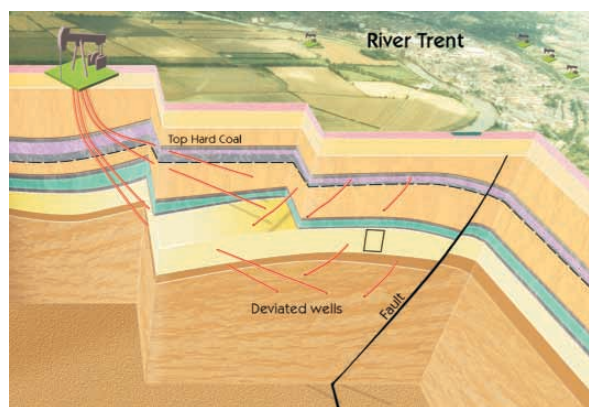
# Sustainable Energy and Geophysical

## Programme overview

The Sustainable Energy and Geophysical Surveys programme provides research and information to support many of the objectives of the Energy White Paper (2003), and to deliver NERC strategic science priorities (for example, *Towards a Sustainable Energy Economy*). These include technologies for securing a 60% cut in carbon dioxide emissions by 2050, coupled with finding and using affordable, reliable and yet diverse energy supplies. The programme is also responsible for improving our understanding of the UK's subsurface geology to sustain energy-related activities and to underpin other BGS environmental applications and core research.



**UK coal resources:** cleats in coal. This natural system of fractures imparts some permeability to the coal which allows methane to be extracted.



**Onshore hydrocarbons and coal resources:** three-dimensional schematic representation of the Gainsborough/Beckingham oilfield used in a poster and flyer developed with the Science and Society project for the Environment Agency (detail).

## CO<sub>2</sub>Store

The BGS is part of a multinational team participating in this EC/industry Fifth Framework project researching into greenhouse gas mitigation measures. The Sleipner gasfield produces carbon dioxide (CO<sub>2</sub>), which is being injected into the Utsira Sand, a major saline aquifer beneath the North Sea. An important part of the project is concerned with the monitoring of this CO<sub>2</sub> injection by time-lapse geophysical methods. Data from 4D seismic reflection surveys were acquired in 1999, 2001 and 2002, with respectively 2.35, 4.26 and 4.97 million tonnes of CO<sub>2</sub> in the reservoir. The CO<sub>2</sub> plume is imaged as a number of bright subhorizontal reflections, growing with time, underlain by a prominent velocity pushdown. The seismic data indicate that no leakage has so far occurred from the reservoir, the CO<sub>2</sub> being trapped as a series of thin layers (just a few metres thick) ponded beneath intra-reservoir beds of mudstone. Possible future storage regulations might make it important to demonstrate that seismic methods can be used to quantify and verify the amount of CO<sub>2</sub> *in situ*. With this aim, we have derived a 3D saturation model of the CO<sub>2</sub> plume by inverse modelling of the seismic data. The plume saturation model is consistent with the known amount of injected CO<sub>2</sub>. In addition, synthetic seismograms of the plume saturation model show a good match with the observed data (see *bottom right*), suggesting that verification can be confirmed, within the bounds of parameter uncertainty. By coupling reservoir flow simulations with geochemical work and advanced seismic analysis, we hope to further improve our understanding of CO<sub>2</sub> transport processes in the Utsira reservoir.

## Onshore hydrocarbons and coal resources

A number of projects are ongoing under this theme. An onshore hydrocarbons and coal resources geographical information system (GIS) is being developed to use subsurface geological, geophysical and geochemical digital datasets collated by the BGS. The East Midlands is an area where ongoing hydrocarbon exploration and recent coal exploitation have created an unparalleled dataset of subsurface information. GIS technology makes accessing, manipulating, cross-referencing and visualising this information relatively simple. This provides the opportunity to reappraise the 3D subsurface stratigraphical and structural development of the region with the results underpinning future research into the exploitation of its rich natural resources. Petroleum related work is ongoing in a number of areas. We have provided biostratigraphical support to national oil and gas exploration and production companies in Saudi Arabia and Oman. Dating and correlating Mesozoic and Palaeozoic sections have contributed to determining the spatial distribution of reservoir–seal pairs during exploration, field development and production phases. We have also been involved in diagenetic studies in the Palaeozoic (clastic) reservoir successions in Saudi Arabia. In Germany, we are developing a sequence stratigraphical model of the Upper Carboniferous in the Schneeren-Husum field (near to Hanover) for Gaz de France and its concession partner EMPG. The main aim is to develop a fully attributed 3D reservoir model suitable for upscaling to reservoir simulation. In the UK, a poster and leaflet has been produced for the Environment Agency summarising the origins, history and development of the Gainsborough/Beckingham oilfield.

# Surveys



## UK Coal Resources for New Exploitation Technologies

This project, commissioned under the Department of Trade and Industry's Cleaner Coal Technology Programme, provides a major new series of maps, including a summary map at 1:750 000 scale and two sets of twenty-one more detailed 1:100 000 scale maps covering all coalfield areas. The first set shows areas of past and present opencast and underground mining, major coal mines and mining licences and prospects for extracting methane from abandoned mines. The second set details the UK coal resources available for exploitation by new technologies such as coalbed methane production and underground coal gasification. They are available as paper copies or on CD-ROM. An accompanying report is also available.

## Ground source heat pumps

This BGS and Carbon Trust co-funded project looked at the potential in the UK for ground source heat pump (GSHP) development and technology. GSHPs use the thermal store of the Earth in either a closed or open-loop heat exchange system, which is then released at a higher temperature. GSHPs are the most energy-efficient, environmentally clean, and cost-effective space-conditioning systems available and are well suited to domestic and small commercial heating (or cooling) requirements. Each residential GSHP installation typically saves about two tons of carbon dioxide emissions annually and are common in the USA, Sweden, Austria and Germany. Running costs for a GSHP system can be about 50% of conventional space heating, and carbon saving can be about 40%. However, only about 300 installations exist in the UK due, in part, to the low prices for primary energy. This project provides GSHP installers with site-specific data online via the Internet to assist system design and performance and reduce risk, and thus enhance the commercial adoption of a proven low-carbon technology.

## Airborne environmental surveys

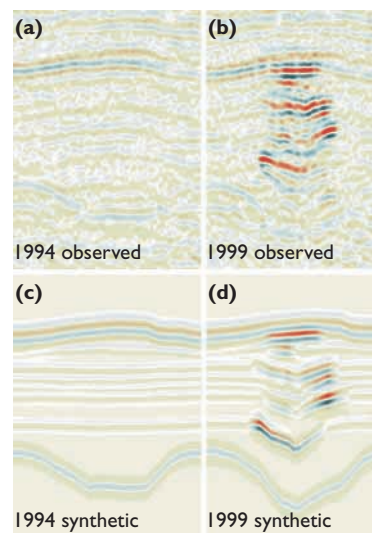
We plan to acquire modern, high-resolution, airborne electromagnetic, magnetic and radiometric data across the entire onshore UK. This will provide information on the shallow subsurface and measure the environmental impacts of various industrial, agricultural and other human activities. The first baseline survey was flown in the English Midlands in 1998 and has been used to develop the concepts and assess some of the many potential applications of the data. These include the detection and monitoring of pollution plumes in the shallow subsurface, which are sometimes associated with waste tips and colliery spoil heaps. In order to develop this application further, we undertook a small trial survey (1 x 2 km) in 2004 using an advanced, helicopter-borne, multiple frequency electromagnetic system. Such systems can be used for detailed follow-up investigations of significant features identified during regional-scale baseline surveys. The trial survey acquired data over a legacy landfill site in West Lothian adjacent to land being considered for opencast coal mining and subsequent regeneration. The main aim of the survey is to determine whether a conductive plume crosses a fault separating the landfill from the development land. Initial modelling of the conductivity distribution associated with the landfill shows possible leakage of conductive material below the base of the landfill at depths in excess of 30 metres.

## Weyburn, NASCENT, GESTCO and CARNOT:

These four EC funded projects finished during the year and have successfully delivered final reports. Details can be found on our website. The picture shows soil gas monitoring of a carbon dioxide injection site at Weyburn oilfield, Canada.



**CO<sub>2</sub>Store:** synthetic seismograms of the plume saturation model show a good match with the observed data. Seismic reflection data acquired in 1994 (a) and 1999 (b) closely match the synthetic seismic models of the two datasets (c) and (d).



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# Geological Survey of Northern Ireland

## Northern Ireland

**T**he Geological Survey of Northern Ireland (GSNI) is part of the Department of Enterprise, Trade and Investment (DETI). It is staffed by BGS scientists under contract to DETI, which allows the GSNI to draw on expertise from within other parts of the BGS. The GSNI carries work out for other Northern Ireland government departments and collaborates closely with the Geological Survey of Ireland on cross-border projects.



GSNI © Crown Copyright

**Environment:** brine seepage at Frenchpark (top) and after rehabilitation (above).

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### Landscape heritage and public awareness of science

The Breifne Mountain Project is managed by a consortium of partners, including the GSNI and the Geological Survey of Ireland (GSI) and was one of two major projects funded during the year. The Breifne project focuses on the natural and cultural landscape of five counties in the border region of Ireland and is designed to facilitate sustainable tourism in an underdeveloped region.

Complementing the Breifne Mountains project, the GSNI is the lead partner in a Northern Ireland / Republic of Ireland / German Geoparks initiative. This major project is designed to heighten public awareness of the landscape and will develop linkages between partners in the expanding Geoparks network. The GSNI continues to promote the European and Global Geoparks Network and has been appointed as an official advisor to UNESCO.

The GSNI organised a successful series of seven lectures under the 'Geology Works' banner. All of the speakers came from the BGS and described many of the relevant and practical aspects of applied geoscience to large and enthusiastic audiences.

### Environment

The programme continued to monitor and assess the health and safety issues associated with Northern Ireland's legacy of abandoned mine workings in support of the Department's responsibilities. Mine workings that may represent an actual or potential danger to the public are identified and remedial action proposed. Issues associated with abandoned salt mines continue to represent one of the major aspects of the sector's work. The GSNI continued to monitor surface-level changes over the Frenchpark and Carrickfergus / International mines and in addition managed the successful rehabilitation of brine seepages at Frenchpark.

The GSNI is a statutory consultee to many planning applications and this represents a major growth area in GSNI activity, reflecting the increased environmental awareness as a result of EU directives. Development work continued on a geoscience data and information system to cover the Belfast Metropolitan Area (BEEGMap). This system will have applications for land-use planners and civil engineers and will enhance the GSNI's ability to deliver geoscientific information.

### Minerals and energy resources

Mineral and petroleum rights are vested in the Northern Ireland Department of Enterprise, Trade and Investment (DETI). The GSNI acts as advisors to DETI and monitors technical aspects of the licence holders.

A new Minerals and Petroleum Promotional Strategy was implemented. This included the production of a new Minerals Pack containing information on aspects of exploration in Northern Ireland. This was launched at the Prospectors and Developers Conference in Toronto, Canada and attracted a wide range of interest from delegates. The GSNI was also mainly responsible for the Mining Journal 'Ireland' supplement, the first all-island publication of its type.



Mineral exploration remained focused on gold and the GSNI provided data and advice in support of companies' exploration programmes during the year. The area under licence for minerals in Northern Ireland remains at its highest level for 20 years. New hydrocarbon licence applications were received for the Fermanagh and Rathlin Basin areas. The working relationship between the GSNI and the Department continues to grow closer and new procedures will result in the more efficient processing of licences.

A study of the sand and gravel distribution of the Strabane and Omagh Districts was completed for Planning Service and more opportunities for this type of research are anticipated. Integration of these datasets facilitates the sustainable development of Northern Ireland's natural resources. To ensure consistency across government, the GSNI has proposed undertaking responsibility for the central management of the national quarries database.

### Resource and Environment Survey of Ireland

Work progressed on advancing the Northern Ireland component of Resource and Environment Survey of Ireland (RESI). Detailed planning of the geochemical and airborne geophysical aspects of the project was progressed in parallel with an independent scoping study and cost-benefit analysis. Both of these reports recommended proceeding with the project. The personnel to manage and implement the project have been identified and, subject to Ministerial approval, data collection will commence in the summer of 2004. The resulting information will be relevant and of value to environmental monitoring, geohazard identification, agriculture and mineral exploration.

### Mapping and publications

The publication of *The Geology of Northern Ireland — Our Natural Foundation* represented one of the highlights of the year. The 318-page book is a full colour production, which describes the geology of Northern Ireland from 900 million years ago to the present day. The book is written for the geologist but is designed to appeal to a wider, non-technical, audience and each chapter has been colour-themed to complement the 1:250 000 map that it describes. Sales of the publication have been excellent and reviews have been very enthusiastic. One review states that 'it is the finest statement of regional geology in the UK and its revolutionary approach will influence similar publications appearing from now on.'

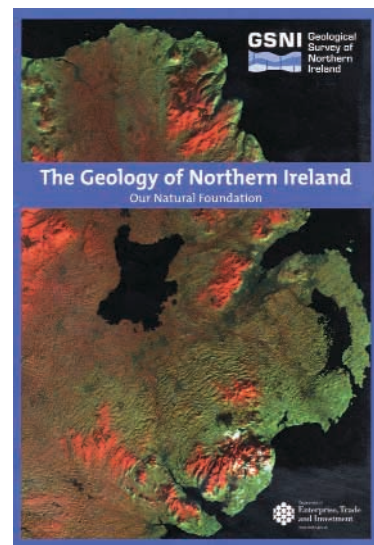
Rapid geological surveying was completed over the Newtownstewart area (1:50 000 sheet 25) aided by satellite imagery and aerial photographs. Work is well advanced at ensuring the publication of the Lisnaskea map (1:50 000 sheet 57) in the forthcoming year. GSNI is part of a consortium collecting aerial photographic coverage of Northern Ireland and this information will facilitate rapid geological mapping in the north-east and south-east of the country.

**Minerals and energy resources:** drilling at the Curraghinalt project, Sperrin Mountains.

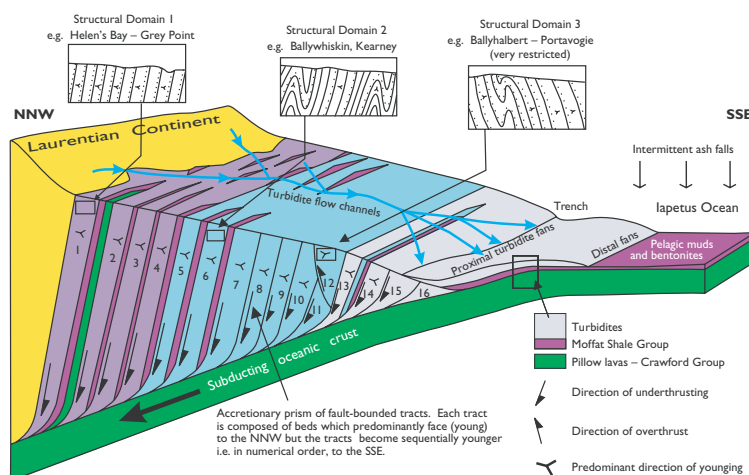


GSNI © Crown Copyright

**Mapping and publications:** the popular book 'The Geology of Northern Ireland' (below) with one of its illustrations (bottom).



GSNI © Crown Copyright





# Environment and Hazards



The **Environment and Hazards Directorate** operates through five programmes to deliver information on how geoscience impacts on humans and their environment. The **Electrical Tomography Service** sub-programme exploits the near surface monitoring, imaging and technological developments of this important geophysical technique. We aim to better understand the many complex physical and chemical processes that interact in both the near-surface and at depth to influence the landscape, how and where they occur and the consequences to humans as they go about their business.

The **Groundwater Systems and Water Quality** programme continues to produce high quality research on processes and information relating to both groundwater resource and quality. A multidisciplinary approach dramatically increases the understanding of how aquifer systems work and how they interact with surface water bodies. This information aids better sustainable management of finite water resources. The programme is active overseas, studying rural water supply solutions in India and highlighting the occurrence of high natural arsenic levels in aquifers around the world.

The **Seismology and Geomagnetism** programme continues to monitor and disseminate valuable information on seismic events and geomagnetism. A project to update instrumentation is under way. Research into fracture anisotropy and fluid content, exploited by the hydrocarbons and water industries, has advanced significantly. Industry consortia continue to grow, keeping the quality and usefulness of the science and information relevant. We continue to advise customers on the impact of solar flares on electrical power systems and satellites.

The **Urban Geoscience and Geological Hazards** programme is using protocols established over the past few years to collect and collate data to establish risks associated with the near-surface hazards found in cities. Urban studies, for instance in Manchester, have shown the value of bringing geologists, engineers, hydrogeologists, geochemists and modellers together with planners and developers to improve land use and protect groundwater. This resource must be sustained to provide potable water and heat for the community.

The third year of the **Environmental Protection** programme has resulted in the development of a wide variety of activities in the areas of geochemistry, mineralogy, geophysics and hydrogeology. Advances continue to be made with physiological extraction tests that mimic the human digestive system as one way of understanding how the environment impacts on human health. Remotely accessed computer-controlled testing systems research the interaction between nuclear waste and rocks.

The **Coastal Geoscience and Global Change Impacts** programme aims to understand past and present patterns of erosion, transport and storage of sediments (and associated materials including pollutants) in order to predict and better manage future change. Survey work on sediments is leading to a better understanding of marine habitats. Studies in the Thames Estuary are helping to shape the design of flood protection systems for the next 30 years.

Executive Director	
Marketing, International & Corporate Development	
Environment & Hazards	Geoscience Resources & Facilities
Lands & Resources	
Information Services & Management	
Administration & Finance	

Environment & Hazards <b>Mr D C Holmes</b> 0115 936 3566 dcho@bgs.ac.uk		
Coastal Geoscience & Global Change <b>Dr J G Rees</b> 0115 936 3296 jgre@bgs.ac.uk	Urban Geoscience & Geological Hazards <b>Prof. M G Culshaw</b> 0115 936 3380 mgc@bgs.ac.uk	Groundwater Systems & Water Quality <b>Dr D W Peach</b> 0149 169 2351 dwpe@bgs.ac.uk
Environmental Protection <b>Dr B Smith</b> 0115 936 3423 bsmi@bgs.ac.uk	Seismology & Geomagnetism <b>Dr D J Kerridge</b> 0131 650 0220 djkk@bgs.ac.uk	Electrical Tomography Service <b>Dr R D Ogilvy</b> 0115 936 3359 rdo@bgs.ac.uk

(Opposite) St Monance harbour and syncline, Fife.

# Groundwater Systems & Water Quality

## Programme overview

The Groundwater programme provides science support for sustainable development and management of the water environment both in the UK and overseas. The portfolio of projects includes strategic science, survey and information provision funded by the NERC, co-funded or fully commissioned. This year has seen a continued decline in DFID-funded international work but a rise in co-funded work with the Environment Agency (EA) and water industry and collaborative work with universities. New ventures include a large co-funded (EA, United Utilities, BGS) study of nitrate variability and transport in relation to recharge processes in the Eden Valley. Several large successful projects are drawing to a close including notably COMMAN and European Baseline. The programme continues to produce high class scientific outputs in the literature, most notably perhaps on the subject of arsenic in groundwater.



**Arsenic in groundwater:** arsenic poisoning from drinking contaminated groundwater is a major problem in Bangladesh. A Bangladeshi woman is here showing her hands that have been badly affected by keratosis, induced by drinking arsenic-rich groundwater. The only cure is to change to a source of low arsenic drinking water.

## Arsenic in groundwater

It has become apparent in recent years that high arsenic concentrations are found in groundwaters from many parts of the world. The arsenic is largely natural, and is derived from the aquifer sediments by a complex series of chemical reactions, which are not completely understood. High arsenic concentrations in drinking water are now a major issue in many countries. Since 1992, we have been working on the groundwater arsenic issue in various countries including Ghana, Bangladesh, China, Argentina and the UK. BGS hydrogeochemists have written, or contributed to, various reports and reviews on the subject for clients including the Environment Agency (EA), UK Department for International Development (DFID), UNICEF, World Health Organisation (WHO), and World Bank. As a result of the experience gained from this work, they have published several reviews on the subject including in the recently released *Treatise on Geochemistry* (2003) and contributions to various journals. A recent review on arsenic geochemistry, published in the *Journal of Applied Geochemistry* in 2002, was featured in the ISI Essential Science Indicators as one of the fastest breaking papers in the geosciences.

## Community management of groundwater resources in rural India

In the context of severe water shortages in India resulting from years of overabstraction of groundwater, a DFID-funded research project, led by the BGS, has been undertaken to examine the potential for local, user-based approaches to groundwater management. This involved close collaboration between seven Indian and international NGOs and research institutes. The project concluded that, although community-based strategies generate important and substantial benefits for local people, these are unlikely to be effective as a primary response strategy for addressing groundwater overabstraction. Under existing rights systems the rules of capture, that effectively allocate all power to individual landowners, create strong disincentives for collective management based on the ability to exclude non-participants. Moreover, the rights of landholders to pump as much water as they want are generally not contested by those without land and without direct access to groundwater. Defining resource and user-group boundaries, a key prerequisite for natural resource management, is also pertinent. It is a technically complex task to identify hydrological system boundaries for management in both hard-rock and alluvial areas. Mechanisms to control free riders are also problematic. The project proposes that far more attention should be devoted to processes that anticipate and proactively support the adaptation of households, communities and regions to other forms of livelihood, as intensive irrigated agriculture becomes increasingly less viable in locations where overabstraction is severe.

## Eden Valley groundwater project

The Eden Valley in Cumbria is underlain by Permo-Triassic sandstones which form the major aquifer in the region. This aquifer is important not only because it is a major source of water supply for potable supply, industry and agriculture but because it also helps maintain river flow. Monitoring of abstraction boreholes by the Environment Agency (EA) has shown that while most have low nitrate concentration there are a significant number of boreholes with a nitrate concentration above 20 mg/l (as  $\text{NO}_3$ ) and which show a rising trend. The spreading of animal slurry on grassland is thought to be the principal cause of the elevated nitrate concentrations found in some groundwaters. There is concern





about the long-term impact on water resources given the considerable lag in time between rainfall infiltrating through soils and its arrival in an abstraction borehole. Accordingly the BGS, EA and United Utilities (formerly North West Water) have joined together to investigate the processes controlling groundwater recharge and flow and its interaction with surface water. This four-year research programme will consider the interrelationship between land use and the quality of groundwater recharge, the changes in water chemistry along a groundwater flow-path from recharge to discharge areas, and the timescales involved.

### Baseline quality in European aquifers: a basis for aquifer management

This Europe-wide project assessing the baseline quality of European groundwaters was co-ordinated by the BGS with partners from 12 countries. Co-funded by the EU, it provided a scientific basis for defining baseline quality as well as a forum for discussion with policy makers and end-users. Detailed studies were completed of 24 aquifers, including water quality, timescales of groundwater movement using state-of-the-art techniques and trend analysis. The results have been reported to the EU and have been used as a basis for underpinning baseline concepts used in the Water Framework Directive. Further details can be found on our website ([www.bgs.ac.uk/hydrogeology/baseline/](http://www.bgs.ac.uk/hydrogeology/baseline/)).

### Groundwater protection and management for developing cities

It is predicted that, by 2010, half the world's population of 6500 million will live in towns or cities. Much of the increase will be concentrated in the developing world, which accounted for 85% of urban population growth between 1980 and 2000. A high proportion of these urban dwellers will depend on groundwater for day-to-day domestic, industrial, and commercial water supply. Against this background we undertook a collaborative research project from 1998 to 2002 with partner organisations in Kyrghyzstan (the Kyrghyz Research Institute of Irrigation) and Bangladesh (University of Dhaka). The project was funded by DFID under its Knowledge and Research Programme as part of the UK's technical assistance to developing countries. The project aimed to demonstrate how to develop a technically and socio-economically appropriate urban groundwater protection policy. It used the two cities of Bishkek, the capital of Kyrghyzstan, and Narayananj, a fast-growing city near Dhaka as case studies to show how various tools and techniques could be employed and to compile a set of guidelines for wider use.

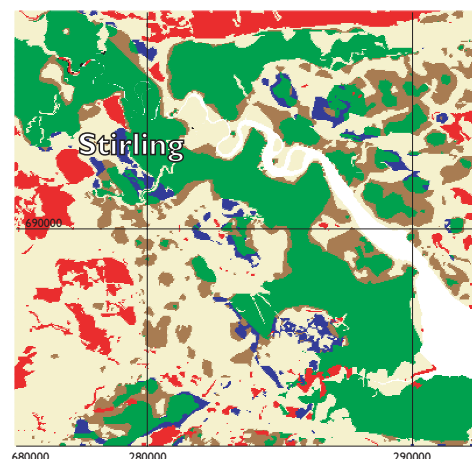
### Groundwater vulnerability

A major project carried out in Scotland during the year was the production, for the Scottish Environment Protection Agency, through SNIFFER, of a groundwater vulnerability methodology and maps for Scotland and Northern Ireland. Contaminants moving downwards from the ground surface can have a varying impact on the underlying groundwater system, depending on the permeability and thickness of the superficial cover layer, type of groundwater flow, and depth to the water table. The new maps incorporate this digital information to produce a five-fold classification system for vulnerability. The methodology, based on a geographical information system, is designed for future integration with other layers of information, including aquifer productivity, for strategic planning purposes.

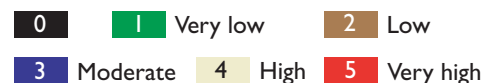
**Community management of groundwater resources in rural India:** large dug well in Tamil Nadu, India, which has had to be deepened due to a regional decline in groundwater levels.



**Groundwater vulnerability:** an example from the Stirling area of the groundwater vulnerability map of Scotland.



**Groundwater vulnerability**



# Seismology and Geomagnetism

## Programme overview

The Seismology and Geomagnetism programme operates the UK seismic network and magnetic observatories which monitor seismic activity and geomagnetic field variations. It provides services to government, industry and academia which include rapid access to data and information following significant earthquakes in the UK and abroad, and during adverse 'space weather' causing magnetic storms. Analysis of global seismic and geomagnetic datasets provides essential information on seismic hazards and accurate models of the geomagnetic field for navigation. Research into advanced seismic methods improves the determination of rock properties and rock–fluid interactions as well as the imaging and management of hydrocarbon reservoirs.

### National earthquake monitoring

A sequence of eleven earthquakes occurred between 20 June and 15 September 2003 near Aberfoyle in central Scotland, of which eight were felt locally. Their seismograms showed a high degree of similarity, suggesting the earthquakes were the result of repeated similar movement in a small source volume. Analytical techniques applicable to such event clusters allowed relative event location and fault movement to be estimated with a high degree of accuracy, indicating movement on a WSW–ENE fault parallel to the Highland Boundary Fault.

A similar sequence of felt events in Somerset on 29 January created media and public interest, and analysis of two events reported near Bridgwater revealed that two pairs of closely spaced events had occurred, again allowing a good description of the fault orientation.

In both local and global earthquake research, there is much interest in the nature of the earthquake rupture process. Broadband sensors enable recording of a wide range of seismic wave amplitudes and frequencies, and the data can be filtered to reduce background noise allowing a wide range of analytical methods to be applied in individual and collaborative experiments, including studies of rupture processes and earth structure. We have installed four new broadband stations in the UK since June 2003.

### Variation of expected earthquake intensity

A study of felt reports from UK earthquakes in the past several years has allowed the production of a new equation linking the expected degree of shaking to distance and magnitude. This relation can be used to estimate the felt effects of possible significant UK events in the future. It is also useful in hazard and risk studies where one wishes to estimate the probability of earthquake damage to property, as well as studies comparing computed hazard values with historical experience at a given site.

### National Geomagnetic Service

We provide information about variations in the Earth's magnetic field to a wide variety of interested parties, and this service is supported by co-funding from several organisations. Activities include: operating magnetic observatories, modelling the geomagnetic field, and collaborative ventures such as participation in INTERMAGNET (an international programme for the timely exchange of magnetic data) and operation of a World Data Centre for geomagnetism.

The magnetic information on Ordnance Survey maps is derived from a regional model of the UK geomagnetic field which we update each year according to the latest UK geomagnetic data. The Ministry of Defence and oil companies support data collection and modelling work. The oil industry uses high quality near real-time geomagnetic data to enable accurate directional drilling, and this requires information on short-term geomagnetic field changes to process survey data collected while drilling the wells. Near-real-time data from our



**National Geomagnetic Service:** a new observatory was established in hostile conditions at Prudhoe Bay in Alaska to provide data for local oil drilling operators.



observatories are used to provide services to oil companies working in UK waters and, in October 2003, we established a new observatory at Prudhoe Bay, Alaska to help improve the success of directional drilling there.

Long-term changes in geomagnetic activity can also be monitored through the *Aa* index which, starting in 1868, is one of the longest running continuous datasets in geophysics. Collaborative work has confirmed an increasing trend in the *Aa* index over the past century, supporting the idea of an increase in solar coronal magnetic field strength. Such interesting evidence of changes in solar–terrestrial interactions may have a bearing on the natural component of climate change due to solar variability.

### Space weather

Two massive solar flares erupted from the same sunspot on 28 and 29 October 2003 — one the third largest since records began 25 years ago — and gave the UK its largest magnetic storm since 1989. The flares produced coronal mass ejections (huge clouds of charged plasma ejected from the sun) which headed directly to Earth. Due to their location at the centre of the solar disk these caused large variations in the magnetic field observed at the UK observatories. Such storms cause geomagnetically induced currents which can be harmful to electrical power distribution networks.

We had warned Scottish Power of the approaching magnetic storm and they were able to take steps to avoid possible damage. The aurora borealis, or northern lights, are usually visible at higher latitudes. However, the magnitude of these magnetic storms gave rise to two nights of spectacular auroral displays throughout the UK.

### Edinburgh Anisotropy Project

The Edinburgh Anisotropy Project (EAP) develops and applies innovative data processing and analysis techniques to multicomponent seismic data acquired by the oil industry to solve a variety of problems associated with the investigation of hydrocarbon reservoirs. It is supported by a consortium of oil industry companies, who have been quick to adopt and apply EAP techniques.

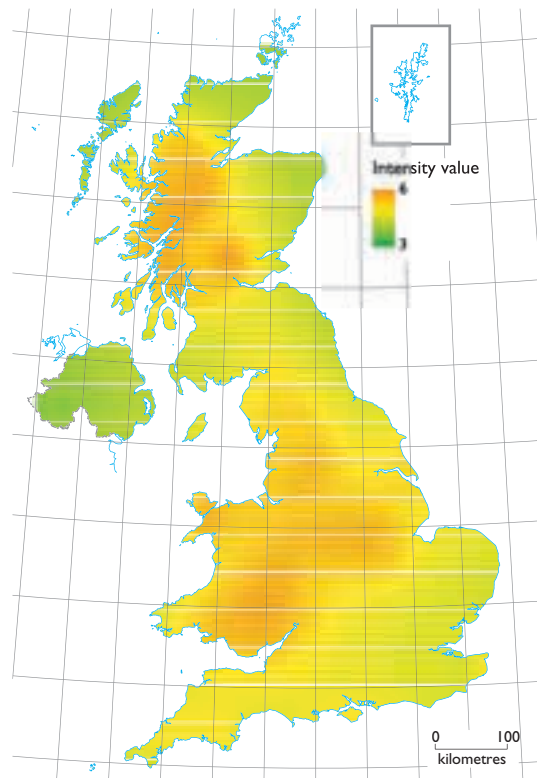
One example is the growing use of converted waves, which are impractical to use with conventional processing techniques. Processing algorithms developed by the EAP for these waves permit imaging under gas clouds and in other problematic zones, where results using conventional methods are poor.

We have also developed theoretical rock physics models which allow the length-scale of rock fractures and fluid–rock interaction in a rock mass to be described through the analysis of frequency-dependent anisotropy determined remotely from seismic waves. This exciting capability has received acclaim from industry, and was presented at the House of Commons during British Science Week.

**National earthquake monitoring:** a new broadband seismometer station installed at Lerwick Observatory, Shetland.



**Variation of expected earthquake intensity:** variation of expected earthquake intensity — the expected strength of earthquake shaking in the UK with a 10% probability of being exceeded in the next 50 years.







contaminant sources and pathways. The study area has a legacy of heavy industries, notably in metal manufacturing, which may have caused contamination of soils and groundwater. Recent developments in borehole modelling have allowed us to improve our understanding of the complex three-dimensional geometry of the superficial deposits. This, supported by a water table elevation model and development of methodologies to model surface water and groundwater flow paths, permits a regional understanding of contaminant pathways. Current and former land use have been assessed, in relation to the extent and nature of artificial deposits, to identify potential contaminant sources. Characteristic ranges of heavy metals are determined for these potential source areas, with hazard ranking of sites relative to published Soil Guideline Values. A BGS site prioritisation tool has been applied to prioritise the risk associated with contaminated land for the industrial sites and generate a regional 'risk' map.

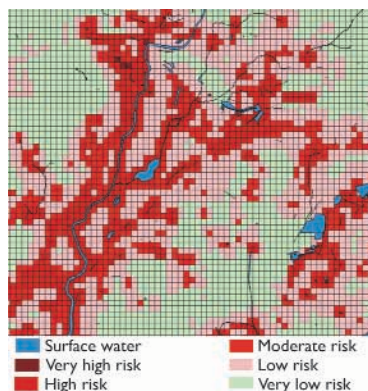
### Assessment of railway trackbed performance

In collaboration with the Railway Research Centre at the University of Birmingham we are studying how geology and geological processes contribute towards poor trackbed performance. Research on a regional scale aims to identify the geological factors affecting strength and stiffness properties of railway subgrade. Work is focusing on the derivation of subgrade susceptibility maps along linear routes from three-dimensional geological databases. Research at a site scale aims to assess the processes causing railway subgrade problems. Geophysical monitoring tools have been developed to study the effect of long-term subgrade property changes on track performance. A monitoring site has been set up near Leominster station where the subgrade is within alluvial deposits of inconsistent stiffness. The installation comprises probes within parts of the trackbed and underlying formation to measure vibration, shear wave velocity and resistivity. Resistivity tests indicate highly variable moisture conditions in the subgrade. The shear wave velocity increases with depth in the subgrade, and measurements indicate the stiffness has remained constant at the top but has increased at the bottom of the monitoring interval. Sub-10Hz vibration amplitudes from freight trains increase as energy is transmitted from the sleeper and propagates to greater depth into the subgrade. Research continues to assess if there are any direct links between the vibration amplification and the subgrade stiffening processes.

### Swelling and shrinking clay-rich soils

Much of Britain is underlain by clay-rich soil and rock formations. These formations may constitute a significant hazard due to their ability to shrink or swell as their water content changes, putting homes, buildings and infrastructure at risk. Estimates put the cost of damage at some £400 million a year under current climate conditions and as many as one in five homes in England and Wales may be damaged during their lifetime. Homes and roads in the south-east of England are the worst affected. If predictions of hotter, drier summers with wetter winters are correct, damage is likely to become more severe and more widespread. Research is being carried out into ground movements caused by shrink/swell susceptible clays in the UK and has been completed for the Gault Clay, Mercia Mudstone Group and the Lambeth Group; work is in progress on the Lias Clay and the London Clay. The amount of ground movement depends on the type of soil or rock on which a building is founded. Combining geological expertise and experience with geotechnical data, hazard maps have been prepared and areas particularly at risk of ground movement have been identified.

**Contamination risk assessment:** an integrated GIS methodology for prioritisation of potentially contaminated sites has been modified to develop a regional prioritisation scheme which scores the relative risk from contamination across the entire project area (shown on a 100 metre grid).



**Assessment of railway trackbed performance:** testing the ballast and subgrade at Leominster railway station.



# Environmental Protection

## Programme overview

The Environmental Protection programme undertakes research and survey activities in areas related to environmental protection, human health, waste disposal and mining. The programme has undertaken commissions for a wide variety of governmental, international and local authority clients, an increasing number of which are co-funded projects that help to develop core research and knowledge development within the BGS as well as benefiting the customers concerned.



**Environment and health:** children waiting to be weighed in China. Children with iodine deficiency disorder (IDD) can grow up stunted, apathetic, mentally retarded and incapable of normal movements, speech, or hearing.

## Nuclear waste disposal

During the course of the year the Environmental Protection programme has continued to undertake novel mapping and experimental developments in conjunction with commissions from the nuclear industry. A key event in these activities was the design, building and commissioning of an underground laboratory to underpin the Svensk Kärnbränslehantering AB (SKB) full-scale gas release test. The laboratory was built on the Keyworth site and shipped to SKB's underground experimental facility, Äspö, in Sweden. This laboratory, containing over two kilometres of wiring and pipe-work, will be interactively controlled from our Keyworth office over the Internet. Other developments have included continuing contributions to systematically mapping and characterising core, fracture coatings and pore fluids via commissions for the Japanese nuclear waste programme, and involvement in various international consortia such as the Fifth Framework programme.

## Environment and health

While issues of contaminated land and its impact on human health continue to be the subject of research in the UK, other, more insidious, effects due to trace element deficiency continue to affect large parts of the world's population. We have assisted in improving the understanding of the causes of such disease by investigating, with medical co-workers, the geochemical cycling of iodine in China and North Africa. These studies, funded by the Department for International Development, have highlighted not only the importance of baseline data on the occurrence of iodine in relation to these diseases, but also the need for a more detailed knowledge of processes that lead to iodine fixation in soils. Within an international context UNIDO and UK Ministry of Defence commissioned us to study mercury contamination from small-scale gold mining in Tanzania and militarily derived depleted uranium contamination in the Balkans.

## Waste and contamination

Septic tanks have been used for many years as a preferred option for the disposal of domestic sewage in rural settings. However, increasingly strict groundwater regulations and continuing concerns in respect of diffuse nitrate pollution and potential contamination of groundwaters by pathogens have led to the Environment Agency commissioning us to reassess the impact of septic tanks on groundwater quality. This work commenced in December of 2003 and uses a range of expertise including electrical tomography and microbiological characterisation. The latter is being provided through collaboration with microbiologists at CEH Lancaster. In a broader environmental context we have developed jointly with English Nature a version of our successful CONCEPT GIS site prioritisation software to identify risks to humans, ecosystems, controlled waters and property from sites of special scientific interest associated with hazardous minerals.



**Nuclear waste disposal:** large scale gas injection test (Lasgit) 420 metres below ground at the Äspö Hard Rock Laboratory in Sweden. A BGS scientist stands next to a gantry crane positioned over the large diameter test borehole.



## Electrical Tomography Service

The Electrical Tomography Service (ETS) continues to develop innovative electrical techniques for mapping and monitoring the shallow subsurface. New long-term research commissions have been secured from the Onyx Environmental Trust, English Partnerships, the Coal Authority, and the European Commission. ETS leads a consortium of 11 international partners under the EU Sixth Framework Global Change and Ecosystems programme. These technologies are also attracting significant interest from industry, particularly for pollution, geohazard, soil and water quality surveys. A spin-out opportunity has been identified and investment secured to assist commercial exploitation. Two new techniques have been developed: Cross-hole Electrical Resistivity Tomography (ERT) and Self Potential Tomography (SPT).

### Cross-hole Electrical Resistivity Tomography

There is growing interest in the use of ERT for the non-invasive characterisation of so-called 'brownfield' sites in the urban environment. However, the practicality of this method is constrained by the need to use electrodes in the ground surface. This invariably precludes surveys in the built environment where engineered surfaces or infrastructure (e.g. roads, factories, houses) prevent electrode emplacement.

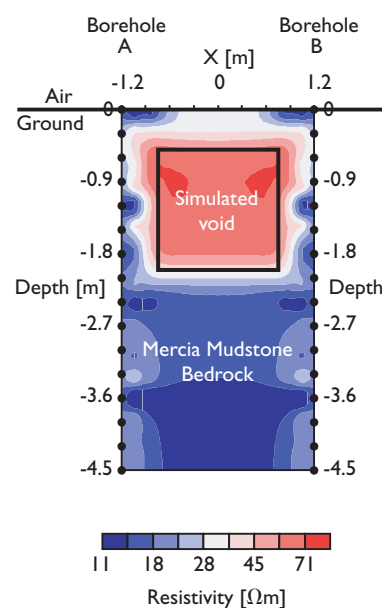
Research is in progress to adapt the surface ERT survey technique for use in boreholes. By using down-hole electrode arrays large volumes of ground can be scanned between two or more holes to detect pollution or geohazards that may occur beneath buildings or underground storage tanks. A test site has been established to help develop new survey concepts and tomographic measurement schemes, including cross-hole, single in-hole and surface-to-hole electrode configurations. This research is supported by a Ph.D. studentship at the University of Lancaster. Related research is being undertaken to develop new ERT technology (hardware and software) for the time-lapse monitoring of landfills using permanent *in situ* instrumentation.

### Self Potential Tomography

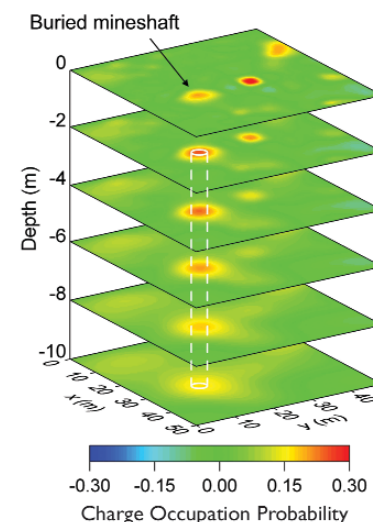
Self Potential (SP) is a fast and inexpensive geophysical survey technique that has been used in mineral exploration for many decades. SP is also one of the few geophysical techniques that will respond directly to fluid flow. However, the potential use of SP for environmental and engineering site investigations has, to date, been severely inhibited by the lack of interpretational tools available for quantitative analysis. Accordingly, a new tomographic image reconstruction scheme has been implemented based on published theory. The algorithm is fast, robust, and makes no a priori assumptions about the subsurface charge distribution. The algorithm calculates the probability that charge is accumulating at a given point in the subsurface from the observed surface potential.

Unlike a simple contour plot, Self Potential Tomography (SPT) gives spatial information about the subsurface charge distribution and hence the geometry of the causative source as a function of depth. The new SPT technique has been successfully used to detect a concealed mineshaft. Other potential applications include the detection and monitoring of leaks from landfills, migrating solution cavities, or incipient landslides. Research is ongoing to adapt the SPT method for the remote *in situ* monitoring of waste and hazardous sites. This research involves collaboration with the University of Nottingham (Physics and Astronomy), Federico II University, and CNR, Italy.

**Electrical Resistivity Tomography:** simulated void detection using cross-hole ERT at a test site. The advanced 2D inversion algorithm clearly recovers the spatial geometry of the buried target.



**Self Potential Tomography:** horizontal depth slices showing the tomographic imaging of self potential charge distribution in the shallow subsurface. This new imaging algorithm was successfully used to detect a buried mineshaft for the Coal Authority.



# Coastal Geoscience & Global Change

## Programme overview

**T**he Coastal Geoscience and Global Change programme aims to predict and better manage future environmental change on the basis of an understanding of past and present patterns of erosion, transport, transformation and storage of sediments and associated materials. The programme addresses issues ranging from the geological controls on drivers of climate change to the impacts of sea-level rise or increased storminess on coasts.

## Endocrine disruption in the marine environment

Endocrine disrupting compounds (EDCs) are a diverse group of substances that have an ability to mimic or antagonise the effects of endogenous hormones or disrupt synthesis and metabolism of endogenous hormones and hormone receptors in humans as well as animals. Together with the Marine Biological Association, we are examining how the biological effects of EDCs in estuaries are modified by natural environmental conditions, particularly sediments. A critical first step in understanding and predicting the fate of these compounds in estuaries is to characterise their partitioning of potent EDCs such as 17-alpha ethinyl oestradiol (the main component of the oral contraceptive pill) in sediment and water. Experiments are currently under way to determine the role of salinity, pH, and sediment characteristics on the partition coefficient of four selected EDCs. Additional experimental studies to determine the kinetics of bioaccumulation and loss in EDCs in the mollusc *Scrobicularia plana* will be used to determine the relative importance of sediments and water as assimilation pathways for oestrogens and xenoestrogens as well as reproductive impairment.

## Estuarine contamination: Clyde Estuary

The first stage of a study of contamination in the Clyde Estuary, supported by Glasgow City Council, the Scottish Environmental Protection Agency and the Glasgow Humane Society, has been completed. It forms part of a broader investigation under our Estuarine Contamination project. This first phase of the work focused on the inner part of the estuary from the extreme tidal limit near Carmyle to Milton. Surface sediment samples, sediment cores and water samples were collected in this part of the estuary. The sites covered a range of possible contaminant sources and pathways reflecting the long history of urban and industrial development in Glasgow. Sub-bottom profiling was undertaken along the main channel from Greenock to the tidal weir in Glasgow to investigate structure within the sediments. The sediment samples were subjected to a wide range of testing and analysis, including: classification and engineering tests and geochemical analysis. The ultimate aim is to link the estuarine studies to a sister project, which is investigating the geochemistry of the Clyde tributaries.

## Cohesive foreshores

Some of the most rapidly eroding shorelines in the UK are characterised by cliffs of cohesive sediments such as clays and clay-rich glacial tills. Shoreline retreat on these coasts occurs through a combination of cliff erosion together with erosion of a shore platform which extends seawards from the toe of the cliff. This platform may be concealed beneath beach sediments or, in areas where shoreline retreat is rapid, it may be intermittently exposed, especially below the level of mean tides. During storms the beach may be partially or completely removed allowing erosion of the platform right up to the toe of the cliff. Where the eroding formations include coarser sediment grains the platform may be a more significant source of beach sediments than the cliff. In other cases the platform erosion provides no beach grade sediment and beaches are typically thin and provide little protection for the cliffs. Cohesive platform erosion may thus play a critical role in the rate of shoreline recession on these coastlines. The rate of platform erosion is affected by a wide variety of physical and, in some cases, biological processes. We have been examining the processes which control cohesive platform erosion in order to understand the sensitivity of these dynamic coastlines to the impacts of future



**Estuarine contamination:** Mackereth Corer used to collect sediment cores during the Clyde Estuary survey.





environmental changes such as sea-level rise and increased storminess. Increased understanding will also assist in the assessment of the impacts of a variety of management interventions.

### Geological controls on climate: the carbon cycle

We have carried out a comprehensive review of geological aspects of carbon cycling. The carbon cycle operates over many timescales; over the short term only a small fraction of carbon resides in mobile superficial reservoirs, such as the atmosphere, oceans, soil and biota, whereas over the longer term, carbon is stored mainly in rock and sediment. The recognition of rapid and abrupt climate change demonstrates the importance of the geological record in providing longer-term background climate data critical to understanding climate change. The long-term data provide a control on the predictive climate models at present being formulated. Although the general features of carbon cycling are well researched there are still major unanswered questions including those over the fluxes between the land and the ocean across the continental shelf, the controls on thermohaline circulation and the major driving forces associated with methane fluxes, especially those related to methane hydrates.

### Thames Estuary flood defences beyond 2010

Driven by concerns about future climatic change and possible increased rates of sea-level rise, the Environment Agency's Thames Estuary Flood Risk Management project is currently assessing the stability of the existing flood defence structures bounding the Thames Estuary. The design life of these ends in 2010; the longer-term objective is to upgrade and extend their design life until the year 2100. As part of a baseline study, we were commissioned to undertake a geological and geotechnical appraisal. The output was configured for a geographical information system application and included: a review of the geological and geotechnical data held in our archives; a geological and geotechnical appraisal of the ground beneath the flood defence structures; and recommendations about possible further geotechnical investigation work needed. Based on an interpretation of mainly archival borehole data, plan views of the surface geology falling within a 500-metre corridor and linear geological cross-sections were produced along the centreline of the flood defence structures supported by a geotechnical appraisal.

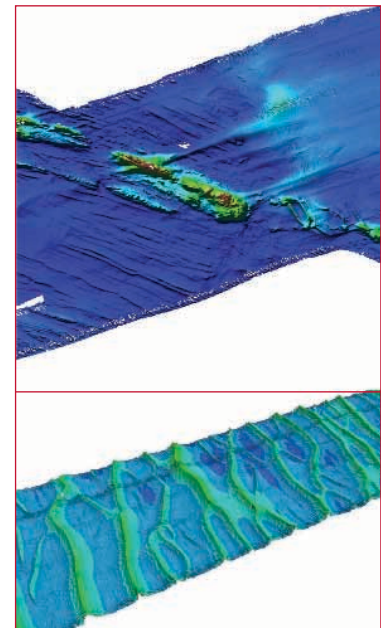
### The Outer Bristol Channel marine habitat study

The Outer Bristol Channel is an area that may have marine aggregate resource potential in the future. With the National Museums and Galleries of Wales, we are leading a study of the marine habitats of the area, which covers about 2400 square kilometres of the sea bed between Carmarthen Bay and Lundy Island. This is a collaborative venture involving marine geologists and biologists. The aim of the study is to address the lack of broad-scale biological and geological data in the area, and produce an integrated approach to providing baseline data and an understanding of marine habitats for the sustainable development of seabed resources, including fisheries, aggregates and wind farms. It also aims to inform the planning and regulatory process with regard to marine conservation, and national and EU legislation. A marine geophysics survey with multibeam, sidescan and a sub-bottom seismic reflection system was completed during the year in addition to a sediment and benthic fauna survey.

**Cohesive foreshores:** cliff erosion of clay-rich sediments.



**Outer Bristol Channel:** sand streaks extending away from a rocky outcrop (below), and a sand wave field (bottom) imaged during a marine geophysics survey of the seabed.





Geological  
Water Sites  
Geological Field  
Geological Field  
Geological Field

# Information Services and Management



The Information Directorate had a very positive year in 2003/04. A major external review of the BGS (the Science and Management Audit) concluded that, in the field of geoscience information delivery, we are a world-leading organisation. It is on this sound base that we began to develop our information strategy and programme for the next five years.

There were a number of highlights in the year. We were able to obtain significant amounts of funding from the NERC and the Coal Authority to make a large number of digital scans of unique paper maps and borehole records. Although the scanning contract has not been without its problems, completion of this work early in 2004/05 will ensure the security of the documents and allow their wider and easier dissemination in the future. We have also successfully negotiated the establishment of the National Hydrocarbons Data Archive with the DTI and representatives of the oil and gas industry. This agreement, announced by the Energy Minister, Steven Timms MP in September 2003, will ensure that invaluable hydrocarbons exploration data have a long-term secure repository. On a related topic, we were inspected by the National Archive (previously the Public Records Office) and were pleased to receive confirmation that we meet the required standard and can continue as an official 'Place of Deposit' for public records.

In the field of information generation and delivery — an essential component of the transfer of our knowledge — the second version of DiGMapGB-50 was released, providing near seamless digital geological map cover of Great Britain. In this digital era the dataset is proving to be the fundamental foundation for much of our science. In particular, it provided the base on which we were able to design and build national geological hazard datasets. Following the completion of the three-year GeoHazarD project, these datasets were launched under the GeoSure brand name at the Globe Theatre in March 2004. The market for our data continued to expand, and demand for data, products and services rose again for the fourth year in succession. The Enquiry Service is a critical part of our delivery strategy — an important interface with our users; while we continue to take advantage of information technology to improve the efficiency and effectiveness of this part of our organisation, it is, as elsewhere in the BGS, the commitment and skills of our staff that are making the difference.

Finally, late in the year a new atlas of digital information was published. *Britain beneath our feet* describes in plain language, complemented by rich illustrations, the digital data we hold and how it may be used. The atlas was widely distributed to existing and potential users of our knowledge base and we were delighted by the positive response it received.

**Britain beneath our feet:** a new atlas of digital information published during the year.



Executive Director	
Marketing, International & Corporate Development	
Environment & Hazards	Geoscience Resources & Facilities
Lands & Resources	
Information Services & Management	
Administration & Finance	

Information Services & Management <b>Mr I Jackson</b> 0115 936 3214 <a href="mailto:ij@bgs.ac.uk">ij@bgs.ac.uk</a>		
Information Management <b>Mr J R A Giles</b> 0115 936 3220 <a href="mailto:jrag@bgs.ac.uk">jrag@bgs.ac.uk</a>	National Geoscience Information Service <b>Dr C A Green</b> 0115 936 3587 <a href="mailto:cagr@bgs.ac.uk">cagr@bgs.ac.uk</a>	Publications Production <b>Mr K Becken</b> 0115 936 3554 <a href="mailto:kb@bgs.ac.uk">kb@bgs.ac.uk</a>
GeoHazarD <b>Ms J C Walsby</b> 0115 936 3271 <a href="mailto:jcw@bgs.ac.uk">jcw@bgs.ac.uk</a>	Digital Geoscience Spatial Model <b>Mr I F Smith</b> 0115 936 3391 <a href="mailto:ifs@bgs.ac.uk">ifs@bgs.ac.uk</a>	

(Opposite) The BGS Enquiry Service team at Keyworth.

# Information Management

## Programme overview

This programme is responsible for the management of all data and information within the Survey. This includes databases, paper records and archives, and material collections, including rocks, minerals, fossils and core. Access to the information is provided in a coherent and integrated manner for the benefit of the citizen, government, commerce, the NERC and our own scientists. The archive comprises more than nine million items, including field slips, geological maps, borehole records, site investigation reports, offshore data and technical reports. A dedicated enquiry service and online search facilities provide fast access to this huge resource. Several new initiatives were implemented this year: the National Hydrocarbons Data Archive; the KaR Geoscience Knowledge Database; improvements to our lithostratigraphical lexicon; environmental monitoring of the collections; and a new version of the eGDI.

### National Hydrocarbons Data Archive

The National Hydrocarbons Data Archive (NHDA) is a major new initiative launched by the Minister, Stephen Timms, MP at Offshore Europe 2003. The objectives are to:

- make data more readily available, to encourage research and future exploration of the UK continental shelf;
- reduce costs to the offshore industry; and
- remove the obligation to store data in perpetuity from licensees.

The BGS operates the NHDA and will extend the National Geoscience Data Centre to accommodate the data collected by offshore operators from UK oil and gas exploration and production. Licensees will have the option to transfer the archive datasets to the NHDA at the time of licence relinquishment and at the end of production of a field. Some 650 licences are already relinquished and operators are being encouraged to archive relevant data. The ongoing archive pilot project currently involves BG, BP, Shell, ChevronTexaco, Total, ConocoPhillips and Kerr McGee.

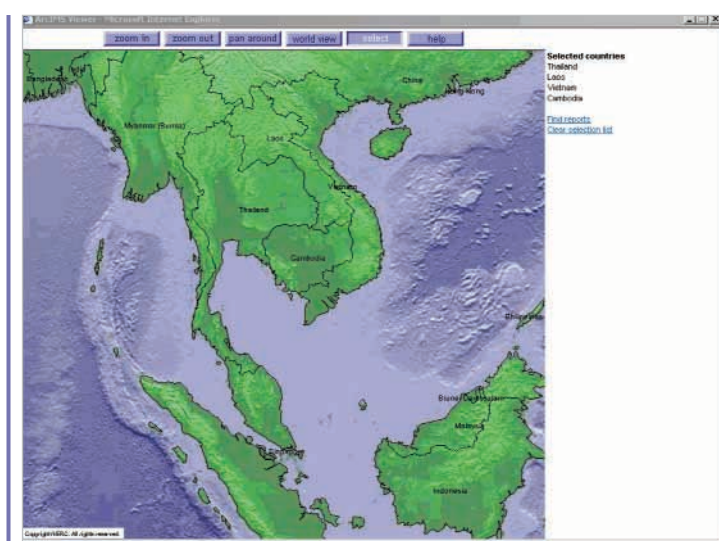
### The KaR Geoscience Knowledge Database

Since 1989, projects supported by the Knowledge and Research (KaR) Geoscience programme have produced reports covering a wide range of applied geoscience topics relevant to international development. However, this resource has been under-used because the potential user community are not always aware of it. In order to address this problem the Department for International Development (DFID) commissioned us to make the scientific and technical reports produced by this programme more readily accessible.

The project has created a database of KaR geoscience reports and a website ([www.bgs.ac.uk/dfid-kar-geoscience/database/](http://www.bgs.ac.uk/dfid-kar-geoscience/database/)) to disseminate them. The database includes all the scientific and technical reports produced by projects under the geoscience programme up to the beginning of 2004. This now comprises 169 separate reports totalling over 10 000 individual pages. The website has a graphic interface which allows spatial searching by particular countries, by the report topic, by keywords drawn from a geoscientific thesaurus, and by specific text strings.

### Improvements to the BGS lithostratigraphical lexicon

Generating digital geological models, and producing digital geological maps requires unique terms and codes to identify recognised rock units. Definitions of these rock units are stored in our lithostratigraphical lexicon, which also acts as a dictionary of unique codes. Nearly 12 000 single named rock units and groupings of named rock units that have appeared on our maps and other



**KaR Geoscience Knowledge Database:** the spatial selection screen zoomed in to south-east Asia with four countries selected for report retrieval.



publications are listed (including terms that are now considered obsolete). Full details can be viewed on our website at: [www.bgs.ac.uk/lexicon/lexicon\\_intro.html](http://www.bgs.ac.uk/lexicon/lexicon_intro.html).

This year, important gaps in the data needed by the DiGMapGB system were targeted and filled, existing rock unit definitions were revised, and many new definitions were compiled and validated. At the same time, new data entry and editing applications were designed and built, and new queries were added to lexicon pages on our Intranet. Plans have now been developed to link the lexicon more closely to the BGS rock classification scheme, and to recently revised geological age terminology.

### Environmental monitoring of the collections

The National Geoscience Materials Collection holds a wide variety of core, rocks, minerals and fossil from Great Britain and around the world, including 200 kilometres of drill core, and more than four million individual specimens. Many rocks, minerals and fossils are very sensitive to the environmental conditions in which they are stored.

Sub-fossil bone, tusks and teeth (such as those from the Pleistocene deposits) retain some collagen which is very sensitive to relative humidity (RH) changes. These must be stored in constant conditions around 50% RH. Clay and shale, whether as rock specimens (such as borehole core) or as matrix around fossils, may dry out and disintegrate at RH below 40%. On the other hand, pyrite and marcasite (and fossils containing these minerals) may oxidise (commonly known as 'pyrite decay') at a relative humidity above 55%.

We monitor our collections via a series of miniature electronic humidity and temperature sensors and the results are analysed on a weekly basis. When readings are outside acceptable tolerances, the cause is investigated and corrective action taken. Certain items in the collection are at risk from the oxidation of pyrite that can seriously damage or even destroy specimens. The details of the process are currently being investigated using a variety of analytical techniques, including scanning electron microscopy and X-ray diffraction.

### New version of the Internet Geoscience Data Index

The Internet Geoscience Data Index (eGDI) provides a map-based index to our datasets. The site received around 36 000 visitor sessions this year. The eGDI was made easier to use by incorporating the Ordnance Survey 1:10 000 scale topographical data for the whole of Britain. A new computing architecture was installed, to provide the processing power required. This brings several important benefits: the data-serving capabilities of the eGDI are enhanced; the stability of the service is greatly improved; and capacity has been created for further development and improved ease of use. In particular, the reliability issue is becoming increasingly critical as the eGDI architecture design underpins many of our e-commerce ventures, most notably providing the background processing to GeoReports.

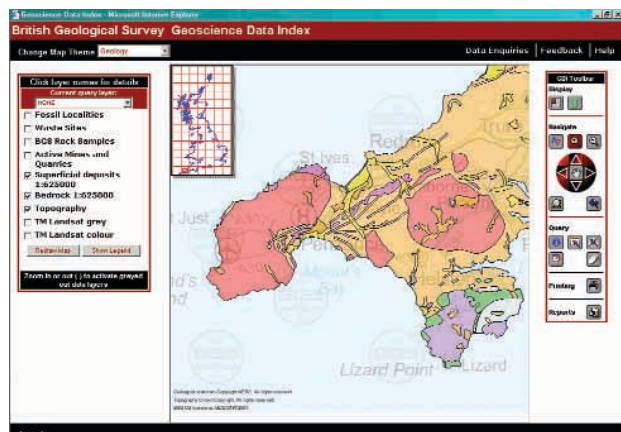
### Environmental monitoring of the collections:

image produced by the scanning electron microscope of the surface of a fossil specimen, showing various oxidation products growing on the pyrite. These oxidation products include sulphur crystals and various iron sulphate phases.



### New version of the eGDI: a geological map of south-west England displayed in the new Internet Geoscience Data Index.

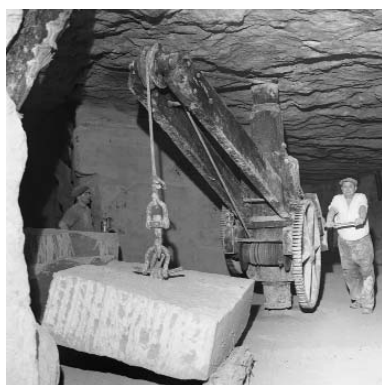
Topographical material. © Crown copyright. All rights reserved



# National Geoscience Information Service

## Programme overview

The National Geoscience Information Service (NGIS) is the programme responsible for all activities related to the delivery of BGS data and information. These comprise the Digital Geological Map of Great Britain (DiGMapGB), Electronic Dissemination of Information, Science and Society, the BGS Library, Enquiry Service, Sales, and Copyright and Data Licensing.



**Library:** an open day was held to celebrate World Book Day (top). An example image from the digital image archive: a picture from the recently donated Hugh O'Neill collection of historical earth science photographs (above).

## Electronic Dissemination of Information

The popularity of our main Internet site continues to grow. Visitor sessions per month reached over 60 000, compared with about 50 000 a year earlier. The site is the 'shop window' for our science and business, and changes as these and the needs of clients and users develop. Following a major external consultation with stakeholders, we initiated a major restructuring and redesign for the site. The new site has greater responsiveness and easier navigation, and is due for launch early in 2004/05. Interest in our e-businesses, the Online Bookshop and GeoReports, continued to rise as we made new products and services available for online purchase. The BGS Intranet, an essential element of our scientific and administrative operation, was developed further and has over 50 000 static pages and 3000 scripts. The Report Management System increased significantly the digital document resources now available to staff via the Intranet, and demand has risen substantially as a result.

## Library

Service provision to our own geoscientists and the public has been maintained through the year, in particular through significant additions to GEOLIB (the online public access catalogue) including accession of over 15 000 BGS reports, an increasing number of which are available as digital downloads. Library services were promoted at a number of events including World Book Day. The Library was successful in winning external grant-in-aid to support further digitisation of our collection of historical and educationally valuable earth science photographs. The images will be promoted within the BGS National Archive of Geological Photographs. The Library has also initiated a popular 'Friends of BGS' scheme to encourage volunteers from a range of backgrounds to assist in cataloguing and digitising the 'legacy' photograph collections.

## Sales

Sales are one of the key components in the dissemination of BGS information and play an active part in the publication process, providing a channel for information from our customers (for example, market research for our new publication *Exploring the landscape of Assynt*). A unique half-scale reproduction from our archives of William Smith's 1815 geological map of England and Wales was published in 2003 and received an enthusiastic response, especially from overseas. Our Online Bookshop has seen a growth in business of 30% over the year. Developments continued in order to increase the functionality of the online shop — expanding the content and increasing the range of products available. Despite some reduction in promotional activities because of the effort needed to implement fully the sales management system, overall Sales income held up well and was close to last year's record.

## Science and Society

We promote the earth sciences and publicise our work to as wide an audience as possible. We contribute to many national and regional popular science events. Our Edinburgh office held an Open Day and Schools Week as part of Scottish Geology Week, while in England we celebrated National Science Week with several events — the highlight being when over 700 children from 16 local schools visited Keyworth for our annual Fossil and Rock Show. The Education section of our website continues to grow in popularity, visits being



up by nearly 33% on last year. A number of our scientists registered as experts in the international web-based GLOBE initiative. The BGS also joined SETNET and we are contributing to the Science and Engineering Ambassadors scheme supported by the DTI and DFES. In our first contribution to the Engineering Education Scheme, we worked with a team from Loughborough Grammar School to design and build a prototype 'undulometer', a towed instrument for measuring irregularities in road surfaces caused by minor ground movement. We continue to provide adult education in partnership with organisations such as the Workers' Educational Association, design geological information boards and flyers for public sites, and run tours of our sites for community and academic groups.

### Enquiry Service

The Enquiry Service responded to 6500 enquiries by members of the public, representing a 30% growth from the previous year, and continued to meet its customer response targets. The commercial side of the service also continued to grow strongly, dealing with over 12 000 enquiries. The GeoReports automated report-generating service has proved highly successful, with 20% of orders now being made through the online shop, and an ever-widening customer base from the UK environmental information and site-investigation sectors. The GeoRecords service, which provides copies of the National Geoscience Records Centre collections, also grew strongly and efficiency was improved significantly by increased use of scanned documents.

### Copyright and Data Licensing

Demand for licences for BGS digital data rose for the fourth successive year and the Intellectual Property Rights (IPR) team continued to contribute to extending the market and reach new clients. Business from the value added reseller sector is strong. The IPR section continues to protect our copyright and ensures that the Survey itself complies fully with copyright regulations. Recruitment to the section allowed us to improve both our response to copyright enquiries about analogue and digital materials, and the delivery of digital data. A catalogue of digital data available under licence was released on our Internet site.

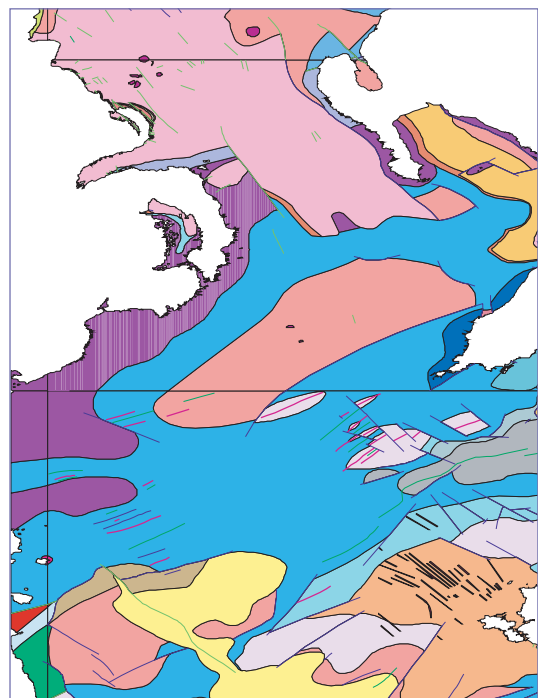
### DiGMapGB

DiGMapGB is a geographical information system containing national digital geological map data in vector format at a range of scales from 1:625 000 to 1:10 000. During the year, we continued to build and improve the essential core data. At 1:50 000 scale, we completed the major task of refitting linework and rationalising geological descriptions from Version 1, and released an interim dataset. This work will ensure that Version 2 is as near to seamless as possible. This DiGMapGB-50 dataset is the prime reference for many aspects of our work, including derived datasets such as the natural stability product, GeoSure. DiGMapGB-10, the 1:10 000 scale product, now contains 564 released 5km x 5km tiles of onshore data, and another 1000 tiles are in preparation. The first version of the 1:250 000 scale offshore Bedrock map was completed and released.

**Science and Society:** one of the ways we promote the earth science and publicise our work is through our magazine, *Earthwise*. During the year, we published editions on the themes of *Energy and mineral resources* and *Modern geological mapping*.



**DiGMapGB:** detail from the 1:250 000 scale offshore Bedrock map, completed and released during the year. This image shows the area around the Isle of Man.



# Publications Production

## Programme overview

The Publications Production programme publishes the BGS's formal output: maps, books and reports. It is a major contributor to our digital data holdings, in particular the Digital Geological Map of Great Britain (DiGMapGB) and images for the National Archive of Geological Photographs. It also designs and produces marketing and promotional materials such as web pages, posters, brochures and flyers. Publications Production played a major role in the BGS submission for ISO 9000 compliance during 2003/04.

## Cartographic production

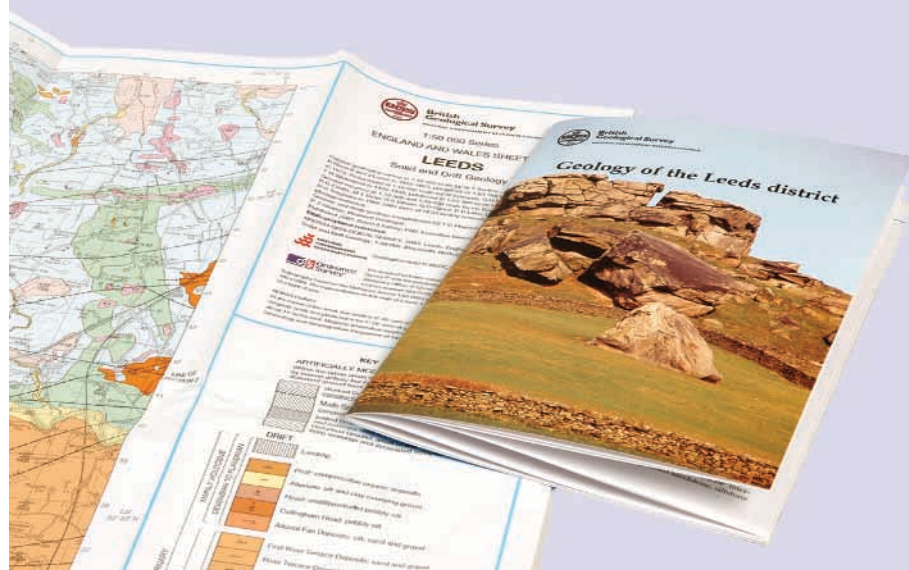
Maps are produced and published at a variety of scales and reflect output from a wide range of scientific surveys. This year saw rapid acceleration of 1:10 000 scale digital map data generation. Cartographers use geographical information systems (GIS) to capture the information, build the digital spatial databases, and input comprehensive geological attribution for the data. Customised interfaces and operating procedures increase efficiency and provide quality controls on the Digital Map Production System (DMPS). The DMPS is the route to delivering DiGMapGB (see page 39).

## Graphic design and publishing

A range of high quality books and print-on-demand reports have been published, from Sheet Explanations and Sheet Descriptions complementing the 1:50 000 scale map, to special publications such as memoirs, *Britain beneath our feet*, *A geological survey in transition*, Minerals Yearbooks, *Earthwise* magazines, and Holiday Geology Guides. Many reports are converted to digital documents in portable document format (PDF) and made available as free Internet downloads. Demand for the internal graphic design service increased dramatically, notably for many promotional and advertising events, such as National Science Week. The group took the lead in refreshing and strengthening the corporate brand.

## Reprographic and Photographic Services

Significant advances were made in moving from traditional film and chemical processes to a fully digital environment. Large format reprographic and photographic cameras and a film plotter, together with an accompanying chemical processor, were decommissioned and replaced with professional digital cameras and publication quality scanner. A digital imaging laboratory was designed and installed.







## Output in 2003/04

Digital map and book data and printed copies include:

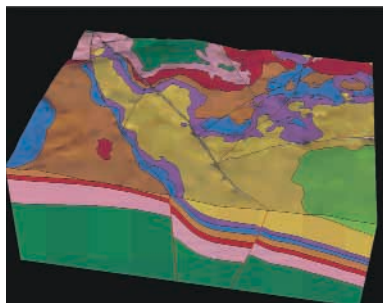
- Additions to the 1:50 000, 1:25 000 and 1:10 000 scale map databases, including 564 map tiles at 1:10 000 scale, representing approximately 5% coverage of Great Britain at this scale.
- Additions to the horizontal sections database for the Digital Geological Spatial Model project.
- Twenty-seven maps published or in press at 1:50 000 or 1:25 000 scale.
- Two memoirs.
- Two regional geology guides.
- Three sheet descriptions.
- Fifteen sheet explanations.
- Seven annuals.
- Three 'special' publications.
- Three titles in the popular publications series.
- Twenty-four multimedia CD-ROM and website original designs.
- In excess of 200 posters and brochures.



Examples of output from the Publications Production programme during 2003/04.

Publications include technical reports, brochures, BGS maps and sheet explanations, websites, and multimedia presentations for internal and external customers: (above) selection of print and digital output, (opposite, from left to right): 'Mineral Matters' factsheet on construction materials; 'River Mining' commissioned report on behalf of DFID; 1:50 000 scale Solid and Drift map and accompanying Sheet Explanation on the geology of the Leeds District; multimedia presentation on the history and capabilities of the BGS; and 'Foundations of the Peak' a virtual tour of the Peak District produced in partnership with Derbyshire County Council, the Derbyshire Wildlife Trust, the Mineral Industry Research Organisation and the National Stone Centre.

# Digital Geoscience Spatial Model



**DGSM:** a 10 x 10 x 2 kilometre block model of the Ayrshire Coalfield in the Midland Valley of Scotland, constructed in EarthVision™ using outcrop, borehole and mine-plan data. Seven Permian and Carboniferous horizons have been modelled, showing syn- and post-depositional faults. The superficial deposits have been removed to show the bedrock 'geological map'.



**DGSM:** a regional model of subsurface Britain, constructed from information from the 1:625 000 scale geological map, drilling and deep geophysical investigations. It represents ten layers, from the Moho (at a depth of around 30km) up to the base of the superficial Quaternary deposits (at a depth of a few hundred metres). Despite its regional coverage, the model is consistent with the most detailed interpretations of the shallow geology.

## Digital Geoscience Spatial Model

Our understanding of the Earth and its processes is enhanced by visualising earth models in three-dimensions on the computer screen. In order to build such models a wide range of data is scrutinised, validated and evaluated. These data might include geological maps, borehole logs, rock descriptions, geotechnical, geophysical and hydrogeological properties; when they are made accessible together with the model, a powerful geoscience information system is created.

These concepts are crucial to all the Survey's future activities and are being developed in the Digital Geoscience Spatial Model (DGSM) project. This has been the fourth of five years funding by the NERC Science and Innovation Strategy Board, which is matched by BGS funding for modelling projects that benefit from the methods developed.

The DGSM Framework is building the technical infrastructure for modelling, developing standards and methodologies. Key elements are:

- Geoscience Spatial Framework (GSF) — holds spatial data in a shareable form. Users can access the database to view and download the surfaces over the Internet.
- Geoscience Large Object Store (GLOS) — holds a wide range of proprietary model files with key information on the modelling application, so that models can be reused.
- TextBase — stores and searches digital text using XML, the standard 'mark-up' language. The database contains reports for the models in the GLOS and GSF.
- Metadata — every model stored has discovery and inference metadata that conforms to international and BGS corporate standards.
- Best Practice — a formalised system to establish and record the procedures and standards used in modelling.
- The Data Portal — allows rapid access to a range of 3D data for modelling purposes. It includes boreholes, digital terrain models, cross-sections and geological lines.
- Collaborative development of GSI-3D software — allows an intuitive working environment for building models in complex near-surface stratigraphy.

The DGSM-UK tests the data structures and procedures that are appropriate for a range of geological environments. The following topics were studied during the year:

- Methods for describing the uncertainty of a model have been tested on three areas.
- A majority of geological cross-sections on 1:50 000 scale maps have been digitised ready for inclusion into models.
- Midland Valley of Scotland — detailed models have been merged into systematic seamless coverage of part of the area and a low resolution model created.
- Atlantic Margin — best practice methods have been extended and, using them, new models have been built for the West of Shetland region.
- UK regional model — a low resolution model showing the major discontinuities has been improved and extended.
- Nottingham–Melton area — following an initial outline model, detailed borehole interpretations have been made prior to making a detailed model for a restricted area.

# and GeoHazarD projects



## GeoHazarD

Geological processes affect not only our health and safety but also the value of assets such as property. Public and commercial awareness of this is growing. Changes in our climate, which are now regarded as inevitable, will exacerbate changes in ground conditions and underline the need to take geological information into account in planning and development.

In response to the increasing need for detailed ground stability and other hazard information, we initiated the GeoHazarD project in 2000. The objective was to produce high-resolution datasets with national coverage that identified and assessed potential geological hazards. We have now completed the project and released digital ground stability datasets for soluble rocks, shrink-swell clays, landslides, compressible ground, running sand, and collapsible deposits.

These new products, collectively branded as GeoSure, were launched in March 2004. At the same time, the BGS Enquiry Service released a new Natural Ground Stability GeoReport, which incorporates the GeoSure datasets.

In addition the following underpinning digital datasets were developed:

*Superficial deposit thickness model.* Superficial deposits (sometimes referred to as Drift or Quaternary deposits), and specifically their thickness, are key factors in assessing ground stability and also in site investigation, foundation design and mineral exploration. Digital superficial thickness data is available as modelled grid or contour polygons for all of Great Britain at a resolution of 50 metres.

*Rockhead elevation.* The elevation of the bedrock surface above mean sea level (frequently referred to as rockhead) is a complementary dataset to superficial deposit thickness. It is also available as modelled grid or contour polygons at a resolution of 50 metres.

*Scanned onshore borehole logs for Great Britain.* The BGS holds a national archive of over 1 million records from the drilling of boreholes dating back to 1740. These represent the results of site investigations for construction work, drilling for minerals or water and deep wells for oil exploration and extraction. They have all been scanned for security and ease of access. The data are held in tagged image file or portable document formats (TIFF or PDF) and an index to the information is available via our Geoscience Data Index.

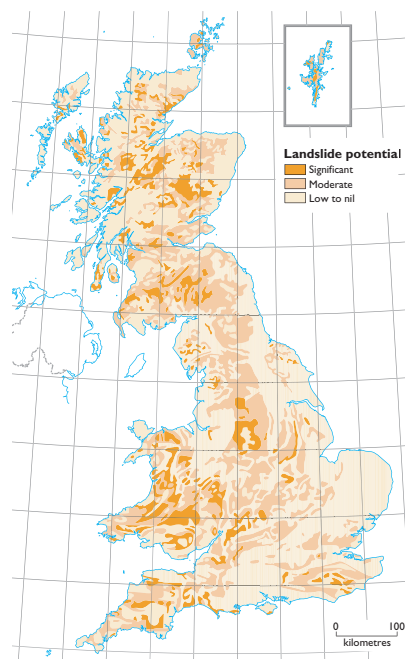
*Permeability datasets.* Permeability values are an essential indicator of the vulnerability of the rock to groundwater pollution from the surface. They are a measure of the speed by which a pollutant could travel through rocks and enter an underground water body. Permeability data are available as a geographical information system (GIS) polygon dataset.

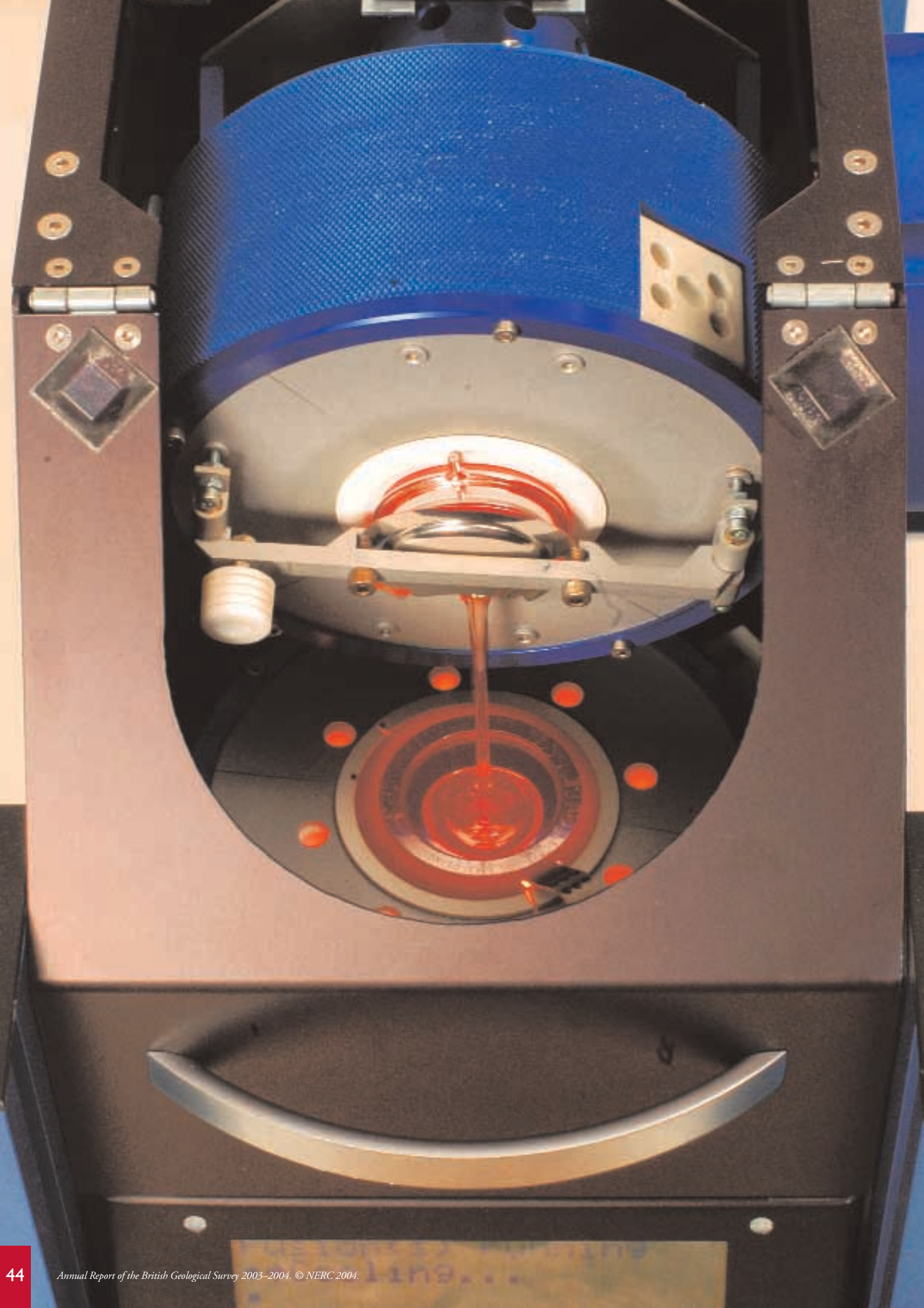
The work of the GeoHazarD project will be continued under a new programme known as GENI (Geoscientific National Information). In 2004/05 it will include the following deliverables: a radon hazard GIS dataset for England and Wales using combined BGS and National Radiological Protection Board data; investigation of the inclusion of climatic data in ground stability products; a database of non-coal mine plans; and methodologies for creating new nationwide applied geoscience datasets.

**GeoHazarD:** a large slump in glacial till led to the destruction of the Holbeck Hall Hotel, Scarborough, in June 1993.

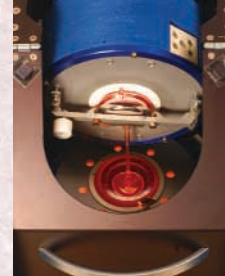


**GeoHazarD:** this map indicates the potential for landslides to be a hazard. The detailed dataset that underlies this map is based on the most important factors that cause landslides. These include the type of geological material and its geotechnical properties, discontinuities, slope angle, and the position of the water table.





# Geoscience Resources and Facilities



The role of the Geoscience Resources and Facilities Directorate (GRFD) is to ensure that adequate human and physical resources are available for us to deliver our scientific programmes, and to develop our scientific capability so that we are ready to meet expected future needs. Scientific staff are managed and deployed by four Heads of Discipline covering the areas of **Geology, Geotechnics and Palaeontology; Geophysics and Marine Geoscience; Geochemistry, Mineralogy and Hydrogeology;** and **Information Systems**. A separate Head of Discipline is responsible for Administration and Finance staff.

Pre-planned staff deployment during 2003/04 exceeded 99%; the modest amount of unallocated staff resource was responsively deployed to activities including production of *Britain beneath our feet*, data management tasks, fast-track development of information products and services, preparation of papers for publication, and strengthening capability. The software system that supports staff deployment has now been linked to our project management system, providing advance warning of likely requirements for staff and their skills. Pending the development of our five-year programme beginning in 2005, we continued to focus recruitment on meeting specific, previously identified, skills.

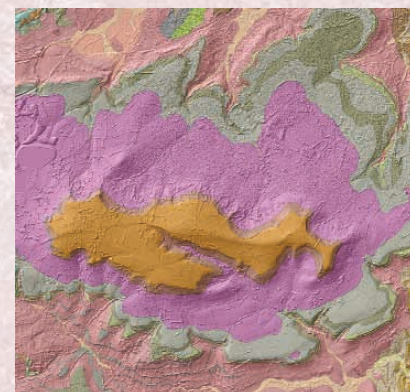
During 2003/04, a budget was established to support the preparation for publication of results from within our Commissioned Research Programme, and this has already led to the submission of more than 20 manuscripts. A proposal has been presented to the NERC for the establishment of a School of Field Geology, through which, in partnership with leading universities, we will provide field-based postgraduate training. The GRFD funded attendance at more than 50 conferences and meetings, and supported over 50 staff serving as members of external scientific committees and learned societies. Our staff continue to hold high-profile appointments and leadership positions within various scientific and professional bodies, and as editors of both peer-reviewed and popular journals.

Work continued on a number of substantial projects to develop our scientific infrastructure; the GUIDE project successfully procured and installed a gigabit LAN upgrade and Storage Area Network facilities for 15 terabytes of data. Agreement was reached with GTK (Finland) regarding the establishment of a Joint Airborne Geoscience Centre.

During the year we continued to provide staff training and development opportunities. There were major initiatives in the areas of Quaternary mapping, as part of the Quaternary Methodology and Training project; project management, to coincide with the introduction of our new Project Management System; and ArcGIS8™ and 3D visualisation software, in support of the interpretation of large spatial datasets. We also maintained a wide-ranging portfolio of in-house and externally sourced, scientific, IT, personal development and health and safety training courses. New recruits and those undertaking major job changes received workplace coaching and there was support for a number of staff working towards further education qualifications (eight postgraduate degrees, twelve undergraduate degrees, four NVQs and eleven other qualifications).

(Opposite) Casting a fused glass bead of molten rock for analysis by X-ray fluorescence spectrometry.

## NEXTMap Britain



We have recently acquired, on behalf of the NERC, a new national high resolution digital elevation model (DEM) dataset for England and Wales, known as NEXTMap Britain. Some projects are now beginning to use it at all stages of the geological mapping process. Existing 2D maps can be draped over the model (above) and rapidly checked for 3D consistency. Orthophoto field-slips are more rapidly produced and combined with Ordnance Survey base maps, and printed on waterproof paper. Synthetic stereopairs using orthophoto mosaics and the NEXTMap DEM can now be routinely produced for whole 1:10 000 map sheets. Previously, one was confined to just the area of overlap of a pair of aerial photos. These products are then visualised in 3D either by using anaglyphs in the field or on ImageStation™ in the office, and the geomorphology and geology interpreted and checked during fieldwork. Finally, the NEXTMap DEMs and revised geological maps are being combined into a new series of printed 1:50 000 products called 'Geology and Landscape'.

Executive Director	
Marketing, International & Corporate Development	
Environment & Hazards	Geoscience Resources & Facilities
Lands & Resources	
Information Services & Management	
Administration & Finance	

Chief Scientist <b>Prof J A Plant</b> 0115 936 3521 <a href="mailto:japl@bgs.ac.uk">japl@bgs.ac.uk</a> Geoscience Resources & Facilities <b>Dr D J Morgan</b> 0115 936 3138 <a href="mailto:djmo@bgs.ac.uk">djmo@bgs.ac.uk</a>		
Geochemistry, Mineralogy & Hydrogeology <b>Dr J M West</b> 0115 936 3530 <a href="mailto:jmwest@bgs.ac.uk">jmwest@bgs.ac.uk</a>	NERC Isotope Geosciences Laboratory <b>Prof R R Parrish</b> 0115 936 3427 <a href="mailto:rrp@nigl.nerc.ac.uk">rrp@nigl.nerc.ac.uk</a>	Geophysics & Marine Geoscience <b>Dr J R Evans</b> 0131 650 0213 <a href="mailto:jre@bgs.ac.uk">jre@bgs.ac.uk</a>
Geology, Geotechnics & Palaeontology <b>Dr J H Powell</b> 0115 936 3123 <a href="mailto:jhp@bgs.ac.uk">jhp@bgs.ac.uk</a>	Information Systems <b>Dr W Hatton</b> 0115 936 3217 <a href="mailto:wha@bgs.ac.uk">wha@bgs.ac.uk</a>	Training & Career Management <b>Mr M P Hawkins</b> 0115 936 3187 <a href="mailto:mpha@bgs.ac.uk">mpha@bgs.ac.uk</a>

# Development of Capability

## Programme overview

The Geoscience Resources and Facilities Directorate (GRFD) carries out strategic scientific research that is designed to underpin our Core Strategic and Commissioned Programmes. The Development of Capability programme is managed as a single entity, emphasising the initiation and assimilation of new scientific and technological developments that will be applicable across a range of our activities in the future. Each scientific Head of Discipline takes responsibility for a group of projects within the overall programme. In addition to the projects highlighted here, the topics covered within the ongoing Development of Capability programme range from the introduction of new equipment and methods to leading-edge research.



**Development of capability:** loading soil samples for trace element analysis by automated energy-dispersive X-ray fluorescence spectrometry.

## Early Permian climate change

A new technique using combined palynological (pollen) and carbon isotope data has been developed for the study of past climate change. The research, carried out jointly with NIGL staff, and based on borehole samples from Oman, highlights changes in the atmosphere and plant ecosystems during a shift from cold glacial to hot desert conditions in the Early Permian. A major revision of the lithostratigraphy of the Quaternary deposits of Great Britain was carried out, which will be published online in conjunction with the Geological Society Stratigraphy Commission. Stratigraphical research on the UK bedrock was underpinned through an upgrade of the Stratigraphical Lexicon and publication of lithostratigraphical framework reports (such as the Carboniferous of the UK and Chalk Group) via our website. New developments include a revision of the Lower Cretaceous rocks and a new (lithodemic) classification of intrusive rocks. Biostratigraphical research included a revision of the important Wenlock graptolite genus *Cyrtograptus*.

## Forensic geoscience

When mud, soil or other earth-derived materials are found on items such as clothing or vehicles in a forensic investigation, it is often crucial to establish where this material may have come from. Fortunately, soil across the UK landscape varies greatly in terms of the properties of its mineral and organic components and the chemical, microscopic and physical analysis of forensic samples can yield vital clues concerning their source. In addition to contributing to forensic analysis on high-profile criminal cases, we have been investigating the potential synergy of a range of analytical techniques. In a test case analysis using three different methods proved to be extremely effective in identifying the characteristics of the original sample locations.

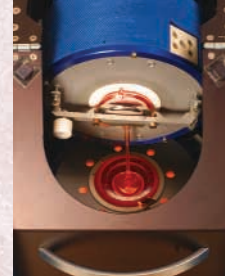
## Information systems development

We continued to develop the underlying attribute data model for System for Integrated Geoscience Mapping (SIGMA) project, following extensive consultation on the structural geological data component. An ArcGIS interface (the GSD2) was developed to populate and interrogate this database and is being rolled out for use by our geologists and cartographers in 2004/05. The Remote Sensing team developed several outputs based upon the NEXTMap Britain elevation dataset to support geological mapping activities. Anaglyph images enable easy stereo viewing in the field and 'false stereo' allows ortho-rectified datasets to be viewed in stereo. Work has continued on the development of the Geoscience Markup Language (GeoSciML) using XML technologies and the work was presented at the 2003 Annual Meeting of the Geological Society of America.

## Coastal sediment transport

We are developing methods to measure and understand coastal sediment transport through three approaches: determining the *in situ* electrical resistivity of sea-floor sediments, quantifying volumes of unconsolidated beach sediment, and integrating land and marine geochemistry databases. Integration of these approaches takes into account the similarities in techniques and processes, such as the strong dependence of both electrical resistivity and geochemistry on sediment grain size, which will allow both to be used as tools for coastal zone and seabed sediment characterisation. Initial investigations at an onshore sand bench have demonstrated the potential of several techniques, including ground-penetrating radar, electrical resistivity and shear-wave refraction to determine beach thicknesses.

# NERC Isotope Geosciences Laboratory



## Fingerprinting ancient mints using lead isotope signatures

Laser ablation plasma mass spectrometry (LA-PIMMS) has been used to fingerprint the lead isotope ratios of well provenanced Roman and Syrian coins. Each mint with its own particular ore supplies and 'coin recycling' policies will develop a unique lead isotope signature. Results from a joint project with the University of Nottingham demonstrate inherent heterogeneity within coins that can reflect aspects of the manufacturing process. Due to the relatively simple sample preparation, this is a fast analytical method. The first application of this technique has shown that Roman and Syrian coins from AD 192–211 can be clearly discriminated.

## High-resolution climate reconstruction using stable isotopes

A high-resolution record of lake oxygen isotopes, recording changes in summer evaporation, was obtained from Nar Gölü, a varved crater lake in central Turkey, in a joint project with the University of Plymouth. Comparisons with records of the Indian and African (Sahel) Monsoon at an annual–decadal resolution through the instrumental time period show periods of increased evaporation in Turkey, associated with periods of increased monsoon rains in India and Africa. The largest inferred shifts in the atmospheric circulation system over this time-frame occurred about AD 530 and AD 1400, and are associated with shifts between relatively warm and cold states of northern hemisphere climate. Decadal scale cycles, found in the 900-year-long annually resolved part of the lake isotope record and proxy records of the Indian monsoon suggest a solar forcing control on the Eastern Mediterranean–Indian–African summer climate system throughout the past two millennia.

## Volcanic sulphur dioxide

Volcanic emissions make a substantial contribution to the global budget of a number of atmospheric pollutants. The Masaya volcano in Nicaragua, for example, releases up to one thousand metric tonnes of sulphur dioxide per day, and constitutes a major tropospheric point source of sulphur pollution. The NIGL is working with the University of Cambridge on one of the first detailed sulphure isotope studies of the relationship between the magma sulphur and the emitted sulphur dioxide. The data are being used to assess different magma degassing models and understand more about the chemical evolution of the gas plume. The  $^{34}\text{S}/^{32}\text{S}$  ratios suggest that the Masaya magma contains a larger component of subducted marine sulphur compared to other volcanoes on the east Pacific margin. Concurrent measurements of the sulphur dioxide gas and sulphate particulates are being used to examine the processes leading to the formation of an important component of atmospheric aerosols.

## Age and underlying cause of hot-spring activity, north-east Scotland

The Lower Old Red Sandstone Rhynie Outlier, Aberdeenshire, is renowned worldwide for the fossil siliceous sinters comprising the Rhynie Chert, the oldest known example of a subaerial hot-spring system. These deposits preserve in unrivalled anatomical detail the remains of terrestrial and freshwater biotas that are amongst the earliest known. In a project with the University of Aberdeen, high-precision dating on putative volcanic rocks related to hot-spring activity of the cherts has revealed an age of  $409.6 \pm 1.1$  million years, using uranium–lead dating of titanite and zircon. Given the well-constrained palynological age of the Rhynie Chert, this new U–Pb age has important ramifications for the Early Devonian timescale.

## Programme overview

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

**Fingerprinting ancient mints:** a didrachm of Caesarea struck in the time of Nero in AD 63. Ancient coins produced by different mints may be clearly discriminated using their lead isotope signatures.

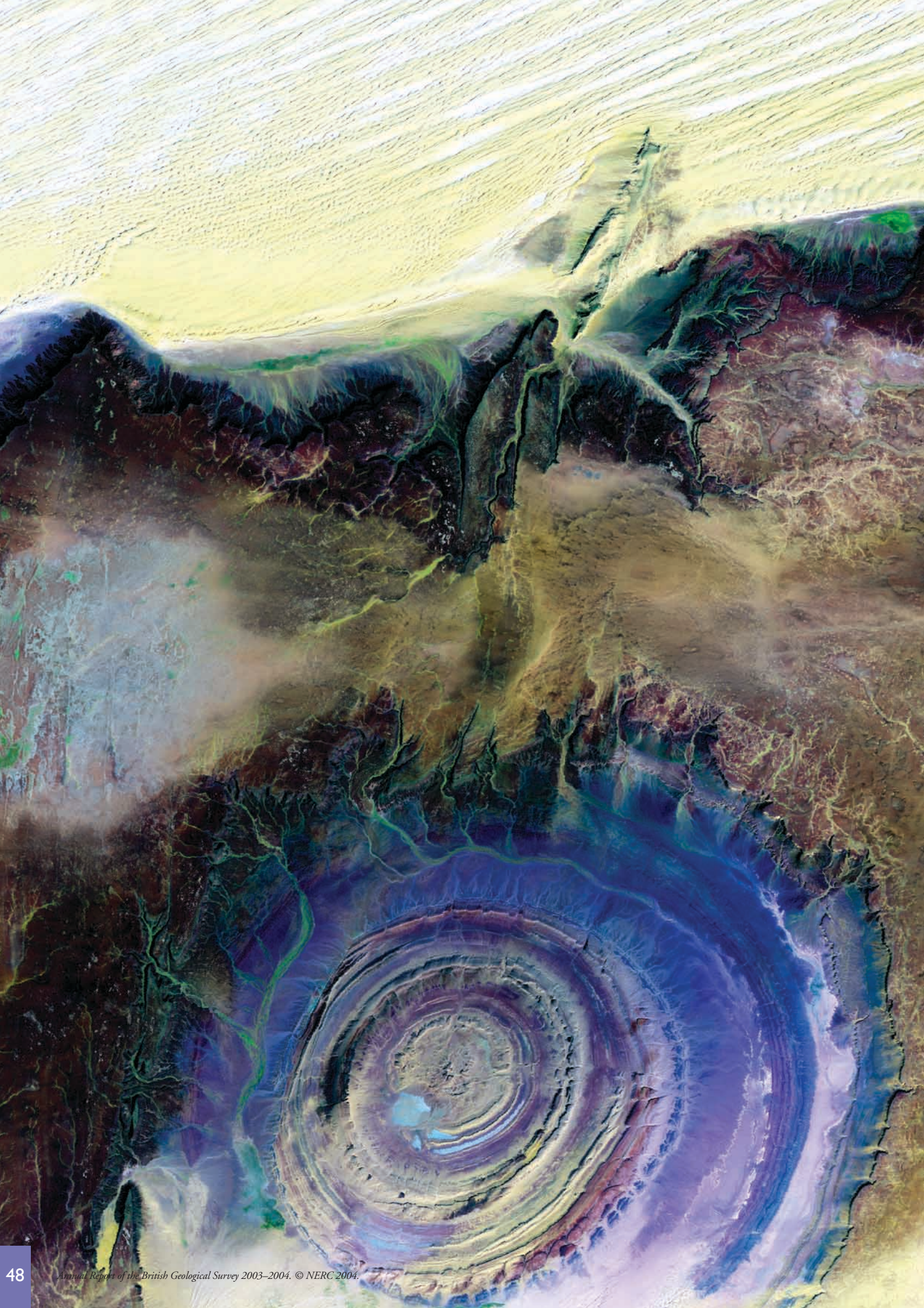


© Matthew Ponting, Department of Archaeology, Classics and Egyptology, University of Liverpool.

**Volcanic sulphur-dioxide:** the Masaya volcano in Nicaragua releases up to 1000 metric tonnes of sulphur dioxide per day and constitutes a major tropospheric point source of sulphure pollution.



© Dr. David Pyle





# Marketing, International and Corporate Development



**M**arketing, International and Corporate Development Directorate (MICD) is responsible for much of the Survey's outward facing roles, including marketing, public relations and strategic development.

MICD contains **BGS International**<sup>®</sup>, which is responsible for co-ordinating BGS activities outside the United Kingdom and the management of major projects; the **UK Business Development** team, which coordinates marketing and customer services in Britain; the **Press Office**, which communicates the activities of BGS to the media and politicians; and the **Central Directorate Support Group**, which provides Board level support and strategic research.

The overall strategy for the marketing and application of our science is to engage with a wide variety of clients and stakeholders. Activities include co-funding arrangements where these support and enhance the Core Strategic Programme, and full cost recovery commissioned research (CR) projects that are appropriate to our core science.

The work of BGS International is funded entirely by external commissions, mainly projects funded by aid agencies and development banks. Many development agencies recognise that long term and sustainable economic growth in poor countries is predicated on using their natural resources, such as minerals, hydrocarbons and water, more effectively. We are also engaged in long-term projects studying environmental impacts from resource development, geohazards and the effects of climate change.

The Press Office continues to communicate our activities and information to the printed and radio/television media, and to politicians in central, devolved, regional and local governments. It also supported the work of the All Party Parliamentary group for the Earth Sciences, at which BGS staff members gave a number of talks.

**Sustainable river mining:** in developing countries sand and gravel are often exploited directly from the active channels of river systems. This example of 'river mining' is in the Yallahs River, Jamaica (see page 50).



<b>Executive Director</b>	
<b>Marketing, International &amp; Corporate Development</b>	
<b>Environment &amp; Hazards</b>	<b>Geoscience Resources &amp; Facilities</b>
<b>Lands &amp; Resources</b>	
<b>Information Services &amp; Management</b>	
<b>Administration &amp; Finance</b>	

Marketing, International and Corporate Development <b>Mr D C Ovidia</b> 0115 936 3465 dco@bgs.ac.uk			
BGS International			
<b>Dr D Greenbaum</b> 0115 936 3224 dgree@bgs.ac.uk	<b>Dr R A Hughes</b> 0115 936 3392 rah@bgs.ac.uk	<b>Dr W McCourt</b> 0115 936 3466 wjmc@bgs.ac.uk	<b>Dr E A O'Connor</b> 0115 936 3476 eao@bgs.ac.uk
<b>UK Business Development</b> <b>Mr M J Brown</b> 0115 936 3477 mjbro@bgs.ac.uk	<b>Central Directorate Support</b> <b>Mr D K Talbot</b> 0115 936 3508 dkt@bgs.ac.uk	<b>Parliamentary and Media Liaison Office</b> <b>Mrs H J Heason</b> 0115 936 3497 hjhe@bgs.ac.uk	

*(Opposite)* Landsat 7 ETM false-colour image of the Richat structure in northern Mauritania. Once thought to be a meteorite impact structure, it is now interpreted as a periclinal dome uplifted probably by magmatic intrusion and subsequently laid bare by erosion. The ages of the rocks exposed in this concentric structure range from Precambrian to Lower Palaeozoic (see page 51). Processed imagery © NERC

# BGS International®

## Programme overview

**B**GS International co-ordinates all our 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.



**Turkmenistan:** block cutting of dolomite using a rock saw at Arkanshar, south Turkmenistan (top). The dolomite is used in glass and chemical manufacture. In the course of visiting south-east Turkmenistan, these remarkable dinosaur footprints were encountered.

## Natural gas and industrial minerals in Turkmenistan

Turkmenistan, one of the newly independent states of the former Soviet Union, has immense reserves of natural gas. Unfortunately, it has neither the geographical advantage (being landlocked) nor the infrastructure to enable it to safely and economically deliver its product to the world's markets. One way around this difficulty is to foster new uses for natural gas within Turkmenistan itself. Under a European Union Tacis programme, the BGS was subcontracted by Industrial Mining Consultants Ltd (IMC) to provide specialist geological advice on the potential for exploiting Turkmenistan's industrial minerals. The idea is that natural gas would be used as an energy source for transforming the raw materials into marketable products. A variety of industrial minerals were examined, including baryte, bentonite clay, kaolinite (china clay), common clay and shale, limestone and dolomite, phosphorite, sodium and potassium salts, sulphur, and celestite. The last-named mineral (strontium sulphate  $\text{SrSO}_4$ ) is a major source of commercial strontium carbonate, a vital component in the production of computer and television screens, as well as having many other specialist applications. The country's deposits of celestite provided the former USSR with the bulk of its requirement for strontium carbonate but have not been worked since the collapse of that regime. Turkmenistan has an impressive inventory of mineral deposits (currently being entered into a national mineral resource information system), but until local and regional markets improve it would seem that celestite, together with limestone for cement production, and bentonite for iron and steel product manufacture and drilling muds, have the best potential for further development.

## Sustainable river mining

Sand and gravel deposits are an essential source of aggregate for the construction industry. In developing countries they are often exploited directly from the active channels of river systems, where they are easily extracted and usually require almost no processing other than size selection. They are often considered a renewable resource. However, in-channel or near-channel mining of sand and gravel inevitably alters the sediment budget of a river system, and may subsequently alter channel hydraulics. The impacts of such mining on farmland, river stability, flood risk, road and bridge structures and ecology are typically severe. The BGS is leading a multidisciplinary team of researchers with specialists drawn from UK universities and the private sector in a DFID-funded Knowledge and Research project which aims to find ways of reducing the environmental degradation caused by river sand and gravel mining through more effective management of resources. Field investigations have been carried out on selected case-study river systems in Jamaica and Costa Rica. Planning guidelines and a Code of Practice are amongst the principal outputs from this project.

## The search for new copper deposits in Cyprus

Copper has been produced on the island of Cyprus since at least 1900 BC. Indeed, the word *copper* is derived from the Latin *cyprium*, which was the name given by the Romans to the 'Cyprus metal'. In Cyprus, known economic deposits of copper are confined almost entirely to submarine volcanic rocks in the Troodos ophiolite complex, an uplifted section of oceanic crust in which cupriferous sulphides occur as massive lenses, disseminations and veinlets. In the late 1970s copper mining in Cyprus declined markedly and today there remains only one operating mine. Prospecting by the Geological Survey Department of Cyprus and the private sector



has failed to discover any further significant reserves using traditional exploration methods. We have now been contracted by the Geological Survey Department to develop new exploration methodologies for the identification of new copper deposits in Cyprus. Pilot mineral potential or prospectivity mapping has been carried out using statistical modelling techniques (such as weights of evidence and fuzzy logic) applied to spatial digital data such as geology, aeromagnetic and gravity geophysics, multi-element geochemistry, mineral deposit occurrence, and satellite remote sensing. To date, the methodology has identified eight separate areas of high mineral potential. The next phase of the project will involve refining this approach by incorporating additional geoscience datasets and new scientific observations that have improved our understanding of the factors controlling the location of the deposits. In the final stage of the project, drilling will be carried out to evaluate the best targets defined by the prospectivity analysis.

### Rapid geological mapping in north-western Mauritania

In an extension to a major mapping project in southern Mauritania for the country's Ministry of Mines and Industry, we have been further contracted to undertake a rapid geological survey of six map sheets at a scale of 1:200 000 (a total area of about 58 000 square kilometres) in the north-west of the country bordering Morocco (former Western Sahara). A tight deadline, combined with the difficulties of working in this remote region of the Saharan desert, means that much reliance has been placed on using all available existing data combined with satellite remote sensing imagery and aerogeophysics to create working maps for field checking and sample collection. The mapping area includes the important Zouerate iron ore mining district in the north-west, and the remarkable structure known as Guelb er Richat in the south-east. This prominent circular feature measures some 50 kilometres across and has long attracted attention since it was first captured in the earliest pictures from space, its eye-like appearance being particularly conspicuous in an otherwise featureless expanse of desert. Initially thought to be a giant meteorite impact structure, it is now interpreted as an uplifted dome, the internal bedded structure of which has been exposed to view by erosion to give the appearance of concentric rings when viewed from space.

### Monitoring the Soufrière Hills Volcano, Montserrat

The BGS continues to be responsible for the management of the Montserrat Volcano Observatory (MVO) with funding from the Government of Montserrat. The observatory was established in July 1995 in response to eruptions of ash from Soufrière Hills Volcano in the south of the island. The function of the MVO is to monitor continuously volcanic activity and advise the Government of Montserrat and the public of any immediate hazards presented by the volcano. In July 2003 the collapse of a lava dome within the volcanic crater led to a series of large scale pyroclastic flows which swept over the north-eastern flanks of the volcano and into the Tar River Valley. This activity was accompanied by explosions in which ash and pumice were projected up to an altitude of 15 kilometres. Around 1.2 million tonnes of ash fell over the populated and cultivated areas of the island. Towards the end of July 2003 a new dome began to form in the explosion crater. A year later, the dome remains relatively small and has shown no further growth. Prior to the eruption, the MVO was able to provide warnings to the civil authorities of a possible imminent collapse of the dome based on high levels of earthquake activity. This led to an enforcement of the exclusion zone around Isles Bay and Old Towne. The latter place was subsequently covered by up to 15 centimetres of ashfall.

**New copper deposits in Cyprus:** open-pit mining at Skouriotissa, the last operating copper mine in Cyprus. The BGS is assisting the Government of Cyprus to locate new deposits.



**Volcanic monitoring, Montserrat:** the Soufrière Hills Volcano continues to pose a threat to the population of the island. This eruption of ash occurred in early March 2004.



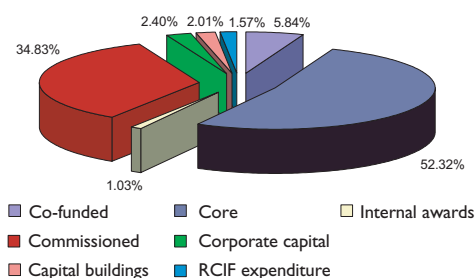
# Finance

## BGS summary of income and expenditure 2003/04

Income	£ million
Science Budget	20.931
Other income	17.732
<b>Total</b>	<b>38.663</b>
Expenditure	£ million
Salaries	24.742
Other expenditure	12.998
<b>Total</b>	<b>37.740</b>
Excess	0.923

## BGS funding

We receive funding from our parent organisation, the NERC, to carry out our Core Strategic Programme. This programme encompasses long-term surveying, monitoring, databasing, environmental research and the provision of scientific advice, as well as the public understanding of science. Funding from the NERC in financial year 2003/04 was £20.931 million, including capital and contribution to infrastructure, and comprises the Science Budget income stream indicated in the table (*top left*) and chart (*bottom left*). This funding represents a 13% increase over the previous year which can be attributed to a £1.5M infrastructure addition, the second year of Research Council Infrastructure Funding capital, special in-year funding for the purchase of NEXTMap Britain for both the BGS and CEH, further digitisation of scientific data and an injection of capital for the refurbishment of H-Block at Keyworth. A smaller amount of income is received from the NERC's internal competitive awards, which comprise thematic and non-thematic projects.



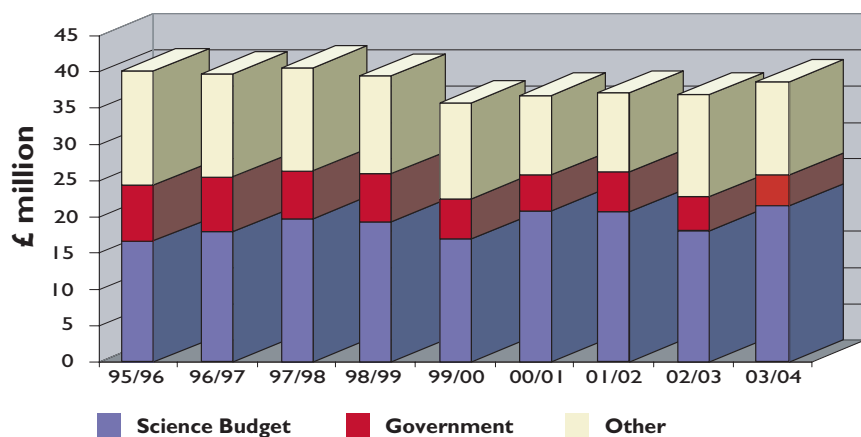
BGS expenditure during the financial year 2003/04.

We earn about 50% of our non-capital budget from research commissioned by external partners and customers, chargeable services, products and data licensing. The Commissioned Research Programme comprises strategic commissions, partnerships and contracts with a wide range of clients including government departments, public agencies, local authorities, the European Union, international aid agencies and development banks, as well as industry, commerce and the public. 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. We commissioned a study in 2003 from consultants Roger Tym and Partners to assess our contribution to the public good and wealth creation in the UK economy, primarily through the Commissioned Research Programme. The study, a summary of which is published on our website, concluded that the value we add considerably exceeds our annual turnover and makes a vital contribution to sectors of the UK economy, themselves valued at between £34 and £61 billion.

We have an obligation to the NERC to balance our income and expenditure over the Government's Spending Review period (three years). In practice, we have adopted a business development strategy to build a modest reserve to reinvest in priority

activities and to cope with inter-annual variability of income. In 2003/04, the surplus of income over expenditure in the accounts presented in the summary table opposite was £923 thousand, in addition to £550 thousand carried forward to 2004/05 earlier in the financial year, through agreement with the NERC.

Ongoing large capital schemes in year include establishing a Joint Airborne Capability project with the Finnish Geological Survey (GTK), the storage area network project (GUIDE), a new Sea Bed Corer and the purchase of a new Mass Spectrometer for the NIGL. These projects continue into 2004/05. A start was also made on the NERC Hazard Assessment and Environmental Materials Handling Facility which will be managed by the BGS and located at Keyworth.



Sources of BGS income 1995/96 to 2003/04 (at 2003/04 prices).

# Personnel



## Personnel

We resumed a full programme of graduate recruitment in 2003/04 to continue building our scientific skill base and long-term staff replacement strategy. Nine scientists at first degree and postgraduate level were recruited. Other appointments have mainly covered replacement staff attributed to resignations, retirements or specific appointments for newly won contracts. In line with NERC policy, we encourage applications from all sections of society, including minority groups and people with disabilities. An increasing number of applicants are from other countries in the European Union and further afield. This year saw a further decline in the number of staff leaving the organisation, with only 13 resignations during the period (*right*). Most new recruits are employed on an open-ended basis, though there are circumstances where a fixed term is more appropriate.

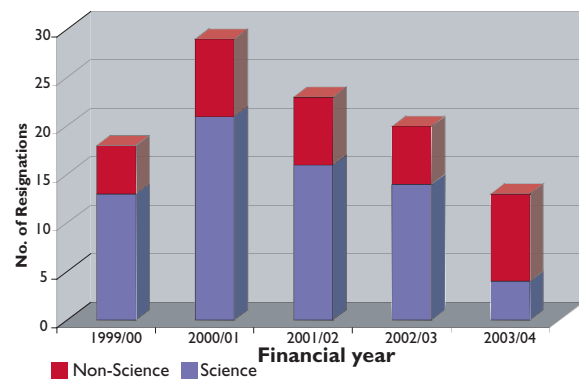
Expectations in respect of retirement are being affected both by impending changes in European directives, expected in 2006, and by demographic and economic pressures on the UK public sector. The NERC is taking a pragmatic approach and have relaxed the previously strictly observed policy of retirement at age 60. Staff reaching this age can now be retained on a voluntary basis, subject to health, efficiency and business need. Given the age profile of the Survey, with large cohorts of scientists reaching 60 from 2006 onwards, this policy has advantages in retaining scarce skills for rather longer than previously anticipated, although it will be equally important to ensure a steady stream of new recruits and remove blockages to staff development, if demographic imbalance is not to be perpetuated into the future. The Heads of Discipline are monitoring these issues carefully and also ensuring knowledge transfer takes place between staff retiring and those taking their place.

Staff have been populating their personal records on the corporate personnel database throughout the year with details of their skills and publication records. This database provides invaluable intelligence to the Heads of Discipline in allocating both staff to projects and in planning future personal development of staff. For example, curricula vitae can be prepared and tailored to customer formats. Further development of the system will continue with the planned introduction of a fully automated NERC appraisal system during the forthcoming year.

Personnel staff have continued to promote equal opportunities and diversity within the Survey and have set up open meetings to discuss these issues. The work in this area is continuing and Personnel are the main link between individual staff and management. Family friendly policies continue with part-time working, job sharing, special leave and career breaks being granted for family purposes. Support for young families, in the form of a childcare allowance, is made available to staff.

Stress levels, as evidenced by medical statistics and other indicators, are regularly monitored and, where appropriate, support is provided, recognising that not all stress on staff and families is generated by work. Proactive measures in helping staff to cope with stress include the provision of regular on-site visits from occupational health advisers.

Resignations from BGS have declined in recent years with only 13 staff resigning in 2003/04.



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<b>Lands &amp; Resources</b>	
<b>Information Services &amp; Management</b>	
<b>Administration &amp; Finance</b>	

Administration & Finance <b>Mr F G Curry</b> 0115 936 3157 fgc@bgs.ac.uk		
Personnel Administration <b>Mr J Orr</b> 0115 936 3156 jorr@bgs.ac.uk	Facilities and Infrastructure <b>Mr G S Bowick</b> 0115 936 3243gsb@bgs.ac.uk	Finance, Accounts & Contracts <b>Mrs A Clewes</b> 0115 936 3609aclewes@bgs.ac.uk

# Facilities and Infrastructure



**Environmental management:** colonies of the rare Bee Orchid have been discovered on our Keyworth site. These have probably survived since the site was built in the 1960s.

## Facilities and Infrastructure

The past year has seen a major initiative in tackling many years of under investment, especially on the Keyworth site. We prepared for the expected injection of £1.5 million additional infrastructure funding in 2003/04 by forming an estates committee and formulating a five-year maintenance plan which informed the priorities and order of work. As a consequence, we were able to demonstrate to the NERC that the funding was being used efficiently and sensibly and NERC Council has approved the integration of the additional funds into the Survey's baseline.

Funding has gone predominantly into building fabric, window replacements, toilet refurbishment, energy efficiency, services and the completion of a suite of public meeting rooms to the latest standards. This work will continue into future years.

At Edinburgh the main entrance has been extended, both to increase security and to provide a much improved, spacious reception area for visitors and showcase for our products and outputs. Development plans are being prepared for both the Keyworth and Edinburgh sites.

Two major capital schemes were started during the year. Firstly, the refurbishment of H-Block at Keyworth, to be completed in June 2004, will provide modern office accommodation for some 30 staff and open areas for scientific displays and project teams. It will set the vision and style for a future Keyworth, retaining the pleasant surroundings and open areas associated with its past as a training college but introducing the modern, contemporary office environment to which a high quality scientific workforce should aspire.

The second capital project saw the start on-site of the NERC Hazard Assessment and Environmental Materials Handling Facility (HAEMHF) at Keyworth. This compact but highly complex building will provide the UK's most advanced facility for the reception and preparation of contaminated materials and waste and, although managed by the BGS, will be available for the whole NERC community.

## Quality and environmental management

There has been considerable progress in the development of management systems throughout the Survey to the point where, at the end of the year, we were on the brink of achieving registration, through the British Standards Institute, to ISO 9001:2000 and had a little further to go to register to ISO 14001, the environmental standard.

We are working towards these standards, both to engender a common culture of continuous improvement in the organisation and to be able to demonstrate this clearly to customers.



**Facilities and Infrastructure:** the reception area at Murchison House has been extended and improved to provide a more secure entrance and to create a spacious showcase for our products and services. The shop fittings have been substantially upgraded, there is a comfortable reception area for visitors and disabled access has been enhanced.

# Health and Safety



## Health and safety procedures and guidance

Work has progressed on procedures and guidelines at the NERC and BGS levels, both to ensure best practice and to meet changing needs. For example, a handbook on a safe system of fieldwork and guidance on contaminated land have been issued during the year. Control of contractors and a revision of the transport manual have also been produced.

## Occupational health

Services provided by the Queens Medical Centre in Nottingham and the Institute of Occupational Health in Edinburgh have been extended to regular site visits, enabling staff to seek advice and assistance easily and conveniently. Screening of certain personnel whose work exposes them to particular potential hazards takes place on a regular basis and is well received by staff. Negotiations are taking place with the Queens Medical Centre to provide a more comprehensive service to staff designated to work overseas, including health checks, vaccinations and first aid training. The expansion of overseas work, particularly in remote areas, has made this initiative a pressing necessity.

## Accidents, incidents and near misses

The number of accident book entries declined significantly in 2003. Reportable accidents recorded remained at two, neither of which could be categorised as serious. The general category of accident remained at the minor level with very few requiring attention from the first aiders. Prompt attention by one first aider, however, to a stroke victim resulted in a clear cut case of life saving which was highly commendable. The BGS accident rate overall remains at the NERC average and within the education sector norm, as defined by the Health and Safety Executive.

## Office health and safety

Regular inspections of offices continue with the aim of ensuring a general level of housekeeping commensurate with low exposure to fire risk. These inspections are having a marked impact both on safety and the general appearance of offices across the sites. Heavy use of computers does continue to pose risks to individual health. We have invested heavily in appropriate office furniture and awareness of health risk to combat this problem, a policy which is resulting in considerable improvement.

## Risk assessments

The culture of risk assessments, both for generic activities and for new initiatives, is now becoming embedded in the Survey's culture. Risk assessment has been incorporated into the newly introduced Project Management System with the consequence that, without a risk assessment, a project simply cannot proceed.

## Health and safety training

New entrants are provided with a brief introduction on their first day of service and this is followed up by a more comprehensive session on the main induction course. Further courses were held during the year on manual handling for those staff likely to be involved. NERC-funded training for all staff, appropriate to their level of responsibility, has continued during the year and should be completed substantially early in 2004/05. The Survey will then take on responsibility for follow-up courses for new staff and refresher training.

**Facilities and Infrastructure:** construction of the new NERC Hazard Assessment and Environmental Materials Handling Facility began at Keyworth in early 2004.



**Health and safety training:** because of the size of the site and the large complement of staff at our headquarters, First Aid training (below) was stepped up in 2003/04 to allow cover to be doubled at Keyworth.





**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK  
Tel: 0115 936 3100 Fax: 0115 936 3200 Websites: [www.bgs.ac.uk](http://www.bgs.ac.uk) & [www.geologyshop.com](http://www.geologyshop.com)