

Annual Report

2002–2003



**British
Geological Survey**







NATURAL ENVIRONMENT RESEARCH COUNCIL

NAVIGATION

HOW TO NAVIGATE THIS PDF DOCUMENT

There are three important tools you should use to navigate through this pdf file: arrow buttons in the toolbar at the top of the screen, links and bookmarks.

☐ TOOLBAR BUTTONS:

- | | |
|--|--|
|  First Page goes to the first page of the file |  Last Page goes to the last page of the file |
|  Previous Page goes to the previous page of the file |  Next Pages goes to the next page of the file |
|  Go to Previous View lets you return to the last pages you viewed |  Go to Next View reverses the path you took using Go to Previous View |

☐ LINKS: Links take you to another page, another file, a web site, or e-mail. The links in this document take you to the second page of the article, e.g. by clicking on 'Continental Shelf and Margins' in the top left hand banner, you will go to the next page.

☐ BOOKMARKS: Bookmarks are the easiest way to navigate from one place to another within the volume. Each file has been prepared to open with the bookmarks showing in a separate window on the left side of the screen. There are individual bookmarks in this document for each of the scientific programmes described.



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

01793 411500

www.nerc.ac.uk

NERC's Research Centres:

British Antarctic Survey

☎ 01223 221400

www.antarctica.ac.uk

British Geological Survey

☎ 0115 936 3100

www.bgs.ac.uk

Centre for Ecology and Hydrology

☎ 01793 442524

www.ceh.ac.uk

Proudman Oceanography Laboratory

☎ 0151 653 8633

www.pol.ac.uk

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

Bibliographical reference

BRITISH GEOLOGICAL SURVEY, 2003.

Annual Report of the British Geological Survey 2002–2003.

(Swindon, Wiltshire: Natural Environment Research Council).

© NERC 2003. All rights reserved.

Printed in the UK for the British Geological Survey by

Hawthornes, Nottingham C30 11/03

Cover: detail of photograph from the series 'The End of the

Land' by Andrew Nadolski. Web site: www.nadolski.com

ISBN 0 85 272 468 3

Editor: David Bailey

Design & Production: Adrian Minks

Print Production: James Rayner

Reprography: Jayne Kmieciak

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.



British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

THE MISSION OF THE BRITISH GEOLOGICAL SURVEY IS TO:

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

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

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

FUNDING BGS SCIENCE

The BGS is a public-good, not-for-profit organisation. BGS funding is split equally between 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 Programme and developing additional products and services.

THE CORE STRATEGIC PROGRAMME

The principal business of the BGS 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 Programme is delivered through three user facing Directorates — Lands and Resources, Environment and Hazards, and Information Services and Management — 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 science research, and the provision of scientific advice (knowledge transfer).

THE COMMISSIONED PROGRAMME

This Programme comprises strategic commissions — partnerships with a wide range of clients, which 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 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 BGS science to government, industry, and society.

Principal offices of the British Geological Survey

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

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

Macleán 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,
Cardif CF11 9LJ
☎ 029-2066 0147

Foreword



BGS © NERC

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

In the foreword to last year's Annual Report, I commented on the joy and enthusiasm of my newfound knowledge of the BGS. So much so that friends and colleagues in other walks of life are now used to being updated on my latest discovery from the BGS's wide-ranging activities. Dinner tables have often become quite lively, with discussions of carbon sequestration, groundwater pollution and historic building restoration replacing those of house prices, schools and taxes. Whatever the specifics of the occasion, however, these conversations always seem to follow a regular pattern.

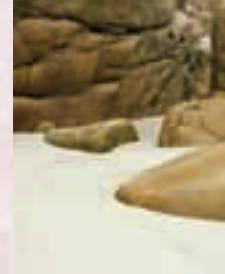
Before long, perhaps hoping to shut me off, someone will inevitably say 'But, surely, there can't be anything left to discover about Britain's geology'. Well nothing could be further from the truth. As the following pages will amply demonstrate, we are learning all the time. Learning as we slowly improve our models of the basic geological processes; learning as we continue to gather more raw data; learning as we improve our techniques for making deductions from the data; and learning as we apply the results of these deductions to an ever-wider range of practical applications.

'Ah!' someone else will then say 'Now that North Sea oil is declining and the coal industry almost finished, there can't be any practical use left in the subject'. Well, even those most familiar with the BGS's activities have been amazed to discover the breadth of its economic significance. A recent independent study on this subject has highlighted the survey's contribution to fields as diverse as water quality, urban renewal, transport infrastructure, tourism and many others. The examples in this report can only give a flavour of the breadth of that contribution.

Then comes the supposed killer question. 'Well, if it's that economically important, why are we funding it from the tax-payer instead of letting the market do the job?' Which is to misunderstand the respective roles of public science and commercial exploitation. Without the accumulation of years — even decades — of data, techniques and expertise, such commercial exploitation would have nothing to exploit. Of course, once we're on to the subject of taxes, we're soon back to schools, house prices . . . and I've lost my chance until next time.

But I hope that, in the process of the debate, a few more people have come a little closer to understanding the tremendous national asset that the BGS represents. If you still have any doubts, read on.

The BGS Board during 2002/03



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 2002/03 this was the NERC Partnerships and Exploitation Policy Director Dr M Tricker); 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 academia, as listed below. Members may be appointed for up to four years in the first instance, and may be reappointed for a further period of up to 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 Assoc.
Dr O Bavinton	Senior Vice-President, Exploration, Anglo American PLC.
Mr J Smith	Managing Partner, Wardell Armstrong.
Mrs R Johnson-Sabine	ChevronTexaco (joined March 2003).
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 Ovadia	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

Dr V L Hards 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 five times a year.

The BGS Board, 17 June 2003, on the steps of Parliament Houses, Stormont, Belfast. Left to right (back row): Mr F G Curry, Dr B R Marker, Dr D J Morgan, Dr M K Lee, Mr D C Ovadia; (middle row): Miss K A Booth, Dr M J Tricker, Dr O A Bavinton, Dr C A Green (deputising for Mr I Jackson), Mr A J Smith; (front row): Dr V L Hards, Dr D A Falvey, Dr G W Robinson, Dr M J Carter, Prof P Styles, Dr R A Scrutton.



BGS © NERC

Director's introduction



BGS © NERC

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

I am delighted to introduce the BGS Annual Report for 2002/03. This year marks the middle of the five year science programme agreed with our parent body, the Natural Environment Research Council (NERC). It has been a successful year, during which we have built on our strengths and continued to develop both our strategic science and business. I will outline a few of the highlights of a year characterised by scientific innovation, coupled with financial stability.

The BGS Sustainable Energy team has played a major part in raising both government and public awareness of the role of underground sequestration of carbon dioxide. This should provide a means of stabilising the levels of greenhouse gases in the atmosphere, while alternative energy sources are brought on stream. We have also worked closely with the DTI clean fossil fuels working group in the formulation of the Energy White Paper and the BGS was a co-convener of the very successful 'Coping with Climate Change' conference. Two successful bids (CO₂Net2 and CO₂Store) were won under the final phase of the EU Fifth Framework Programme, the latter receiving the highest evaluation score under the energy part of the call. Both have attracted sufficient industrial sponsorship, demonstrating the relevance of this work to the needs of UK industry. I am especially pleased to note that this work has led to recognition of the efforts of the Programme Manager, Dr Nick Riley, who was awarded an MBE.

The Millennium Atlas, describing the results of over 30 years of petroleum exploration in the central and northern North Sea has been completed and published. The BGS provided the Editor-in-Chief, the editorial team and also contributed three of the chapters to this benchmark publication.

Extensive concealed zones of high electrical ground conductivity associated with former colliery workings at Thoresby in north Nottinghamshire, previously detected by airborne geophysical surveying, have proved to be saline leachate plumes. The 'ground-truthing' of the geophysical anomalies was provided by a programme of drilling and logging, thus demonstrating the power of such high resolution airborne resource and environmental information (HIRes) for use in land characterisation for energy, mineral and environmental use.

We have completed the Futurecoast Project, in conjunction with Halcrow Ltd. This externally commissioned project for DEFRA emphasised the importance of geology in coastal zone management.

The Geological Survey of Northern Ireland (staffed and managed by the BGS for the Department of Enterprise, Trade and Investment), working in association with the Geological Survey of Ireland, was awarded a 'Peace and Reconciliation II' grant to undertake the landscape and cultural tourism rebranding of the Breifne Park area.

This year saw an increase in dissemination of our science to the community at all levels. Presentations were made to the All-Party Parliamentary Group on Earth



Sciences on 'PSInSAR, ground movements and their geological interpretation' and on CO₂ sequestration. The BGS also received considerable media exposure following the Dudley, Manchester, Italian and Turkish earthquakes. We answered almost 800 general enquiries about earthquakes during the year, plus a further 395 from the media, which included 46 television and 110 radio interviews. There has also been an excellent public response to online macroseismic questionnaires concerning the UK earthquakes. Twenty-two litho-printed maps, eighteen books and fourteen major reports/specials were also published. We have continued to develop our online services: the Internet bookshop and GeoReports service (with full secure credit card handling facility). These represent significant steps forward in our e-business strategy. A free web service entitled 'Ask-about-Geology' was also successfully launched.

Turning to infrastructure, this year has seen continued investment. The National Geoscience Data Centre (NGDC) extension, was completed and opened by Brian Wilson MP, Minister of State for Energy and Construction. We have now put in a successful bid to the NERC to fund the construction of a hazard assessment and environmental materials handling facility. Construction is now under way.

We have also continued to invest in our most important asset, our staff. While this year saw fewer new appointments, a successful targeted recruitment exercise was carried out. These recruitment campaigns continue to align our skills-base with our business. We also successfully retained our Investors in People status.

I hope this introduction has given you a flavour of our achievements during 2002/03. These achievements will, I believe, contribute to a growing reputation for scientific excellence and relevance. The report that follows includes further exciting examples of our work, both in the UK and overseas, which I have not had space to touch upon here. I think this report confirms that the work of the Survey reaches out to all of us, and contributes to a safer and more sustainable community. I hope that you would agree that the BGS, the world's first geological survey, has once again demonstrated that, while its roots were established in the early 19th century, it is very much a part of the 21st century, through the relevance of its geoscience, its focus on delivery, and its future vision.

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
GeoHazardD	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 via six multidisciplinary programmes designed to define the surface and subsurface geology (onshore and offshore), provide information on the distribution of energy and mineral resources, and carry out research on the sustainable utilisation of the land, sea bed and natural resources. A major component of the work is concerned with strategic survey, modelling and research in the UK, supported by a mixture of BGS (Science Budget) 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 (*pages 22–33*) and generate many of the mainstream publications and digital products delivered through the Information Services and Management Directorate (*pages 32–43*).

The **Integrated Geoscience Survey** programmes (Northern and Southern Britain) resumed field activities after the suspension in 2001 due to the outbreak of foot-and-mouth disease, and increasingly focused on characterising the shallow geology (superficial deposits and near-surface bedrock) to underpin a range of environmental, geodiversity and land-use issues. Notable achievements were a new understanding of how geology has shaped the landscape of the Cairngorm Mountains (to support development of the area as Scotland's second National Park) and the development of a prototype '3D shallow geological map' of the Ipswich area to support improved land-use planning and groundwater protection.

The **Sustainable Energy and Geophysical Surveys** programme continued to build its external funding base and international reputation in the fields of clean energy and carbon dioxide sequestration. The team has established a leading position in Europe as the co-ordinator of a major new Network of Excellence (CO₂NET) and played a significant role in advising government on various aspects of clean energy policy in the lead-up to publication of the Energy White Paper (2003).

The **Continental Shelf and Margins** programme saw completion of the EU-supported STRATEGEM project which has provided a unified stratigraphical framework and integrated model of the evolution of the (Neogene) glaciated European Margin. Strategic mapping and consortium-funded research on the outer parts of the UK continental shelf (such as the Rockall Basin) are providing important new information on the development of Palaeogene inversion folds and the geochemical and isotopic character of the basement rocks.

The **Economic Minerals and Geochemical Baseline** programme has focused on the increasingly important topic of developing best-practice methodologies and GIS-based decision support systems to underpin sustainable development of mineral resources. The geochemical survey (G-BASE) achieved a major success by completing the first catchment-based survey (of the Tamar drainage catchment) designed to support assessment of water quality.

The **Geological Survey of Northern Ireland** (operated by the BGS for the NI Department of Enterprise, Trade and Investment) continued to develop its activities in response to demand for its services across all sectors, including mineral and energy resources, hydrogeology and landscape heritage.

Modern methods

In parallel with the six main LRD programmes, two special projects are under way to develop new techniques and digital methodologies for onshore survey activities. The aim of the SIGMA (System for Integrated Geospatial Mapping) project is to implement integrated digital methodologies for the revision of geological maps based on a mixture of GIS-based analysis of landscape and legacy data supplemented by targeted fieldwork. The Quaternary Methodologies and Training programme is developing new survey protocols and skills to meet the increasing need for better information on Quaternary deposits. Both projects are due for completion in 2004 and are already having a significant impact on the way the BGS carries out its work.

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

Lands & Resources Dr M K Lee 0115 936 3356 mkleee@bgs.ac.uk		
Continental Shelf & Margins Mr R W Gatliff 0131 650 0346 rwga@bgs.ac.uk	Integrated Geoscience Surveys (Southern Britain) Mr P J Strange 0115 936 3171 pjst@bgs.ac.uk	Integrated Geoscience Surveys (Northern Britain) Dr M Smith 0131 650 0285 msmi@bgs.ac.uk
Geological Survey of Northern Ireland Mr G Earls 028 9066 6595 gearls@bgs.ac.uk	Economic Minerals & Geochemical Baseline Dr M G Petterson 0115 936 3493 mgp@bgs.ac.uk	Sustainable Energy & Geophysical Surveys Dr N J Riley 0115 936 3312 njr@bgs.ac.uk

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 the Moffat, Cairngorm, Drumochter, Caithness and Solway areas, and new starts made in Hexham and Glasgow. A total of 92 geological maps at various scales, three memoirs including a thematic memoir on the Cainozoic geology of north-east Scotland, a Geological Conservation Review volume, the regional guide for the Tertiary Volcanic District and significant contributions to the new edition of the Geology of Scotland were completed.

Links between geology and landscape in the Cairngorm Mountains

The Cairngorm Mountains have a distinctive landscape in which large U-shaped valleys and spectacular corries incise a high tor-studded sub-arctic plateau. In common with most British upland areas, glaciation has been traditionally presented as the prime 'sculptor' of this landscape. Anticipating the area's designation as Scotland's second National Park, the BGS and Scottish Natural Heritage co-funded a three-year project to examine the role played by geology in shaping the Cairngorm Mountains. Digital field data capture, a geographical information system (GIS) and digital terrain models ensured efficient capture, manipulation and visualisation of data.

Results demonstrate that landscape development at all scales in the Cairngorms is linked fundamentally to the structure of the underlying Silurian granite pluton. The size, shape and elevation of the massif are governed by the form, hardness and crustal level of the pluton. The main glens formed through focused erosion of granite weakened by hydrothermal alteration. The location and size of plateau tors reflects the distribution of weakly jointed domains. Landform and surface analysis in conjunction with A Hall (Fettes College) confirm that Quaternary glaciation merely modified a landscape that already contained the major features, many of which began to develop when the granite was first exposed in the Devonian era.

Geodiversity action plans for Northern England

In early 2003 the BGS, in partnership with Durham County Council, secured funding from the Aggregates Levy Sustainability Fund (ALSF), from the Office of the Deputy Prime Minister via the Minerals Industry Research Organisation, to prepare a geodiversity action plan for County Durham. Additional funding was also won for the North Pennine Area of Outstanding Natural Beauty Partnership (AONB).

These projects, to be completed during 2003/04, will deliver detailed and comprehensive modern audits and evaluations of all geological and geomorphological features, sites and phenomena which give these areas their distinctive character and landscape. The data gathered will frame recommendations and action points to underline Local Biodiversity Action Plans and inform the conservation, sustainable management and interpretation of geological landscape features for a substantial part of northern England. The geodiversity action plan for the North Pennine AONB will play a key role in developing initiatives for the UK's first area to acquire European Geopark status.

3D modelling

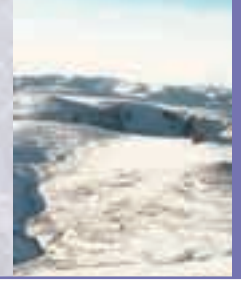
New techniques have been successfully applied to the construction and interpretation of models of strata from the Midland Valley of Scotland. Common to many areas around the UK, the onshore geology of Ayrshire contrasts with that of the adjacent offshore Firth of Clyde area. Here an affordable method for scanning and vectorising paper seismic records was established and digitised data were interpreted on a 3D Landmark seismic workstation to present a revised understanding of the geology. The resulting product and structure is an example of seamless best-practice modelling.



BGS © NERC

Cairngorm Mountains: examining a granite pavement above a glacially modified Cairngorm valley which may have originated in the Devonian.

Northern Britain



Critical for the fit-for-purpose use of models is research into the quantification and visualisation of uncertainty. This has been applied to Midland Valley 3D models where sources of uncertainty, such as geological complexity and data reliability, have been identified, scored and illustrated as darker shading on the modelled surfaces. One application of this research is the identification of a hydrocarbon 'kitchen' area within the Firth of Forth from BGS modelling in collaboration with the University of Edinburgh. The extent of the current oil window within source rock and the hydrocarbon migration pathways were identified from modelled surfaces.

Provenance studies

In the Southern Uplands, U–Pb analyses (carried out by NERC Isotope Geosciences Laboratory) of detrital zircons from Ordovician sandstones indicate derivation from a volcanic island-arc situated close to the Scottish (Laurentian) side of the Iapetus Ocean. The sandstones, locally rich in fresh volcanic detritus, were formerly interpreted as recording contemporaneous volcanism associated with closure of the Iapetus Ocean about 450 million years ago (Ma). However, zircon ages indicate that the volcanic arc is significantly older and was active at about 613 Ma and 570 Ma. These ages, and those of the associated Grenvillian continental crust (about 1043 Ma), are more typical of the English (Avalonian) side of Iapetus.

Further north U–Pb SHRIMP analyses on detrital zircons (P Cawood, Curtin) and whole rock Sm–Nd data (NIGL) demonstrate that the provenance of the Precambrian Dalradian Supergroup is dominated by three source regions. Archean (notably around 2.8–2.7 Ga), Palaeoproterozoic (several age peaks between 1.8–1.5 Ga) and Grenvillian (1.0–0.9 Ma) sources vary in space and time and are consistent with the progressive erosion of a Laurentian hinterland. Archean detritus first appears in the Appin Group and increases in volume up stratigraphy to dominate the youngest strata of the Southern Highland Group. Major shifts in ϵ Nd relate to changes in lithostratigraphy and sedimentary facies and argue for a revision of the Dalradian stratigraphy.

Quaternary research in the northern Highlands

The Moine Thrust project area possesses some of the most dramatic glaciated upland scenery in Britain. Deep U-shaped glens and fjords, ice-worn corries, streamlined hills and striated bedrock are all testament to the power of a former ice-sheet that once covered all but the highest mountains in this area. Ice flow in this region was faster and more dynamic than elsewhere on the UK landmass. Ongoing research indicates that the ice centre in the North-West Highlands migrated with time, probably in response to climatic change and topographical factors. Caithness, famous for its peatlands, also contains evidence for a complex pattern of deglaciation.

A detailed resurvey of the Reay Sheet, co-funded by UKAEA was completed and has revealed evidence for an early glaciation, followed by a more extensive event. Radiocarbon dates from shelly diamicton reveal that the 'glacial maximum' in this area was more recent than previously thought and that Caithness is a key area for studies of the extent, configuration and timing of the last British ice-sheet.

Geodiversity: Dowgang Hush, Nenthead, Cumbria. An example of the landscape modified by mineral working; the deep man-made valley is a surface working for lead ore on the Dowgang–Scaleburn Vein.



B Young, BGS © NERC

Quaternary: typical glaciated scenery in the North-West Highlands; Stac Pollaidh seen from Cul Beag.



T Bradwell, BGS © NERC

Integrated Geoscience Surveys

Programme overview

The Integrated Geoscience Surveys (Southern Britain) programme provides high quality geological map coverage of southern Britain by undertaking multidisciplinary regional survey projects. The information gathered is portrayed as geological maps, 3D geological models and thematic layers, together providing the geological framework for onshore England and Wales that underpins research and development undertaken in other BGS programmes. The projects also ensure the local geological knowledge base is maintained by a process of continuous revision. During the year, a total of 2735 square kilometres were surveyed at the 1:10 000 scale, and five 1:50 000 scale geological maps were completed together with one special memoir and six Sheet Explanations.

Characterisation of the Upper Greensand on the Somerset–Devon border

Systematic surveying of the Blackdown Hills on the Somerset–Devon border has highlighted the need for a 3D approach to understanding the variability of the Cretaceous Upper Greensand, an important minor aquifer in the area. Recharge of the aquifer is dependent largely on the distribution and composition of the overlying Clay-with-flints. The Upper Greensand is also the cause of extensive areas of unstable and potentially unstable land, which results from strong springs issuing from the base of the formation where it overlies impermeable mudstones of Jurassic and Triassic age. Ongoing work is therefore concentrating on modelling the variability of both the aquifer and its bounding strata.

Verification and visualisation of the geological structure using scanned aerial photograph imagery and digital terrain models help to identify areas of active landslide and potentially unstable land for detailed field analysis. Active landslides include rotational and translational types; other slopes are characterised by inactive lobes and mudslides probably formed during a period of periglacial climate. The area is now the subject of a multidisciplinary study to set standards for digital recording into the national landslide database.

Detailed Quaternary surveys in north-west England

Revision mapping in north-west England is progressing from the Rochdale area southwards into the Manchester conurbation. Mapping of sediment–landform associations, in conjunction with aerial photographs and an extensive borehole database, enable a modern interpretation of the deposits to be established. The work has identified a complex system of northerly-trending drift-filled channels in the Rochdale, Bury and Bolton areas.

In the area between Heywood and Royton, the survey has revealed a complex drift sequence, with areas of ‘moundy’ topography, characterised by predominantly red coloured sediments (‘Irish Sea Drift’), overlying grey till (‘Pennine Drift’). It is uncertain whether these deposits result from a single Devensian glaciation, or two separate glaciations. In the city of Manchester, the integrated use of historical maps and drift-thickness data is revealing an intricate relationship between artificial ground, drift deposits and local groundwater aquifers.

Traditional and rapid mapping in the Brecon area

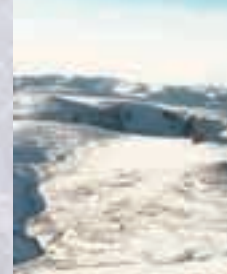
The survey of the Brecon 1:50 000 geological sheet was undertaken during 2002/03. The area includes parts of the Brecon Beacons National Park and the Usk Valley, for which there are no modern geological maps. The project addressed the need for reliable Quaternary data for groundwater modelling, geohazard assessment and identification of bulk mineral resources. The work, co-funded by the Environment Agency, and the Planning and Environment Protection divisions of the Welsh Assembly Government, was carried out using a combination of traditional mapping techniques and photogrammetric interpretation.



Graham Bell © NERC

Mapping in the Brecon area: view from the Taf Fechan reservoirs looking north-west to Pen y Fan. The Brecon Beacons were a centre of ice accumulation during the last main glaciation of Britain about 20 000 years ago. Glaciers, including one in the Taf Fechan valley, flowed from this centre.

Southern Britain



Priority areas of the co-funding partners were surveyed in detail, and the Old Red Sandstone terrain was mapped at a reconnaissance level. Silurian strata in the north-west of the area were surveyed in detail to underpin groundwater monitoring in the vicinity of foot-and-mouth disease burial and burn sites. The results have also led to a better understanding of the complex glacial history of the region. A number of major landslides in the Brecon Beacons and Usk Valley have been identified.

First 3D geological map for Ipswich

A digital 3D geological map has recently been developed for the Ipswich area involving systematic mapping and the classification of some 2500 boreholes. A geological fence diagram of intersecting cross-sections was computer-drawn using these data and combined with a digital terrain model. Mathematical interpolation between these sections produces a cubic geological map composed of calculated grids for the base of each geological unit. The stacked cubic model can be exported for analysis to any geographical information system (GIS). Interrogation of the model at a given point provides automated borehole prognosis, and a geological section can be generated along any specified route, for example for a potential tunnel or pipeline.

Given the 3D model, it is a relatively easy matter to calculate the thickness and volume of resources or a contour map of total aquitard thickness. The latter is particularly important in terms of aquifer protection, groundwater recharge and pollution studies. This cubic map is the first of its kind in Britain and utilises the GSI-3D software tool and methodology developed by Dr Hans-Georg Sobisch (University of Cologne). The BGS is contributing to the further development of this application for use in systematic three-dimensional geological surveys and modelling.

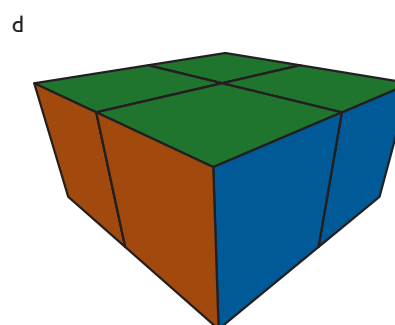
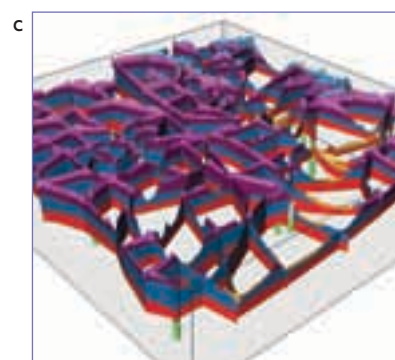
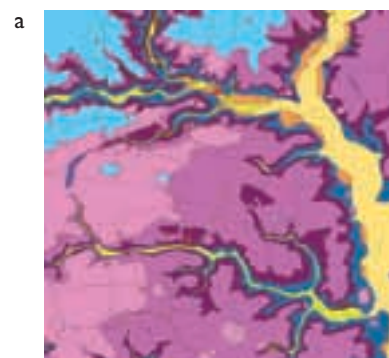
South Midlands development belt

During the past two years, surveying activities have concentrated on updating geological map data for the Kettering, Wellingborough and Bedford sheets. With the exception of the north-eastern part of the Kettering sheet, all of these sheets lie within the Milton Keynes and South Midlands Growth Area defined by the Government, thus anticipating an important potential user requirement for geological data. The Kettering sheet was published, and the updating of the Wellingborough sheet was also completed during the year.

This area covers extensive tracts of ironstone that once supported a large-scale iron and steel industry. With that industry now moribund, the surveys concentrated on mapping and classifying the artificial ground that resulted from the extraction of ironstone and subsequent landfill — brownfield areas that may become the location for renewed industrial development.

The BGS archive of historical topographical maps has proved an invaluable resource for identifying former extractive and industrial sites. The Bedford sheet is currently undergoing a full resurvey as existing map data are inadequate. Detailed engineering geology data acquired during the construction of Milton Keynes are being interpreted and extrapolated to provide applied geology information to assist planners and developers.

3D geological map: the 2D geological map (a) has been integrated with sections based on borehole data (b) to create a geological fence diagram of intersecting cross-sections (c). Interpolation between these sections produces a 3D geological map of stacked cubes (d).



H Kessler-BGS © NERC

Continental Shelf and Margins

Programme overview

The Continental Shelf and Margins programme is concerned with all aspects of geology offshore of the UK, from seabed sediments to the deep crustal structure. Studies around the UK include basin analyses, particularly to support exploration for hydrocarbons, and evaluation of Neogene sedimentary and tectonic processes in terms of environment, site investigation, geohazards and habitats, and how they vary with climate change.

Offshore regional mapping programme

A key element of the Continental Shelf and Margins programme is the geoscientific surveying and understanding of the extensive, largely deep-water areas of the UK continental shelf that are not covered by the published BGS 1:250 000 map series. Over the past decade, co-funding support from the Rockall Consortium (comprising the BGS and numerous oil companies) has facilitated extensive marine operations in and around the Rockall Trough, together with a wide range of associated confidential geoscientific studies.

Recently, the Consortium also supported the publication of a new 1:500 000 scale solid geology map of the Central Rockall Basin, in collaboration with the Irish authorities. Over the past few years, in addition to the Consortium-sponsored activities, cost-effective access to the NERC fleet has allowed the BGS to acquire new marine geophysical and shallow core sample data over other UK deep-water areas.

On the basis of these new data, and other data made available by collaborating organisations, the bedrock geology and subsurface geoscience of areas such as the northern Rockall Basin and the southern Møre Basin are now being investigated. The new data are providing important new insights into aspects such as the development of large Palaeogene inversion folds and the geochemical character and isotopic ages of crystalline basement rocks.

Strategic Environmental Assessments (SEAs)

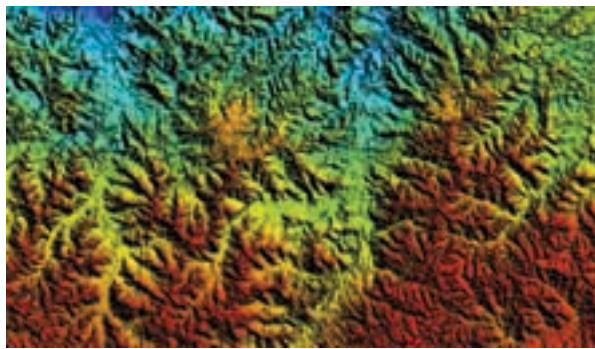
In 2001 the UK adopted the European Strategic Environmental Assessment Directive. Since then, the DTI has had a programme of Strategic Environmental Assessment divided into eight areas covering the UK sector (SEA1-8). During the 2002 field season, support was provided by the BGS to the DTI for acquisition of new swath multibeam and sample data during deep-water surveys (northern North Sea, Faroe–Shetland Channel, Norwegian–Greenland Sea) in SEA4 north of Shetland.

Interpretations of the new data were subsequently incorporated into reviews of geological features and processes relevant to understanding the modern continental shelf and deep-water basin environments in all of the SEA4 area situated to the north and west of Orkney and Shetland.

DTI geoscience consultancy contract

A BGS team based at the Department of Trade and Industry's (DTI) core store in Edinburgh is engaged in projects that assist the DTI in estimating the remaining undiscovered oil and gas resources on the UK continental shelf (UKCS). In addition, the team assists the DTI with its promotional activities. The BGS has compiled for the DTI a 'Promote UK 2003 CD' that includes structure contour maps, seismic profiles and play panels for attractive undrilled prospects and undeveloped discoveries on the UKCS. The CD has helped DTI to attract several 'New Entrant' oil and gas companies to participate in the twenty-first Offshore Licensing Round. The shaded-relief image (*left*) illustrates dendritic palaeo-drainage features that are common within the late Paleocene to early Eocene of the Atlantic Margin, East Shetland Platform and Moray Firth. Valleys up to 100 metres deep

Image published with permission of DTI



DTI contract: shaded-relief image illustrating dendritic palaeo-drainage features that are common within the late Paleocene to early Eocene of the Atlantic Margin, East Shetland Platform and Moray Firth.

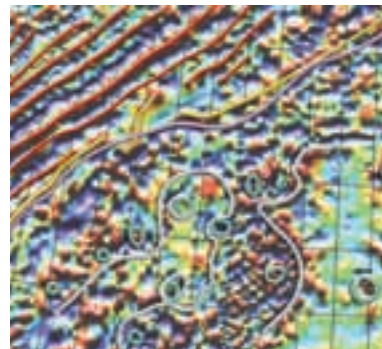


were incised into a deltaic sandstone reservoir in response to rapid uplift. The valleys were subsequently filled by argillaceous transgressive sediments that provide a seal to any oil or gas that later migrated into the reservoir.

Offshore GIS

Data from all projects in the offshore area are being combined into one database, which will be available for future projects through a GIS decision support system. Work is progressing on a modular approach to license these datasets to the user community. In some cases data will only be available to entitled users, for example, sponsors of projects such as the Rockall Consortium, Western Frontiers Association and the Passive Margin Modelling Project, until an agreed release date is reached. Part of the Offshore GIS showing magnetic data from the Passive Margin Modelling Project in the Hatton–Rockall area is illustrated (*top right*). Interpretations of ocean magnetic anomalies (red), the continent–ocean boundary (purple), Palaeogene volcanic scarp (grey) and location of igneous centres (green) are also shown. All data are supported by detailed attribution.

Offshore GIS: magnetic data from the Passive Margin Modelling Project in the Hatton–Rockall area.



BGS © NERC

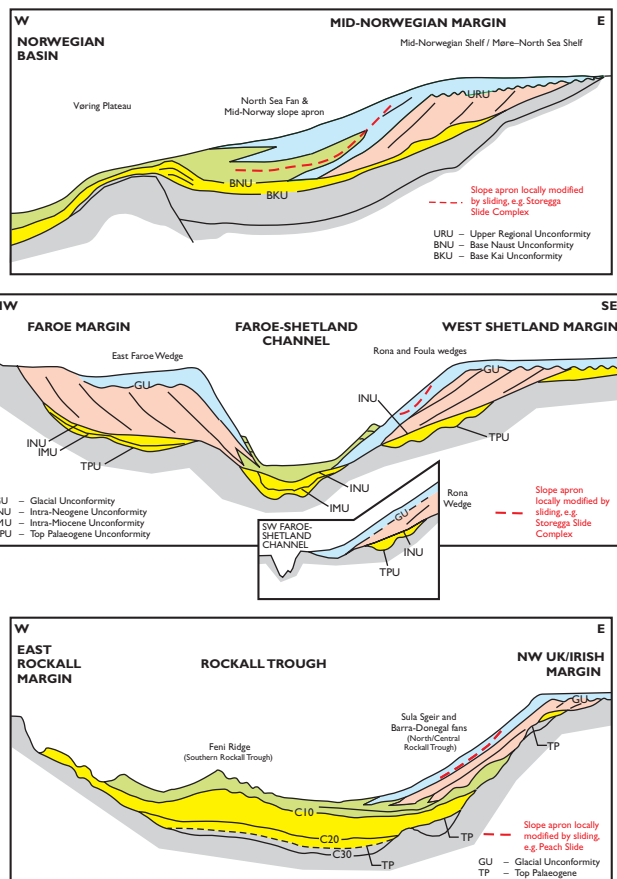
STRATAGEM

2003 marked the completion of the three-year EU-supported ‘Stratigraphical Development of the Glaciated European Margin’ (STRATAGEM) project. STRATAGEM addressed the problem of a lack of regional approach to the Neogene development of the glaciated European Atlantic margin. The BGS has acted as joint co-ordinator for this project, with six other partners from five countries. The main scientific achievements of STRATAGEM have been to produce:

- The unified stratigraphical framework report: *The Neogene stratigraphy of the glaciated European margin from Lofoten to Porcupine.*
- An integrated margin evolution model: *Neogene evolution of the glaciated European margin.*

These documents have been widely disseminated to both industry and academia, and have allowed the BGS and the STRATAGEM partners to remain at the forefront of margin research. STRATAGEM has had close links with the hydrocarbon industry, principally through four Joint Industry Projects active on the north-west European margin, who have provided data for the project from Norway, Faroe Islands, Ireland and the UK. Of particular importance to the BGS has been the support of the Western Frontiers Association, the UK industry consortium on hazard-related issues organised by the BGS. STRATAGEM has been one of several projects that contribute to a better understanding of the UK margin in order to maximise offshore safety and provide a basis for further work to study deep-water sedimentary processes and the response of the margin to climate change.

STRATAGEM: cross-sections through the Neogene of the Atlantic Margin.



BGS © NERC

Economic Minerals and Geochemical

Programme overview

The Economic Minerals and Geochemical Baseline programme (EMGB) delivers information, expertise, advice and research on solid minerals (metallic, industrial, construction, coal) and geochemical baseline surveys (for environmental and resource assessment purposes). These various activities are undertaken on local, regional, and national scales within the UK and throughout the world. EMGB supports, develops and promotes best-practice sustainable development principles within the mineral development and environmental fields.

Sustainable minerals

Sustainable development ensures a better quality of life, now and for generations to come. In the context of minerals, sustainable development is about developing a range of methods and tools to help maximise and sustain the economic, environmental and social benefits and minimise the negative impacts, which may arise from mineral development. Key BGS mineral-related projects are at the forefront of developing these methodologies. The MIRO/MIST¹ project Strategic Environmental Assessment and Future Aggregate Extraction in the East Midlands Region is using existing BGS datasets to develop a tool to aid sustainable aggregates extraction. The project is producing a Future Aggregates Sensitivity Map to help planners make decisions about locating future extraction. For example, the more sensitive an area, the more consultation and consideration may be needed when deciding where to allow future extraction. Alternatively, it may be possible to enhance the environment in areas that have low sensitivity, by allowing short-term aggregate extraction where restoration creates new habitats for wildlife or new recreational areas. The map is an important tool for the sustainable development of aggregate minerals.

¹ MIST is the Mineral Industry Sustainable Technology Programme, managed by the Mineral Industry Research Organisation.

Minerals information and advice

The BGS has recently signed a three-year contract with the Office of the Deputy Prime Minister (ODPM) to provide information and advice on minerals issues. The ODPM is responsible for legislation, policy, guidance and advice on minerals in England. The BGS will undertake a wide range of activities to ensure that the ODPM has quick and ready access to high quality information on minerals, their uses, supply, transportation and the administrative control of extractive operations. This will involve compilation of mineral statistics, monitoring key trends and events and providing information on mineral resources and mineral workings. The BGS minerals web site (www.mineralsUK.com), sponsored by the ODPM and DTI, will be the chief route for disseminating the outputs from this project. The BGS will also publish leaflets concerned with raising the public awareness of the actual raw material demands of society. The first two in this series, known as Mineral

Matters, are concerned with the raw material requirements and associated environmental impacts of Government policies for improving transport networks in England and for developing sustainable communities. Under these policies, new bypasses are to be constructed, motorways are to be improved and thousands of new homes are to be built in south-east England.

Aggregate Minerals Survey

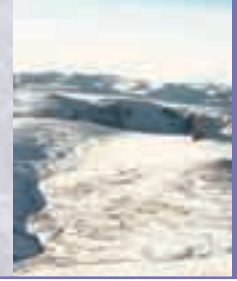
Aggregate Minerals (AM) Surveys are undertaken on a four-yearly cycle for England and Wales to provide comprehensive information for monitoring and providing aggregates at local, regional and national level. The BGS was commissioned to design and implement the latest Aggregates Minerals Survey for England and Wales on behalf of the ODPM and the Welsh Assembly Government and to collate, interpret and report the results. AM2001 presents regional data on sales, consumption, interregional flows and permitted



F. Steadman, BGS © NERC

Sustainable minerals: former sand and gravel quarries can be restored to create new habitats for wildlife and recreational areas. Attenborough, Nottingham.

Baseline



reserves of primary aggregates in England and Wales and for individual regions. Data on china clay waste are also provided. The AM2001 report also presents data on sales and reserves of aggregates for selected environmental designations, sales by transport method and the quantity of mineral granted and refused planning permissions between 1998 and 2001 by site type and environmental designation. A comparison of sales, consumption and permitted reserves in 2001 with data for 1973, 1977, 1985, 1989, 1993 and 1997 is also presented. The survey results have been used to inform government on the production, movement and consumption of aggregates in order to review and update planning policy guidance.

G-BASE in the Humber–Trent region

The G-BASE (Geochemical Baseline Survey of the Environment) project provides high-resolution baseline geochemical databases and maps of the surface environment of the UK for many applications including environmental assessment, metallogenic studies and geological mapping. Scotland, Wales, northern and central England and part of East Anglia have been sampled. Data from the Humber–Trent region are currently being interpreted in preparation for publication as a geochemical atlas. Humber–Trent is the first area of the UK to feature full coverage of sediment, soil and stream water data, enabling comparisons between the different media to be made. The soil maps for the region show many significant features, such as that for arsenic in topsoils. This shows elevated levels in the industrial areas, but the highest arsenic values are associated with natural sedimentary ironstones, notably in the lower Jurassic at Scunthorpe, and in the Lower Cretaceous Claxby Ironstone at the foot of the Lincolnshire Wolds. While high arsenic levels also show in the stream sediments in these areas, they are not visible on the stream waters map, indicating the very low mobility of the arsenic from these ironstone sources. G-BASE data for the Humber–Trent region are available now and the geochemical atlas is due to be published in 2004.

Geochemical survey of the Tamar drainage catchment

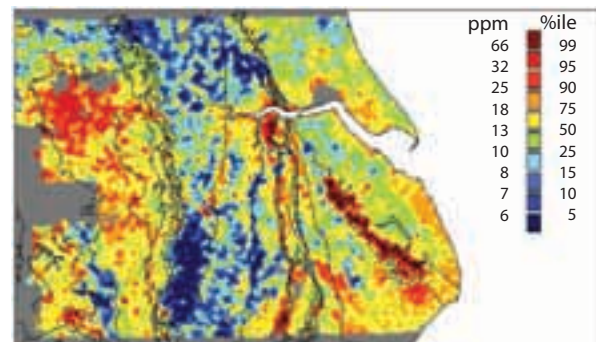
The BGS and Environment Agency have collaborated in carrying out a geochemical survey of the Tamar drainage catchment in south-west England. The survey was designed to provide information on the water quality in the headwaters of the catchment, which subsequently flow into Special Areas of Conservation (SACs) — the Tamar estuary and Plymouth Sound. It also furthered the aim of the G-BASE project to establish a baseline geochemistry of the UK landmass. G-BASE is the only survey programme in the UK which undertakes sampling at a sufficiently high density to identify both diffuse and point sources of pollution at the regional scale. The sampling included the collection of stream sediment and stream water samples from small (headwater) streams, and soil samples. Variations in water quality were also monitored on a daily basis. All samples were analysed for their total concentration of up to 50 elements and other key chemical parameters. The data highlighted a range of significant issues including point sources of phosphorus pollution with implications for water quality and arsenic contamination of soil due to both natural mineralisation and historical mining. It also demonstrated potential problems of trace element deficiency for crops and grazing livestock.

Geochemical survey: panning drainage sediment.



D Cameron, BGS © NERC

G-BASE: arsenic in topsoils in the Humber–Trent region. Elevated levels of arsenic (red) can be seen in the industrial areas, but the highest values are associated with natural sedimentary ironstones.



BGS © NERC

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 and reliable 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.

CO₂Store

This new EC/industry Fifth Framework project started this year, involving several research partners. There are two main parts to the CO₂Store project. The first is to continue developing monitoring technologies for the carbon dioxide storage operation at Statoil's Sleipner West gasfield, located east of the Shetland Islands, in the Norwegian sector of the North Sea. Statoil's operation is a world first for saline aquifer storage of carbon dioxide, preventing emissions of around a million tonnes of carbon dioxide per year to the atmosphere. Saline aquifers under the North Sea have huge potential storage capacity for carbon dioxide, which if realised could make a significant contribution to the UK's 60% emission reduction target. An important aspect is to ensure the long-term safety and integrity of underground carbon dioxide storage beneath the North Sea, which will be essential if the technology is to be widely accepted. New 3D seismic data have been acquired, added to the existing 4D dataset, and are now in the early stages of interpretation. Interpretation will enable us to monitor the spread of carbon dioxide within the reservoir. The second part of CO₂Store is to spread the technology to industrial plant by researching four case studies considered to be early opportunities for carbon dioxide sequestration. One of these, being led by the BGS and Progressive Energy, is investigating the potential for storing the carbon dioxide emissions from a coal-fired IGCC plant to be built in South Wales. Over 6000 line kilometres of seismic reflection surveys have been acquired and loaded on to BGS workstations to achieve this aim, and interpretation is due to start shortly.

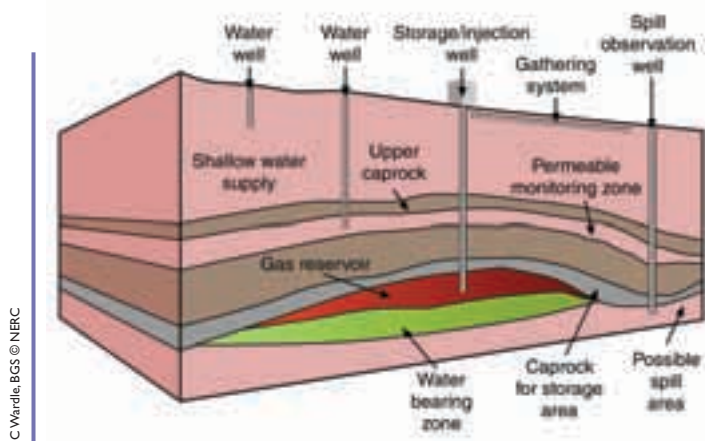
Reservoir characterisation, storage and production

This project has a focus on energy-related storage and exploitation of porous rocks (underground reservoirs). The UK is becoming increasingly dependent on gas for direct use (for example, heating) and in electricity generation. Rapid growth in gas use is set to continue, especially if coal-fired and nuclear power generation is lost. The UK's gas reserves are depleting rapidly which means the UK will soon be dependent on gas imports. Underground gas storage will become increasingly

important in meeting both seasonal and daily swing demand and modulating price fluctuations. One aspect of this project is to identify potential gas storage sites in anticipation of future demand. This year most effort has concentrated on the Hampshire Basin where several potential gas storage sites have been located.

CARNOT green energy from coal

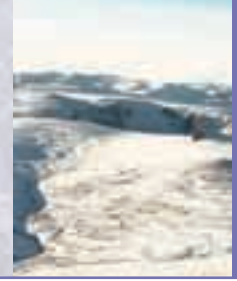
The BGS is undertaking this project, co-funded by the EC Carnot Programme, in collaboration with Progressive Energy and TNO-NITG (Netherlands). The aim is to assess the feasibility for the construction and operation of a partially coal-fired integrated gasification combined cycle (IGCC) power plant in north-east England, and the potential for the sequestration underground of its carbon dioxide emissions. IGCC power plants are ideally suited to pre-combustion capture of carbon dioxide, which greatly reduces the cost of capture. Coal plays an important part in the UK energy mix because of its abundance and relatively stable price compared to natural



© Wardle, BGS © NERC

Reservoir characterisation: in order to maintain reliable and affordable gas supplies and meet rising demand, the UK will have to improve and extend its existing gas storage infrastructure. Underground storage of hydrogen could also become an important technology in the future if hydrogen becomes the energy carrier of choice for use in fuel cells.

Surveys



gas and oil. If coal is to make a significant contribution to energy generation in the future, it is vital that new plant has significantly reduced emissions of carbon dioxide and other compounds, compared to existing plant. Construction of IGCCs also puts in place the building blocks for hydrogen production, should hydrogen become an important energy carrier in the future. The project has identified potential sites for carbon sequestration in the Bunter Sandstone Formation of the southern North Sea and also in nearby oilfields, where there may be the chance of some payback from enhanced oil recovery. It then used an existing Decision Support System developed by TNO-NITG and data from Progressive Energy to model the costs of carbon capture and sequestration.

Nascent

Nascent is a BGS-led EC-funded Fifth Framework project, with research partners from across the EU. Nascent is studying natural occurrences of carbon dioxide in Europe's subsurface. Such research allows us to understand the long-term effects of carbon dioxide on rocks and aquifers over the thousands and millions of years that the gas has been retained underground by natural processes. This provides vital knowledge that can be used to predict the likely long-term feasibility of man-made underground carbon dioxide storage. This year, in addition to the project co-ordination, the BGS, in collaboration with BRGM (France) has investigated changes in reservoir diagenesis on geological timescales as a result of natural carbon dioxide accumulation in a Triassic sandstone. These investigations have indicated that, in sandstone reservoirs, porosities are likely to increase following sequestration as the carbon dioxide dissolves into the porewater and reacts with some of the common sand grains, such as feldspars. The data obtained will help to validate geochemical modelling codes that may be used to predict long-term behaviour of carbon dioxide following geological sequestration. Studies of fractures above the reservoir have also revealed that they are mineralised and partially filled by calcite that precipitated from a carbon dioxide-rich fluid. As the carbon dioxide migrated along these fractures, it also transported light hydrocarbons, in a reflection of the techniques used during carbon dioxide enhanced oil recovery. These natural systems have not been previously investigated.

High Resolution Airborne Resource and Environment Survey (HiRes)

HiRes is developing airborne geophysical acquisition platforms for use in land characterisation, for energy, mineral and environmentally related uses. Extensive 'high' electrical ground conductivity zones associated with former and working collieries in northern Nottinghamshire were detected by the second HiRes airborne environmental survey (1999). Follow-up ground geophysical surveys indicated that the high conductivity zones occurred below the shallow ground and that values peaked within the slightly deeper sandstone aquifer. During early 2003, a final phase of ground truthing took place. Three boreholes were drilled and cored to the east of Thoresby colliery. The geophysical borehole logs confirmed significant increases in electrical conductivity within the aquifer, as predicted by the airborne survey. Pore fluids obtained from the core samples are undergoing geochemical analysis. These results demonstrate that a plume of saline fluid derived from oxidation of the rocks (particularly pyrite) in the mine tip is ingressing the aquifer. They also show the power of the HiRes capability in identifying potential zones of groundwater vulnerability from the air.

CO₂Store: burning fossil fuels is feeding carbon dioxide into the atmosphere faster than our planet can cope with it. We need to reduce emissions by 60% by 2050 to alleviate the threat of global warming and prevent damage to the oceans through acidification. Many creatures, particularly those with chalky skeletons, such as the foraminifera below, will be harmed by acidification of the oceans, unless action is taken globally to reduce emissions.

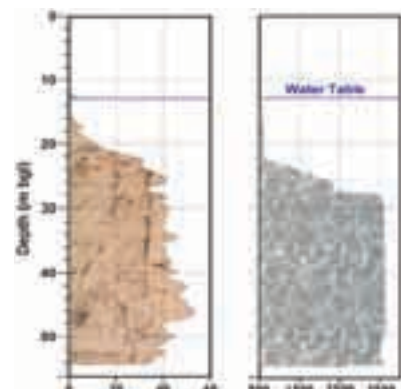


IP Wilkinson, BGS © NERC

HiRes: recent drilling has confirmed that airborne geophysical acquisition can locate environmental changes related to energy use. In this instance mineralised groundwater, caused by saline leachate migrating as a plume from the oxidation of nearby colliery spoil, has been located in a shallow aquifer. The logs below show (l) bulk conductivity (mS/m) and (r) fluid conductivity ($\mu\text{S/cm}$).



BGS © NERC



Geological Survey of Northern Ireland

Northern Ireland

The Geological Survey of Northern Ireland (GSNI) is an office of the Department of Enterprise, Trade and Investment (DETI). It is staffed by BGS scientists under an agency agreement which allows the GSNI to draw on expertise in other parts of the BGS. The GSNI also carries out work for other Northern Ireland departments and collaborates closely with the Geological Survey of Ireland (based in Dublin) on cross-border projects.

Minerals and energy resources

In Northern Ireland, mineral and petroleum rights are vested in the Department of Enterprise, Trade and Investment (DETI). The GSNI continued to develop its advisory role for the Department in monitoring licensed mineral and hydrocarbon exploration, while upgrading minerals and quarry databases. Mineral exploration is focused on gold. The entry of Tournigan Gold Corporation into Northern Ireland is reflected in increased licence applications and Ballymoney Power submitted a proposal to mine lignite in County Antrim. In hydrocarbon exploration, Evergreen Resources completed extended well tests in the south Fermanagh area, however, flow rates were disappointing. A pilot study of sand and gravel distribution in Limavady District was completed and Planning Service commissioned a new study for the Strabane and Omagh Districts. Government departments are becoming aware of issues relating to Northern Ireland's mineral heritage and the need to adopt an integrated and sustainable approach to minerals policy and development.

	Current licences (applications pending)		Relinquished/ expired in the year		Granted in the year	
	Number	km ²	Number	km ²	Number	km ²
Hydrocarbons	8	2800	0	0	0	0
Minerals	12 (6)	1563 (1264)	4	789	6	1259

Environment

The GSNI continued its nationwide survey of mine shafts and adits and is constructing a national database to support and help the DETI meet its responsibilities for abandoned mines. Mine openings that may represent a danger to the public are being identified and remedial action taken. Abandoned salt mines continue to pose a significant risk to public safety and are a constraint to development. The GSNI continued to monitor surface level changes over the Frenchpark and Carrickfergus/International mines and helped plan remediation of the collapsed Maidenmount mine and associated brine seepages. Development work commenced on a GIS-based 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.

Hydrogeology

The hydrogeology function in the GSNI is currently wholly funded by the Environment and Heritage Service (EHS), an agency service within the Northern Ireland Department of the Environment. Hydrogeological expertise was provided with support from the BGS Groundwater Systems and



GSNI © Crown Copyright 2002

Mapping and publications: artist's impression of a Carboniferous landscape, from the Ballycastle 1:50 000 scale map.
Reproduced with the permission of the Director, GSNI.



Water Quality team. In particular, a review of nitrate concentrations in groundwater was completed and four nitrate vulnerable zones were defined under the EC Nitrates Directive. To assist with implementation of the Water Framework Directive in Northern Ireland, a detailed analysis and costing of the groundwater-related work required was produced. Input from the GSNI will be required to assist with river basin district description and characterisation in coming years. Groundwater research undertaken through SNIFFER (Scottish and Northern Ireland Forum for Environmental Research) was supported through project management by GSNI staff on behalf of the EHS.

Landscape heritage and public awareness of science

Promotional work regarding landscape and heritage developed in three main areas. First, through involvement with the European Geoparks Network, the GSNI attended co-ordination meetings of the European Geoparks Network (EGN) and Patrick McKeever was elected as Vice Co-ordinator and member of the Expert Committee of the EGN. Second, the GSNI co-organised the Natural and Cultural Landscapes Conference at Dublin Castle, which was held under the auspices of the Royal Irish Academy. Third, several funding opportunities have been explored. One of these, the Breifne Mountains Project, was formulated in co-operation with the Geological Survey of Ireland and has been awarded 1.6 million euros. Other proposals submitted for funding included an INTERREG IIIC project in collaboration with Fermanagh District Council and the EGN.

Mapping and publications

The 1:50 000 scale Ballycastle map (sheet 8) was launched by the Minister for Enterprise, Trade and Investment. This publication represents the second in a series of geological maps that are focused on the tourist market as well as traditional users. The map contains French and German translations and reconstructions of the geological periods represented. Rapid geological surveying continued in the Newtownstewart area (1:50 000 sheet 25) aided by satellite imagery and aerial photographs. By 2006, the GSNI will have captured complete digital air photographic coverage of Northern Ireland at 25 centimetre resolution. Work continued on the revised (second) edition of the Regional Guide to the Geology of Northern Ireland, which will reappraise and incorporate geological information obtained since 1972.

Information systems and databases

The GSNI continued to upgrade and advance its IT infrastructure, digital data capture and data delivery. Systems were upgraded to 10Mbit/sec, allowing improved communications between Belfast and other BGS sites. All the nineteenth century 1:63 360 scale geological maps of Northern Ireland and accompanying memoirs have been scanned. The 1:50 000 scale geological maps and memoirs will also be made available, subject to agreement over the supply of topographical background. The in-house geographical information system forms the backbone for the GSNI Public Information Service, which answered 583 enquiries for information and advice during the year, and also produced maps to support work on the Water Framework Directive and nitrate vulnerability zones. Eight geological maps were digitally attributed and the completion of Phase 1 of DiGMapNI-50 (the digital versions of all published GSNI 1:50 000 scale maps) is on target for December 2003.

Resource and Environment Survey of Ireland (RESI)

The Resource and Environment Survey of Ireland (RESI) project is a major initiative to provide ground geochemical and airborne geophysical coverage over all of Ireland. Final funding has yet to be agreed on an all-Ireland basis, but the GSNI will manage the implementation of the Northern Ireland component of the survey starting in 2004. The resulting data will be relevant and of value to environmental monitoring, geohazard identification, agriculture and mineral exploration.

Landscape heritage: limestone pavement near Florencecourt, part of the Breifne Mountains landscape interpretation project.
Reproduced with the permission of the Director, GSNI.



GSNI © Crown Copyright 2002



Environment and Hazards



The **Environment and Hazards Directorate** operates through five programmes to deliver information on how geoscience impacts on man and his 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 man as he goes about his 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 our 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 Lowland Catchment (LOCAR) initiative, and other studies, will help in the implementation of the Water Framework Directive.

The Earthquake and Forensic Seismology and Geomagnetism programme, now renamed the **Seismology and Geomagnetism** programme, continues to monitor and disseminate valuable information on seismic events and geomagnetism. It is progressing research into fracture anisotropy and fluid content that is exploited by the hydrocarbons and water industries. Industry consortia continue to grow, keeping the quality and usefulness of the science and information relevant. Detailed geomagnetic information is used increasingly by directional drilling practitioners.

The **Urban Geoscience and Geological Hazards** programme is using protocols established over the past few years to collect, collate and establish risks associated with the near-surface hazards found in cities. Space-based radar is being studied to detect small ground movements that can affect buildings and city infrastructure. Urban studies have shown the value of bringing geologists, engineers, remote sensors, geochemists and modellers together with planners and developers to improve safe land use.

The third year of the Pollution and Waste Management and Extractive Industries Impacts programme, now renamed 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 have been made with physiological extraction tests that mimic the human digestive system. The tests have been used to determine how much arsenic in naturally contaminated soils can be absorbed by, and how much passes harmlessly through, humans. Advanced statistical techniques have related transport properties of clays to simple index measurements.

The **Coastal Geoscience and Global Change** 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. Work on climate change is showing the importance of methane hydrates to the Earth's carbon balance. The programme leads work on climate change for the Tyndall Centre.

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

Environment & Hazards Mr D C Holmes 0115 936 3566 dcho@bgs.ac.uk		
Coastal Geoscience & Global Change Dr J G Rees 0115 936 3296 jgre@bgs.ac.uk	Urban Geoscience & Geological Hazards Prof. M G Culshaw 0115 936 3380 mgc@bgs.ac.uk	Groundwater Systems & Water Quality Dr D W Peach 01491 838800 dwpe@bgs.ac.uk
Environmental Protection Dr B Smith 0115 936 3423 bsmi@bgs.ac.uk	Seismology & Geomagnetism Dr D J Kerridge 0131 650 0220 djkk@bgs.ac.uk	Electrical Tomography Service Dr R D Ogilvy 0115 936 3359 rdo@bgs.ac.uk

Groundwater Systems & Water Quality

Programme overview

This programme supports UK environmental and industrial stakeholders in sustainable development and management of the water environment, as well as the Department for International Development (DFID) and international agencies driven towards achieving the Millennium Goals for water. It consists of about 80 projects equally divided between UK commissioned research, international commissioned research, and strategic science funded or co-funded by the NERC. New developments include strategic research with the Environment Agency (EA) into implementation methodologies for the Water Framework Directive, work with UK Water Industry Research (UKWIR) and the EA assessing trends and monitoring of degrading groundwater quality and, internationally, with the setting up of the DFID Oasis Water Resource Centre.

Sustainability of urban water resources

Assessing and Improving the Sustainability of Urban Water Resources and Systems (AISUWRS) is a three-year urban water research project, partly funded by the European Community. The project aims are to develop a decision-support system, supported by innovative modelling techniques, for cities that depend on underlying or nearby aquifers for their water supply. Case studies from the cities of Doncaster in England, Rastatt in Germany and Ljubljana in Slovenia are being used to develop the system, with the aim of making it robust enough to be used in the many other cities in Europe and elsewhere that depend on groundwater for public and private water supply.

Changing groundwater quality

United Kingdom Water Industry Research (UKWIR), the Environment Agency and the BGS have funded a project, 'Implications of changing groundwater quality for water resources and the UK water industry'. The aims of the project are to improve the identification and understanding of current trends in groundwater quality by developing tools for assessing such trends and defining the monitoring data needed to support such assessments, essential if drinking water supplies and groundwater resources are to be protected. Following a review of current groundwater quality monitoring, quality trends and trend analysis from both the water industry and published literature, a practical guide has been produced, summarising a step-by-step approach to trend detection and ways in which groundwater quality monitoring by the water industry can be improved.

UK regional groundwater modelling

Regional modelling for two groundwater catchments in the Chalk have been developed for a water utility to investigate the effects of changes in the management of groundwater resources. One has been built as a tool to investigate different management options for the operation of an artificial recharge scheme. It predicts the advantages and disadvantages of injecting water into one group of boreholes during times of surplus and subsequent abstraction from another group of boreholes during periods of high demand. The second model has been developed to investigate the impact of new public water supply boreholes, constructed to replace existing licensed abstractions along a river that suffers from low flows.

Lowland Catchment Research (LOCAR)

The BGS are undertaking three research projects in the NERC LOCAR thematic programme. Two projects are under way:

Hydrogeochemical functioning of lowland permeable catchments: from process understanding to environmental management. The aim of this project is to establish the main hydrological and hydrogeological controls on groundwater and surface water quality, including chemical transformations and flowpaths of the principal nutrients (nitrogen, phosphorus, carbon) in the Pang/Lambourn catchments. This involves the establishment of experimental river reaches and their adjacent riparian zones to determine flow pathways, fluxes and chemical transformation processes. Additionally an integrated, process-based modelling



BGS © NERC

Sustainability of urban water resources: Doncaster suburb, focus of the project's modelling tasks.



system describing the hydrochemical and nutrient functioning of lowland permeable catchments will be produced to assist sustainable river ecosystem management.

Flow heterogeneity. This project aims to investigate the heterogeneity of flow in the Chalk, which is known to vary over a range of scales. This has significant implications for water resource management at borehole to catchment scales. The rock mass properties and hydraulic characteristics of the aquifer will be determined using a suite of geological and geophysical survey and hydraulic and tracer tests. While these tests can be used to obtain effective values for hydraulic conductivity and groundwater velocity at a borehole or site scale, extrapolating these observations to larger scales is not a trivial exercise. In collaboration with Imperial College, London, models will be developed to interpret field test results which will aid the development of upscaling methodologies.

Dumfries aquifer study

The Dumfries Basin Aquifer is one of only a few major public supply groundwater resources in Scotland. Previous investigations have provided a basic understanding of the aquifer system, but attempts to simulate the groundwater flow system failed. However, data deficiencies were highlighted and the current project targets these. New geological mapping has been completed, and investigation of the relationship between groundwater and surface water has enabled a new conceptual groundwater flow model to be created. Groundwater chemistry has been evaluated as an indicator of provenance and age to support the model. Current efforts are concentrating on modelling the hydraulic relationship between aquifer and river, and creating an object-oriented groundwater flow model for the basin aquifer.

OASIS

The BGS is a lead partner, together with the Centre for Ecology and Hydrology and Hydraulics Research, Wallingford in the OASIS Resource Centre established by the Department for International Development (DFID). OASIS provides a range of support and advisory services in water resources to help DFID staff, other donors, non-governmental organisations, and developing country governments to create, share and use water resources knowledge to assist in delivering the Millennium Development Goals. BGS staff attended a regional groundwater quality meeting hosted by the United Nations Economic and Social Commission for Asia and the Pacific in Hanoi, and country summaries and subject-briefing notes on groundwater quality for WaterAid have been promoted.

Groundwater and its susceptibility to degradation

This publication prepared for the United Nations Environment Programme (UNEP) provides an overview of groundwater occurrence and of the main issues affecting its quantity and quality. It details how the resource is used in cities, industry and mining, in agriculture and rural water supply; how it sustains many wetlands; how, in its own undramatic way, groundwater has become an integral part of billions of people's lives. Numerous examples illustrate resource management issues and underline the need for active management rather than ad hoc development.

Lowland Catchment Research (LOCAR): borehole array for LOCAR research at Frilsham Meadow in the Pang valley.



BGS © NERC

Groundwater and its susceptibility to degradation: a publication prepared for the United Nations Environment Programme (UNEP).



Seismology and Geomagnetism

Programme overview

The Seismology and Geomagnetism programme is responsible for running the UK seismic network and magnetic observatories, monitoring seismicity and geomagnetic field changes. Application of modern technology gives rapid access to data: following earthquakes and during bouts of adverse 'space weather' causing magnetic storms, near-immediate information is provided to customers in government, industry and academia. Analysis of earthquake data advances our understanding of seismic hazards, and global geomagnetic field data are used to produce models for navigation. Research into advanced seismic methods is improving the understanding of rock–fluid interactions and has applications in the imaging and management of hydrocarbon reservoirs.



5 Sargeant, BGS © NERC

National earthquake monitoring: damage to the chimney and roof of a house in Bloxwich as a result of the Dudley earthquake, September 2002.

National earthquake monitoring

The third strong earthquake to strike central England in the space of two years was centred on Dudley, in the West Midlands, during the early hours of 23 September 2002. It had a magnitude of 4.7 on the Richter scale and awakened people over a wide area. It was felt from Dublin to the east coast of England and from Yorkshire to Devon, but damage was minor being confined to chimneys and roofs in the epicentral area. A month later, on 21 October, a magnitude 3.9 earthquake shook the Manchester area and was followed over the next five weeks by over 100 smaller ones at the same location. About 40 of these were also felt locally owing to their shallow depth of occurrence (three kilometres). The others were detected and pinpointed by the BGS nationwide seismic monitoring network, which is partly sponsored by external organisations, and locates some 200 earthquakes around the country every year.

Forensic seismology

Forensic seismology is an important technique for monitoring nuclear test ban treaties through the detection and identification of underground explosions. Under contract to the Atomic Weapons Establishment, the BGS operates the UK National Data Centre and exchanges seismic data for event detection, location and identification purposes with the Comprehensive Test Ban Treaty Organisation (CTBTO) in Vienna. The BGS provides seismological calibration data for the UK so that the CTBTO can allow for local variations in seismic velocity and attenuation along the wavepath in determining event location and magnitude. BGS station and distance corrections have also been determined from 385 observed shear-wave amplitudes, allowing more accurate determination of local magnitude. The BGS co-operates with UK universities in the determination of the velocity structure for the UK region; for example, a BGS-sponsored student has shown that a prominent slow velocity anomaly at subcrustal depth is strongly associated with Palaeogene volcanic rocks at the surface.

Geomagnetic field modelling

Global magnetic field models, used by the Ministry of Defence and the oil industry, rely on good quality global datasets. With this aim, the BGS plays a lead role in INTERMAGNET (an international project to improve geomagnetic observatory standards and data dissemination), acts as a World Data Centre for geomagnetic data, and is part of an international science team for the Ørsted and CHAMP satellite magnetic survey missions.

In determining magnetic field models, the BGS carefully removes unwanted sources of contamination, such as magnetic fields from the ionosphere and magnetosphere, and magnetic rocks in the Earth's crust. Some of these sources are always present and can be modelled accurately. To characterise these, the 2003 global model for the oil industry includes an extended set of parameters. Magnetic information on Ordnance Survey maps is derived from a regional model which the BGS updates every year to include the latest UK geomagnetic data. The BGS operate six magnetic observatories, three in the UK and three overseas in Ascension Island, Nova Scotia, and the Falkland Islands; hardware and software for environmental monitoring was also recently installed in the Falkland Islands. External organisations have commissioned BGS observatory equipment for installation in China, the Czech Republic, and Alaska.



Space weather

BGS software for the short- and long-term prediction of geomagnetic and solar activity has been continuously used at the European Space Operations Centre (ESOC) in Germany for over ten years. Such data are important for predicting orbit evolution for low Earth orbit observation satellites, such as ERS-1, ERS-2 and ENVISAT. An improved prediction method, using neural network analysis of geomagnetic activity, was developed and delivered to ESOC this year. Variations in measured ERS-2 atmospheric drag were shown to correlate well with other geomagnetic and solar data, demonstrating the potential for further improvements in orbit control.

The BGS was also commissioned to improve its existing geomagnetically induced current (GIC) monitoring and prediction service for Scottish Power. Over two years an extended real-time warning service will be developed which promises a better warning of arrival at the Earth of harmful space weather events and an enhanced model of how these events drive GIC in the power grid.

Tectonic deformation from space

PSInSAR is a new Earth Observation (EO) technique that provides measurements of ground displacements to a degree of accuracy previously unobtainable from conventional interferometry. From repeated surveys over many years, a network of highly reflective ground features (permanent scatterers) is identified against which submillimetre measurements of motion can be made. The scatterers can be any large, permanent angular object, such as roofs, metallic structures, and even large boulders.

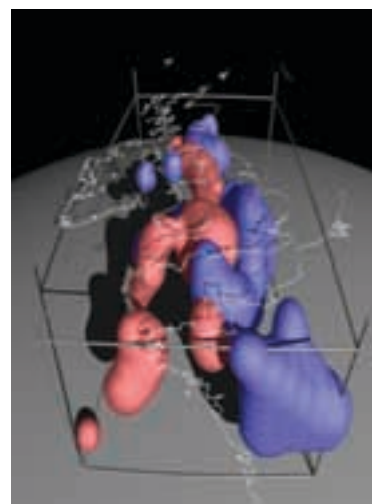
Using PSInSAR, very accurate displacement histories can be obtained from 1991 to the present for any part of the globe with adequate data coverage. PSInSAR data are being tested for applications to tectonic deformation in an area where monitoring of pre-seismic deformation yields clues to the nature of an impending great earthquake. The data are used in a European Space Agency EO project, led by Nigel Press Associates, in which the BGS is a participating member of an international consortium.

The Edinburgh Anisotropy Project

The Edinburgh Anisotropy Project (EAP), supported by a consortium of oil industry companies, has continued to provide solutions to industry problems, and sponsors have enthusiastically confirmed support for the next phase, 2003–06. The project has led the way to the successful industrial application of converted-wave anisotropic imaging through the provision of an improved theoretical basis and innovative processing algorithms. Another innovation has used analysis of frequency-dependent anisotropy to allow better seismic characterisation of the length scale of *in situ* fractures through the analysis of frequency-dependent anisotropy.

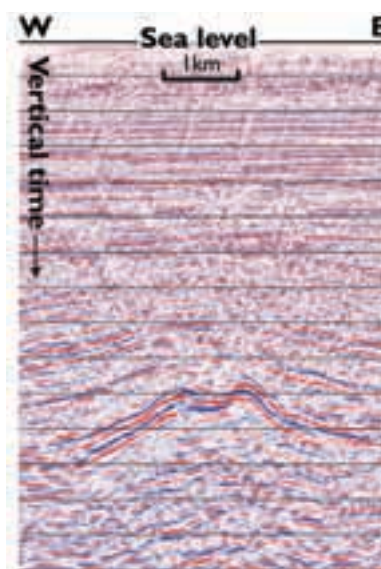
Theoretical studies have, for the first time, established a quantitative link between fluid flow and seismic parameters through the study of time-lapse anisotropy. A rock physics model, incorporating fluid–rock interaction at both the microscopic scale (pores and cracks) and the meso-formation scale (fractures and joints), models fluid movement in cracked rock and was developed in collaboration with the universities of Cambridge and Edinburgh as a result of the NERC ‘Micro-to-Macro’ project.

Forensic seismology: 3D view of a volume from 50 to 600 km depth beneath the British Isles; high (blue) and low (red) P-wave velocity anomaly surfaces enclose regions of over 0.50% higher and lower velocity. The underlying grey sphere represents the 660 km discontinuity.



S. Arrowsmith, BGS & Leeds University

Edinburgh Anisotropy Project: borehole data supplied by BG confirmed this EAP image of a reservoir beneath gas clouds in the North Sea Lomond Field, produced using converted waves where conventional techniques had failed.



F. Mancini & Hengchang Dai, BGS & NERC

Urban Geoscience & Geological Hazards

Programme overview

The aim of the Urban Geoscience and Geological Hazards programme is to provide the user community with information on, understanding of, and solutions to its problems with ground conditions and land quality, particularly in urban areas. These problems include:

- Modelling and visualising the shallow subsurface.
- Measuring the chemical, physical and mechanical properties of subsurface materials.
- Identifying the geotechnical behaviour of rock and soil formations.
- Predicting the likely occurrence of geological hazards, including the movement of the solid, liquid and gas phases.

Modelling the shallow subsurface in the urban environment

Recent work in Manchester, Glasgow and Swansea has led to new methodologies for studying the urban environment. The emphasis on the shallow subsurface reflects the increasing need for information to underpin urban development and regeneration strategies. A radical new approach to data collection and interpretation is required to answer questions such as:

- Is the site stable?
- Is sustainable urban drainage (SUDS) an option?
- Is the site likely to be contaminated?

To meet this challenge, the BGS's GIS and 3D modelling capabilities have been expanded. Models prepared for Manchester, Swansea, Glasgow and parts of south-east Northumberland draw on a range of corporate databases to illustrate the interdependency of geology, hydrogeology and engineering geology for deriving bespoke thematic products. The 3D geological model for central Manchester (*top right*) incorporates information from over 6000 boreholes. Simple interrogation tools provide the facility to produce:

- Synthetic logs and cross sections at user-defined locations.
- Contoured surfaces.
- Deposit thickness maps.
- Composition maps.
- Pipeline-transect maps.

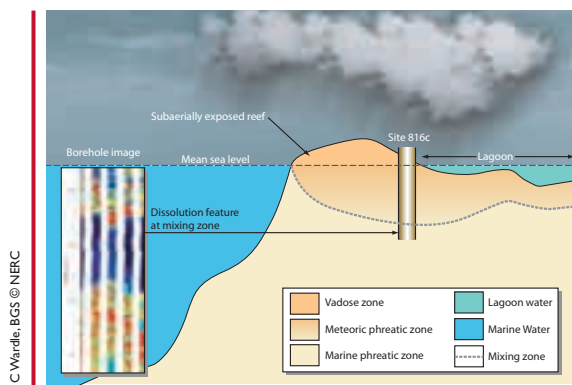
An example of a possible thematic output shows groundwater vulnerability in the Trafford Park area of Manchester (*bottom right*), one of Europe's largest industrial estates. In the uncoloured areas the superficial deposits are thin or sand-dominated, and afford little protection to groundwater in the event of a major pollution incident.

Urban geochemistry

Soil and water sampling continues to form part of the urban strategy, driven in part by legislation and local authority interest in acquiring baseline geochemical information. The geochemistry of Stoke-on-Trent, recently published, is a landmark study on the use of geochemistry in the urban environment. A site prioritisation tool has also been designed which is being used to assist local authorities identify and prioritise potentially contaminated sites. This tool is continuing to be refined to take account of 3D geological variability and in terms of sampling protocols.

Carbonate porosity modelling

Modelling of down-hole compressional wave velocity and electrical resistivity data, obtained during Leg 133 of the Ocean Drilling Program, has identified trends in the connectivity of the pore system at a site on the Great Barrier Reef. This joint research with Enterprise Oil was published at the 2002 annual conference of the London Petrophysical Society. Three-dimensional pore-scale resistivity modelling showed values of Archie's m parameter less than 1.4 to be consistent with connected planar features, and the onset of cementation to be consistent with a change in the nature of the porosity. An interval characterised by



Carbonate porosity modelling: schematic diagram of the environmental interpretation of the Great Barrier Reef and the scanned image of the borehole core.



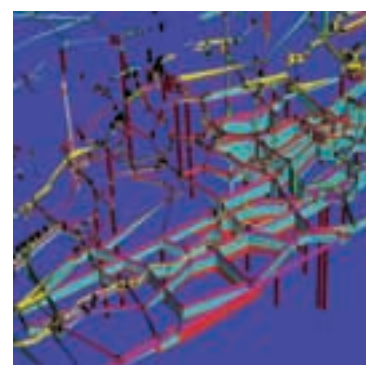
$m = 1.2$, and correlated with borehole image data was attributed to a fracture interpreted as a sub-horizontal dissolution feature. This feature is provisionally interpreted as having been formed as a result of prolonged subaerial exposure of the reef, linked to the major low sea stand occurring in the late Miocene (10.4 Ma). Enhanced dissolution by mixing corrosion between undersaturated and supersaturated fluids was postulated at the interface between marine and meteoric phreatic waters (*bottom left*). A refined understanding of the potential storativity and connectivity related to such dissolution features has significant commercial benefit in modelling fluid flow and storativity.

A potential ground movement information service for the UK

Ground movements represent a significant hazard in the UK, having cost British insurers more than £3 billion in claims over the past 10–15 years. Many of these ground movements are due to natural geological processes, with many being aggravated by more extreme weather conditions, such as wetter winters or drier summers. These geohazards include landslides, shrinking and swelling clays, mineral dissolution, karst subsidence, and consolidation of alluvial deposits. Ground movements are also caused by human activities such as extraction of rocks, minerals and fluids by ancient and modern mining, tunnelling, water abstraction, and the construction of landfill sites (sometimes leading to excessive settlement). Rising waters in abandoned coal mines might also cause reactivated ground movements along pre-existing geological faults. All of these can seriously affect roads, buildings and other infrastructural developments.

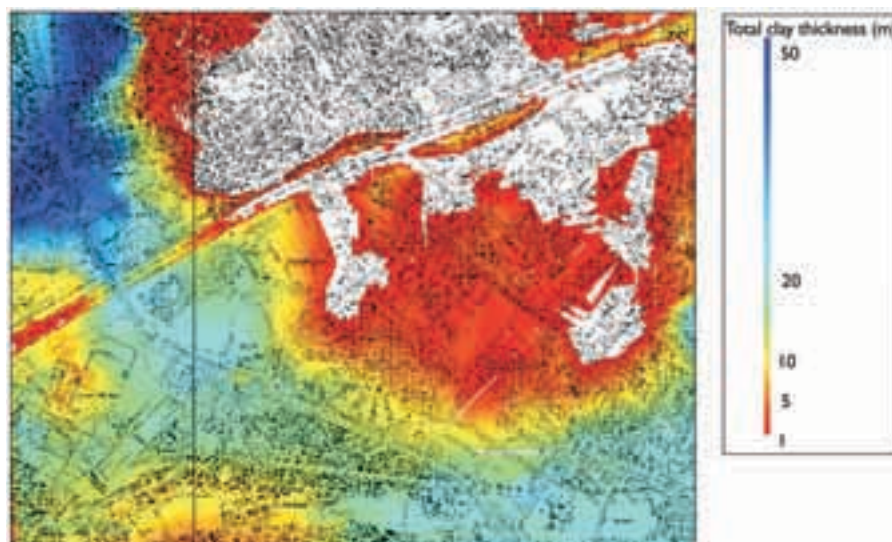
There now exists a new satellite surveying technique known as Permanent Scatter Interferometry (PSInSAR) that was initially developed by TeleRilevamento Europa (TRE) of the Politecnico di Milano, Italy. This can map millimetre-scale movements of suitably oriented building and ground reflector surfaces, towards or away from a satellite, during its current overpass interval every 35 days. By processing a 10-year archive of radar data scenes, collected from European satellites 800 km up in space, it is now possible to produce retrospective, time-average, and relative 35-day displacement histories for individual point reflectors contained within 100 km square blocks of land. The BGS, in association with Nigel Press Associates (NPA), a specialist satellite mapping company, and funded by the British National Space Centre, have been seeking to initiate a National Ground Movement Information Service. Example presentations from the London, Gateshead and Glasgow areas, were made to property developers, insurance companies, civil engineering and extractive industries, and regional and local government agencies.

Modelling the shallow subsurface: sections used to create the 3D model of the shallow subsurface across central Manchester and Salford.



BGS © NERC

Modelling the shallow subsurface: groundwater vulnerability in Trafford Park, Manchester.



BGS © NERC. Topography © Crown copyright. All rights reserved NERC 2K99D8/2003.

Environmental Protection

Programme overview

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

Physiologically based extraction testing

Physiologically based extraction testing (PBET) represents one way to improve accuracy and scientific rigour when assessing risks to human health. The BGS has led the UK in the development and application of these tests to a variety of contaminated land and human health assessments. For example, PBET testing of arsenic in soils from central England has shown that soils naturally contaminated with arsenic may not need to be remediated as this arsenic is present in a form which is not bioavailable. Other studies using this test to study soils from termitaria, which are often habitually consumed by young adults in Africa, have demonstrated that essential trace elements such as iron are more bioavailable in soils from termitaria than from other more available roadside sources. The BGS currently participates in two international working groups in this area.

Mining

The development of the UK during the industrial revolution was driven by the exploitation of natural resources produced both in the UK and the colonies. Today, landscapes resulting from mining and mineral processing dominate some areas of the countryside and are often, perhaps incorrectly, associated with widespread pollution of the natural environment. The Environmental Protection programme has, through an EU Fifth Framework Programme grant, completed the UK-based component of an international collaborative study (MINEO) to investigate how state-of-the-art remote sensing techniques, such as hyperspectral imaging, may be applied to the monitoring and identification of harm resulting from these sites.

Nuclear waste disposal

While UK-based research into nuclear waste disposal essentially remains moribund, the Environmental Protection programme continues to undertake innovative work in this area through commissions from overseas agencies and research bodies. Specific highlights include the commissioning by the Nuclear Energy Agency of a reference book on the self-healing of clays; Svensk Kärnbränslehantering AB (SKB) of Sweden commissioning the BGS to manage and plan their full-scale gas release test; and the successful bid under the EU Fifth Framework Programme of the PADAMOT project, which investigates historical flow in fracture networks and integrates this with other palaeo-hydrogeological data.



BGS © NERC

Mining: hyperspectral image of settling ponds at Wheal Jane, an abandoned mine in Cornwall. Each colour can be matched to a particular mineral, and waste piles as small as 3m across can be identified and analysed by this method.



B. Smith, BGS © NERC

Nuclear waste disposal: The Environmental Protection programme has continued to undertake research work to improve our understanding of how contamination has migrated from existing sites. For example, the programme has undertaken work with the Coastal Geoscience and Global Change programme (pages 32–33) to investigate geochemical processes controlling the migration of radioactive particles containing uranium from the Dounreay site (above).



B. Smith, BGS © NERC



Physiologically based extraction testing: the redevelopment of contaminated land in the UK requires accurate and robust risk assessments to balance the costs and benefits associated with this activity. The development of the PBET methodology represents an important step in this context.

Spectral Induced Polarisation: BGS laboratory model tank with SIP instrumentation.



J. E. Chambers, BGS © NERC

Electrical Tomography Service

The Electrical Tomography Service (ETS) has developed a leading-edge capability in non-invasive electrical tomographic imaging, including instrumentation, sensors, software and innovative field measurement techniques. ETS provides a research-led consultancy service to industry, primarily in the field of environmental, engineering and hydro-geophysics. In accordance with government and NERC policy, new mechanisms are being explored to assist the commercialisation of ETS research. In conjunction with several universities, research has continued on the development of advanced electrical resistivity imaging techniques including:

Spectral Induced Polarisation (SIP): A prototype SIP system has been designed for the non-invasive mapping of toxic non-aqueous phase liquids (NAPLs), including oils and solvents. NAPLs pose a serious risk to groundwater and are resistant to biodegradation and natural attenuation. Laboratory SIP experiments confirm that NAPL distributions and flow-paths can be detected in the complex frequency domain, using differential time-lapse imaging. Advanced 2.5D SIP inversion code has been developed which allows the Earth's multi-spectral response to be modelled in terms of Cole-Cole dispersion parameters. Residual NAPL saturation levels can be estimated from the resistivity models by applying Archie's second equation. However, further work is needed to assess the practicality of SIP tomography at the field scale. This work, funded by a three year EPSRC-Link award, involves collaborative research with the University of Lancaster, University of Birmingham, Advantica plc (formerly British Gas), Technos Ltd, and Campus International Products Ltd.

Capacitive Resistivity Imaging (CRI): A prototype resistivity imaging system has been designed using capacitive electrodes. Non-contacting capacitive electrodes permit continuous data acquisition on highly resistive artificial surfaces (such as tarmac and pavement) as well as natural ground. The theoretical equivalence of electrostatic and DC resistivity at low induction numbers allows the adaptation of existing 2D/3D and 4D tomographic image reconstruction schemes. The system is integrated with a real-time kinematic global positioning system for accurate navigation and location recovery. Ultra-high density resistivity scans can now be obtained with centimetre-scale resolution. The prototype CRI system has been used to detect abandoned mineshafts, and potential exists for the rapid mapping of soils, shallow fuel leaks from storage tanks, or for the non-destructive testing of roads and engineered structures. A patent is pending. This work, funded by a three-year EPSRC Grant award, involved collaboration with the University of Nottingham and the Coal Authority.

Capacitive Resistivity Imaging: BGS-designed, towed CRI system with five channels. A new platform is being designed for production surveys.

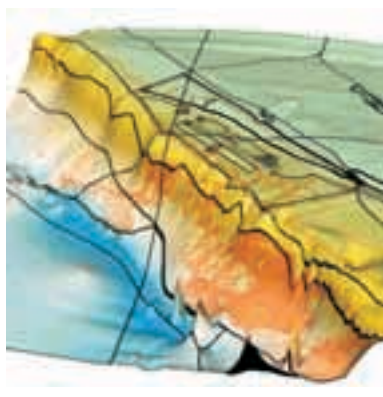


O. Kuras, BGS © NERC

Coastal Geoscience & Global Change

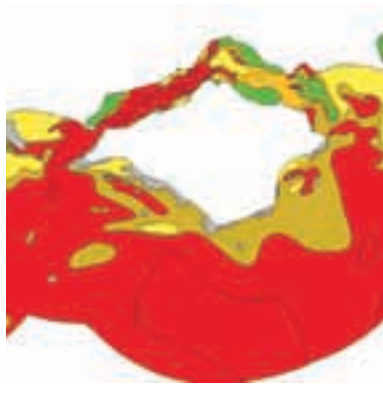
Programme overview

The 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.



BGS © NERC

Whitby Lighthouse survey: model of the Whitby lighthouse area based on the BGS surveys.



BGS © NERC

Sea-bed habitats and features: classification of sea-bed habitats around the Isle of Wight.

Whitby Lighthouse survey

A research programme was commissioned by Trinity House Lighthouse Service to investigate cliff stability around Whitby Lighthouse, on the North Yorkshire Coast to the south-east of Whitby Harbour. The main aim was to establish a baseline study of the area around the lighthouse against which future ground movements could be compared, thus allowing the stability of the lighthouse to be monitored. The rocks underlying the lighthouse consist of the Whitby Mudstone, Dogger and Saltwick Formations of the Lias and Ravenscar Groups. These comprise mixed lithologies with markedly different engineering characteristics. Following a literature review and reconnaissance survey, detailed geological and geomorphological surveys of the cliffs and land surrounding the lighthouse were undertaken using the BGS's terrestrial LiDAR (laser-scanner) and global positioning and geographical information systems. The surveys allowed the formulation of models of landslide mechanisms. Finally, a ground-movement monitoring network around the lighthouse compound and a baseline surface model for future assessment of cliff recession was established using 14 000 high-precision ground control points derived from the survey data. This included the setting-out of stable benchmarks and marker pins. These data were combined to form a three-dimensional model of the cliff and cliff top.

Sea-bed habitats and features

Part of the European Habitats Directive involves selecting, proposing and designating Special Areas of Conservation. These sites are designated to conserve natural habitats and species that are rare, endangered or vulnerable within the European Community. To implement the Directive, English Nature needed to be able to locate where habitats occur. To identify selected sea-bed habitats between mean low water and 12 nautical miles off the English coast, it commissioned the BGS to create a geographical information system (GIS) and database containing primary physical sea-bed features based upon the distribution of rock and sediment at the sea bed. Biological distributions — such as those of *Sabellaria spinulosa*, *Mytilus edulis*, and *Modiolus modiolus* — were integrated into the system. On this basis, English waters were subdivided into 17 areas and a detailed report of the physical environment was produced for each. The GIS and database will be used by English Nature in the process of designating marine Special Areas of Conservation.

Tyndall Centre Coastal simulator

As part of the Tyndall Centre theme 'Sustaining the Coastal Zone', the BGS is leading a project to build an integrated coastal sediment dynamics and shoreline response simulator. This is modelling coastal recession and accounting for the flux of sediment in the nearshore zone around the East Anglian coast between Lowestoft and Weybourne. The modelling is being undertaken in collaboration with several partners including: the Department of Civil Engineering at the University of Bristol, who are providing the modelling expertise through their CliffSCAPE model; the Flood Hazard Research Centre at the University of Middlesex, who are developing a GIS platform to represent the model outputs and the socio-economic impacts of recession; and the Department of Geography at the University of Cambridge, who are providing processed beach profiles from the Environment Agency. Apart from managing the project, the BGS is providing new data on cliff composition, beach thickness, platform heights and assessment of material strength in order to calibrate and develop the CliffSCAPE model. Some of the data used have been collated by laser scanning and geophysical assessment of beach materials.



Oxygen isotope ratios in lignin: a new climatic indicator

Stable isotope compositions of wood and its components (such as cellulose and lignin) are a potential source of palaeoenvironmental and palaeoclimatic information. Past variations in $\delta^{18}\text{O}$ Oxygen in meteoric water are recorded, for example, in polar ice cores and glaciers. However, complementary $\delta^{18}\text{O}$ data from specific components of fossil plants could improve our understanding of palaeoclimate in a wide range of terrestrial environments. Several studies have focused on isotopic information from cellulose because it is easy to isolate, but in fossil wood (older than two million years) cellulose is poorly preserved or absent. This obstacle can be overcome by the analysis of the recalcitrant lignin polymer. The BGS, in collaboration with the University of Nottingham, is researching a rapid procedure using catalytic pyrolysis under high hydrogen pressure to obtain lignin-enriched residues from wood by achieving high levels of devolatilisation of polysaccharides. The pyrolysate water from this hydrolysis is then analysed to determine $\delta^{18}\text{O}$ that is used to provide climatic information and improve environmental change models.

Coastal erosion in Tonga

The BGS has completed a study into a serious problem of coastal erosion in the west of the main island of Tongatapu, Tonga, for the Commonwealth Secretariat in collaboration with the South Pacific Applied Geoscience Commission. The area has been intermittently flooded since the 1970s but now, because villages are imminently threatened, remedial action is urgently needed. The datasets used to evaluate the problems included time-series aerial photography and satellite imagery, detailed field levelling, field observation and photography. The advice of local inhabitants was sought. The study shows that the flooding is likely to be the result of a combination of natural and human causes over the past 40 years. The coastal barrier is low-lying and may have been weakened in the 1970s by beach sand mining and breaching during storm conditions. Subsequently, human activity may have further reduced the resistance of this barrier to erosion and, in 1997, a large area of the coast was severely flooded, and possibly lost permanently to the sea. It has been recommended that the construction of soft engineering defences will help to protect the area from future inundation if human impacts are reduced. All construction work should take account of the local inhabitants' traditional right of access to the sea.

Thames Estuary

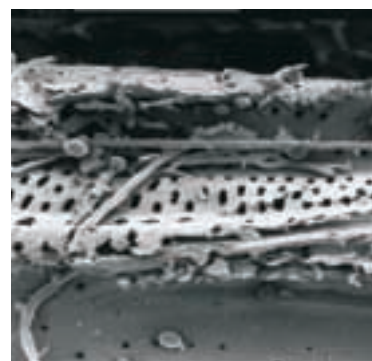
The Thames Estuary is one of the main areas of focus within the BGS Coastal and Estuarine Evolution project. Systematic collation and evaluation of existing data and construction of cross-estuary and down-estuary cross-sections is being undertaken in support of an attributed 3D conceptual model. Based on this model, subsequent phases will comprise data sampling and modelling in areas of poor or sparse data coverage and where the conceptual model is poorly understood. The initiative seeks to improve our understanding of the processes involved in the evolution of the estuary over the past 10 000 years as a key to predicting the impacts of future climate change. It follows best-practice methodologies for systematic data collation and modelling within the Humber and Mersey estuaries adopted and developed within the Digital Geoscience Spatial Model (page 42). Furthermore, it builds on the success of urban geoscience projects in London. Partnerships are being developed with a range of estuary stakeholders and sections of the scientific community, particularly archaeological groups. The phasing and prioritisation of the project will be sufficiently flexible to meet the needs and interests of a wide range of users.

Tyndall Centre Coastal simulator: beach thickness monitoring.



B Humphreys BGS © NERC

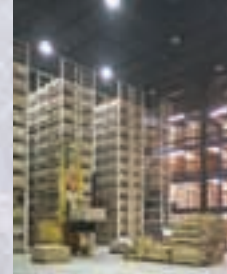
A new climatic indicator: SEM micrograph of wood decay by fungi.



C Vane, BGS © NERC



Information Services and Management



The BGS Strategy places information at the heart of BGS activity. The BGS is now recognised as not only a survey and research organisation, it is also an information organisation. The **Information Services and Management Directorate** (ISMD) is responsible for information management and delivery (through the **Information Management** programme and the **National Geoscience Information Service**) and two major projects the **Digital Geoscience Spatial Model** (DGSM) and **GeoHazarD**. ISMD also manages an internal BGS Service: **Publications Production**.

A highlight of the year for ISMD was the continued strong demand for geoscience information products and services. This is a positive endorsement of the considerable investment in corporate information management and digital capture programmes, and the development of innovative delivery systems, such as GeoReports. An increasing amount of digital data is now being made available, including: updated versions of digital geological map data at a variety of scales; high resolution national models of superficial deposit thickness; and images of one million scanned borehole records.

During the year the DGSM project was reviewed by the NERC (involving international scrutiny); it received a very positive report. There was a strong BGS presence at major public and educational events — National Science Week, Doors Open Day, Earth Alert 2002 and the Earth Science Teachers' Association. In November the Brian Wilson MP, Minister of State for Energy and Construction, opened a major extension to the National Geosciences Data Centre.

The BGS is regarded as an exemplar organisation in terms of environmental information management and delivery. It has received positive endorsements from the NERC and has frequently hosted visits from other geological surveys wishing to observe the systems and procedures that have been developed. Further, it continues to be invited to provide advice and services on geoscience information to several geological surveys around the globe, to central and local government, and to the commercial sector.

Finally, a considerable amount of effort has been invested within the year on monitoring and providing input to the challenging area of UK and EU policy on access to environmental and public sector information.

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

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

Information Management

Programme overview

The Information Management programme is responsible for the management of all data and information within the BGS. This includes all digital databases, paper archives, and material collections including rocks, minerals, fossils and borehole core. The aim is to manage the information in a coherent and integrated manner for the benefit of the citizen, government, industry and BGS scientists.

NGDC opening

Brian Wilson MP, the Minister of State for Energy and Construction, opened the newly extended National Geoscience Data Centre at Keyworth on 5 November 2002. A total of 38 external visitors, including the Minister, the Lord Mayor of Nottingham, the Mayor of Rushcliffe, and representatives from industry were joined by BGS staff who either work in the Centre or who had been involved with the transfer. The Minister was presented with two gifts from the BGS to mark the occasion.

The building of the new extension, the transfer of data and its rehousing, were funded by Nirex, the Coal Authority and the NERC, who also contributed to the staffing required to carry out indexing and digitisation. The material and documents transferred from Nirex and the Coal Authority occupy over 1000 cubic metres. New racking was installed to hold the collections, which consist of more than 470 tonnes of core and other materials. Compact mobile racks were installed for the 8000 boxes of deep mine data, opencast data, seam analyses and reports, occupying over one kilometre of shelving.

BGS Geoscience Imagebase

The BGS has participated in the 'Resources for Learning in Scotland' consortium which is managed by the Scottish Cultural Resources Access Network and funded by the New Opportunities Fund. The BGS contributed 2050 images and metadata in four projects:

- rocks, fossils and minerals of Scotland;
- building stones of Scotland;
- building stones of the Edinburgh New Town; and
- the economic minerals of Scotland.

The Geoscience Imagebase, the new database for photographs and images, is now fully operational for data and image input and is proving very popular as a safe and accessible repository for photographs and digital images from throughout the BGS. The core of the system is a database together with a data entry application and a series of workflows for processing, managing and incorporating the images. The Geoscience Imagebase will underpin the publicly accessible National Archive of Geological Photographs and the forthcoming BGS commercial picture library.

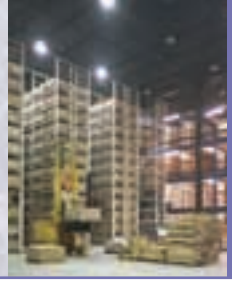
PalaeoSaurus

The BGS palaeontological collection contains over three million fossils and is the foremost British biostratigraphy collection. It contains the fossils that underpin many of the dates on the BGS geological maps. It also includes over 30 000 specimens of taxonomic importance, such as the type specimens of numerous British species, plus many specimens that have been figured or cited in publications. Collections such as these are important in maintaining the stability of Linnaean taxonomy. The collections include material collected before the formation of the Survey in 1835. Some of the specimens were used for the displays in the nineteenth century 'Museum of Practical Geology' in Jermyn Street, and later in the 'Geological Museum' in South Kensington. Palaeontological collections such as these only achieve their full importance if they are easily accessible. To this end, a detailed database, PalaeoSaurus,



BGS © NERC

NGDC opening: Brian Wilson MP and David Falvey with the plaque commissioned to mark the opening of the NGDC extension, November 2002.



was developed during 2000/01 and work to populate it is continuing. Priority has been given to the taxonomically important material used by scientists across the world, as well as to areas such as the Southern Uplands and Caithness that are currently being surveyed by other BGS projects. For the database to reach its full potential, it requires linking to the World Wide Web to allow international access. This is scheduled for 2003/04.

Strategies and systems for maximising data value

This project was carried out by the BGS for the Department for International Development (DFID) under the department's 'Knowledge and Research' programme. The project aims to help Geological Survey Organisations (GSOs) in developing countries get the maximum value from their geoscience data holdings by improving data organisation and accessibility using digital techniques. The work was structured as a series of modules covering: data management issues; the development and implementation of a template geoscientific data model; the development of a geographical information system (GIS), both to act as an interface to data and to illustrate the use of GIS in geoscientific data analysis; and the development of a web site¹ and CD-ROM. Together the modules cover all aspects of geoscience data handling from the organisation of paper records through to dissemination on the web. Training was a key element of the project and, apart from providing some traditional project workshops, was achieved through a distance-learning based training module. By providing online training material, it is hoped that the project web site will be a self-contained resource that can be widely used beyond those GSOs who have collaborated on the project.

¹www.bgs.ac.uk/dfid-kar-geoscience/r7199/

DEAL WellHeaderML

The BGS has managed the Digital Energy Atlas & Library (DEAL) web site (www.ukdeal.co.uk) on behalf of Common Data Access Ltd (CDA) for the past three years. As part of this process, information exchange has been improved and streamlined. One development is the DEAL WellHeaderML Schema, an Extensible Mark-up Language (XML) data exchange system. This is being developed in a collaborative project with CDA, Department of Trade and Industry (DTI) and Petrotechnical Open Software Corporation (POSC). The Schema is derived from the POSC WellHeaderML. The purpose is to provide automatic updates of the DEAL database at various stages of the process in which an oil company receives consent to drill a well from the DTI using the DTI's Well Online Notification System (WONS). The system will transfer key data from the WONS system to the DEAL database using XML. The automated process will improve accuracy, and ensure that the DEAL database has the most up-to-date information. The technical specification of WellHeaderML can be viewed at:

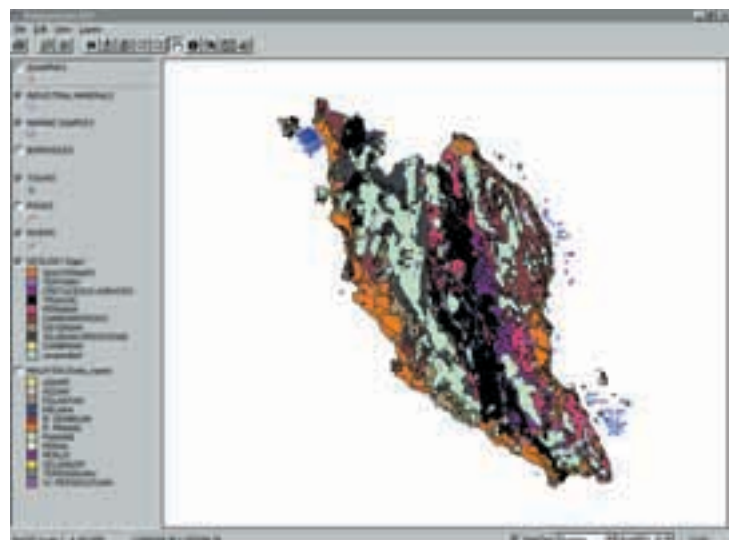
www.ukdeal.co.uk/schemas/doc/deal_wellheaderml_1/deal_wellheaderml_1.html.

PalaeoSaurus: BGS palaeontological collection contains over three million fossils and includes over 30 000 specimens of taxonomic importance.



BGS © NERC

Strategies and systems for maximising data value: the user interface of the demonstration GIS showing geology and sample data for Malaysia.



BGS © NERC

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. Activities managed and operated under the NGIS programme are the Digital Geological Map of Great Britain (DiGMapGB), Electronic Dissemination of Information, Public Understanding of Science, the BGS Library, Enquiry Service, Sales, and Intellectual Property Rights.

DiGMapGB

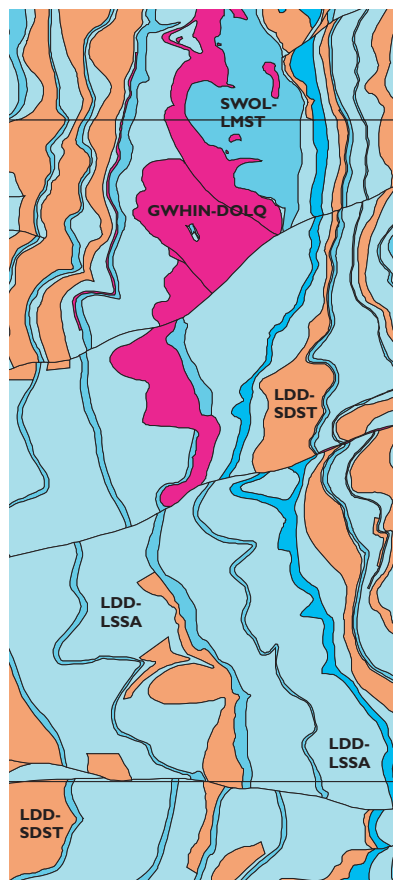
The purpose of this project is to prepare nationwide digital geological map data in vector GIS format at a range of scales from 1:625 000 to 1:10 000. Following the release in 2001/02 of the first version of the DiGMapGB-50 onshore, work at this scale concentrated on the large task of refitting the linework and rationalising the geological attribution to make the second version of the database, which will be as seamless as possible with the data currently available. By the end of the year, about 80% of England and Wales data and about 50% of Scotland data had reached first proof stage. Good progress has also been made on DiGMapGB-10, a dataset particularly important for urban areas. About a thousand 5km x 5km tiles (of an initial target of about 2500) are completed or in progress. Offshore, all the 1:250 000 scale Bedrock (Solid) geology maps were digitised to final proof stage. All DiGMapGB data are available for internal and external use and are the core datasets on which many derived products and new services are being built.

Electronic Dissemination of Information

The main Internet site continues to be popular with a steadily rising rate of visits. By the end of the year, visitor numbers (counted over successive four-week periods) had reached about 50 000, compared with about 40 000 a year earlier. Internally, the site went through a major structural revision to make it more responsive and easier to maintain. The content of the site is in a continual state of growth and update, increasing the information on the BGS and its expertise and providing a wealth of free reference information. The BGS e-commerce site continued to be developed and upgraded with full credit card handling added to the site. The BGS Intranet is a core element of our scientific and administrative operation. It now has over 37 000 static pages and 2500 ColdFusion™ scripts. Over the year, the availability of BGS reports to view internally online and to download from the main Internet site has increased substantially.

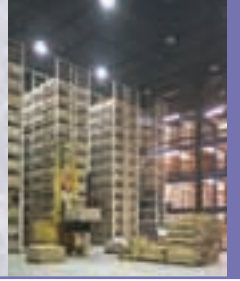
Public Understanding of Science

The BGS seeks to promote the earth sciences generally and to publicise its work to as wide an audience as possible. Our magazine, *Earthwise*, is usually published twice a year; although in 2002/03 because of pressure of other work only one edition, *Energy and Mineral Resources*, was prepared for publication. The BGS's regular contributions to national and regional events have included National Science Week, during which 900 schoolchildren and teachers visited our Keyworth site, and Doors Open Day at our Edinburgh office. In feedback from the British Association, 60% of teachers rated our Science Week event as 'excellent'. Exceptional public events with BGS involvement this year were Earth Alert 2 at Scarborough, where our exhibit, *Tiptoe Through Time*, was enlarged and the educational content and presentation enhanced, and the Earth Science Teachers' Association Annual Course and Conference, hosted at Keyworth. The ESTA event was a major success, raising BGS's profile and improving links with the education sector. The Internet is an increasingly important way to disseminate science information to the general public. Visits to the education section of our web site grew steadily during the year and were 67% up compared with 2001/02. This section continued to be enhanced during the year, most notably with the addition of *Ask-about-Geology*, offering a free online Q&A service for non-specialists. Guided tours of BGS sites and presentations on the work and history of the Survey are regularly given to academic, community, business, and amateur geology groups.



BGS © NERC

DiGMapGB: a sample from DiGMapGB-10, the digital geological map dataset at 1:10 000 scale. The example shown is from the Great Bavington area, to the west of Newcastle-upon-Tyne.



Library

Core library services for BGS users were maintained, although staff shortages throughout most of the year at Keyworth meant that some planned improvements in service have had to be delayed. Continuing population and development of the GEOLIB system was also given a high priority as the drive towards more desktop services was maintained. With the success of the reproduction of the William Smith map of 1820, investigation was undertaken into the more difficult task of reproducing the famous 1815 map. Results are encouraging and publication should happen in 2003/04. The Library in Edinburgh continues to be successful in winning contracts from SCRAN/NOF for the digitisation of archive photographic material.

Sales

A major advance at the end of year was the installation and successful launch of the new electronic sales and stock management system (SMS) in the Keyworth sales desk, reception and publication store. Implementation in Edinburgh is planned for 2003/04. The SMS allows us, for the first time ever, to have an accurate and ready record of all our publication stock and who buys it. Work continued into widening the market base, and actively increasing the number of outlets selling BGS publications, increasing brand recognition and raising awareness of our range of publications and services. This was successful as publication sales were strong throughout the year and gross sales revenue rose by 18% compared with 2001/02. The Internet Bookshop is a growing success, particularly since full electronic online payment was introduced in May. Revenue from online sales was about 8% of the total in the full year, and is still rising significantly.

Enquiry Service

The BGS Enquiry Service recorded over 5000 public good (uncharged) enquiries by members of the public and continues to meet its customer response targets. The commercial side of the Enquiry Service continues to grow strongly. Gross revenue for the year was up about 18% compared with last year. The growth arose mainly from increased sales of site-specific geological reports sold under the newly launched GeoReports service, an automated report-generating service available over the Internet with full e-commerce capabilities. The provision of copies of BGS records was approximately at the previous year's levels; around 6000 enquiries resulted in about 17 000 copies of records (mainly borehole logs) being made.

Intellectual Property Rights

Intellectual Property Rights (IPR) activities continue to ensure the BGS's rights under current intellectual property legislation, and the forthcoming EU Directive on Copyright. Demand for the use of BGS data and information continued to increase. Links are maintained with counterparts in the Scottish Executive, National Assembly of Wales, DETR, Environment Agency, Hydrographic Office, Ordnance Survey, Scottish Environment Protection Agency, Open University, HMSO, and the Cabinet Office. A series of presentations and workshops about IPR and licensing for BGS technical, finance and contracts staff were given. The BGS led for the NERC in the negotiation of the NERC–Environment Agency Corporate Service Level Agreement on data provision between the two parties.

Public Understanding of Science: young visitors examining fossils from the BGS collections during the Open Day at Murchison House, Edinburgh in 2002. This annual event is the BGS's contribution to Doors Open Day in Scotland.



T Harris, BGS © NERC

Library: William Smith's famous geological map of 1815. An original, held in the BGS Library, has been scanned and a reproduction prepared for publication during 2003/04.



BGS © NERC

Publications Production

Programme overview

The Publications Production programme delivers the BGS's formal published output: maps, books and reports, and also is a major contributor to the BGS digital data holdings, in particular the Digital Geological Map of Great Britain (DiGMapGB) and images for the National Archive of Geological Photographs. In addition, it also designs and produces marketing and promotional materials such as web pages, posters, brochures, and flyers. Publications Production continued to make substantial progress towards ISO 9000 compliance in 2002/03.



BGS © NERC



BGS © NERC

Cartographic Production

Maps and diagrams are produced and published at a variety of scales and reflect output from a wide range of surveys. Following field surveys and desk interpretations by geoscientists, cartographers use geographical information systems (GIS) to capture the geological compilation. GIS are used to build the digital spatial databases, and supply comprehensive geoscientific attributions for spatial data. From this, using customised interfaces and production techniques which increase the efficiency and quality control of cartographic production, the spatial data are prepared for supply to specialist map printers. This is the system used to deliver DiGMapGB (*see page 38*), and which also contributes to the Digital Geoscience Spatial Model (*see page 42*).

Book Production

A range of high quality litho-printed books and print-on-demand reports accompany the maps. Memoirs, Sheet Explanations and Sheet Descriptions describe the 1:50 000 scale map, and Regional Guides provide a geological account of a wider area. Many reports are converted to digital documents in Portable Document Format (PDF) and made available as free Internet downloads.

Output in 2002/03

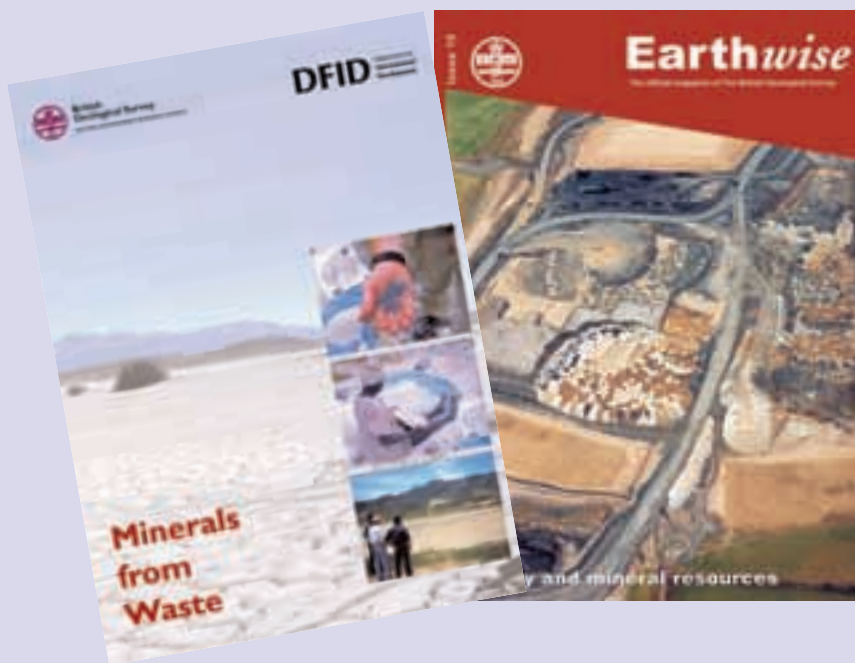
Digital map and book data and printed copies made during this report period include:

- Additions to the 1:50 000, 1:25 000 and 1:10 000 scale map databases.
- Additions to the horizontal sections database.
- Off-shore bathymetry data released for English waters at 1:250 000 scale.
- Twenty-one litho-printed maps at 1:50 000 scale.
- Three gravity anomaly maps released at 1:1 000 000 scale.
- Nine maps in the county minerals series.
- Four memoirs.
- Nine Sheet Explanations.
- Four Sheet Descriptions.
- One Regional Guide.
- Nine Technical Reports.
- Two 'Special' publications.
- Eleven titles in the poster/brochure series.
- Six Annuals.
- Eight web sites designed and constructed for science and education.
- Three titles in the Popular Publication series.



Reprographic and Photographic Services

Over 4000 maps at 1:10 000 and 1:10 560 scale from the Keyworth collection were scanned to serve the needs of the GeoHazard programme, and for print-on-demand sales. The 1820 edition of the William Smith map was scanned, and digitally enhanced to add to the BGS's educational and historical product range. In addition, the 1815 map of fifteen map 'panels' was scanned and digitally combined to create a single large image, ready for printing in 2003/04.



BGS © NERC



BGS © NERC



BGS © NERC



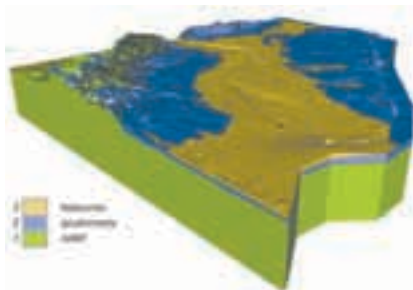
Examples of output from the Publications Production programme during 2002/03.

Opposite: William Smith 1820 geological map extract and popular publications designed for overseas government clients.

Left: 1:50 000 scale series maps and associated Sheet Explanations and design work undertaken for DFID, and the BGS Earthwise magazine.

Above: web site designs for internal and external customers.

Digital Geoscience Spatial Model



BGS © NERC

DGSM: models such as this one of the Holocene, Quaternary and Cretaceous successions in the Humber Estuary have been created using powerful 3D modelling software and stored in the BGS Geoscience Large Object Store.

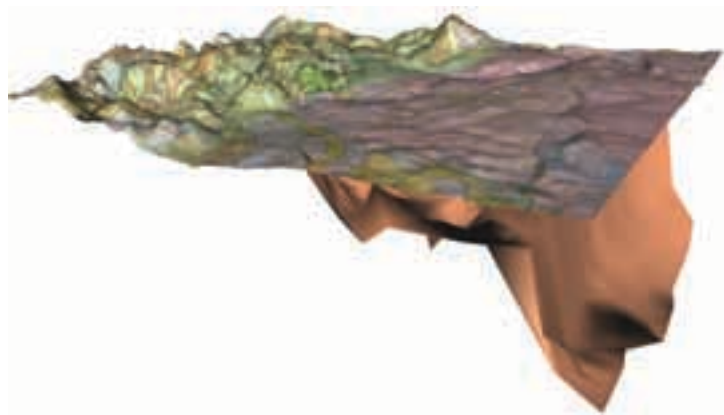
Digital Geoscience Spatial Model

Our understanding of the Earth and its processes can be significantly enhanced by visualising Earth models in three and four dimensions. In order to build such models, a wide range of data needs to be validated and evaluated, and includes geological maps, borehole logs, rock descriptions, geotechnical, geophysical and hydrogeological properties. Thus the model is, in essence, a holistic geoscience information system. The NERC and the BGS are investing considerable resources in building the systems and protocols to develop the UK Digital Geoscience Spatial Model (DGSM). The DGSM is seen as being at the core of all future BGS science activity.

The DGSM project has two major elements:

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

- Geoscience Spatial Framework (GSF) — holds spatial data in a shareable form. Users can access the database and view the surfaces over the web and download the spatial data.
- Geoscience Large Object Store (GLOS) — holds a wide range of proprietary 'rich' model files together with key information on the modelling application, so that they 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 metadata conforming to international standards that allow users to find and evaluate relevant models.
- 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 that allows an intuitive working environment for geologists to build models in complex stratigraphy (especially Pleistocene geology).



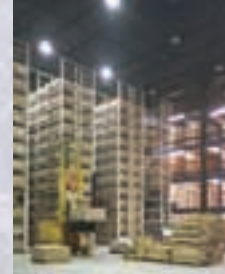
BGS © NERC

DGSM: the Geoscience Spatial Framework contains shareable data for modelled surfaces. The interactive web-based 3D Data Portal allows them to be selected and viewed, as in this image where the base of the Mercia Mudstone Group of the Cheshire Basin crops out adjacent to the margin of the Pennines.

The DGSM-UK element of the project is designed to test the data structures and procedures in a range of geological environments. The following regions were studied during the year:

- South-east England — with emphasis on modelling Chalk aquifers.
- Midland Valley of Scotland — methods for merging and generalising models were investigated.
- Atlantic Margin — best practices were developed for modelling based on marine seismic and geological data especially in the Rockall and Wyville–Thomson areas.
- Cheshire Basin and Humber Estuary.
- UK Regional model — low resolution model of major rock groups is being developed.

and GeoHazarD projects



- Nottingham–Melton area — an initial framework model was constructed, based on seismic and borehole data.
- A large number of geological cross-sections have been digitised with full spatial referencing for inclusion into other models.

This was the third of five years of funding for the DGSM by the NERC Science and Technology Board. The funding is matched by modelling projects within the BGS. During the year, the programme received a very positive review from an external panel, which assessed the scientific and technological achievements and the value for money of the work.

GeoHazarD

Few people are aware that, in Great Britain, geological factors can be a key element in determining the stability (and thus the value) of property and the safety of its occupiers. Changes in our climate and the environment are underlining the need to take geological information into account in planning, developing and insuring property. Public and commercial demand for information about geological hazards is growing. The most pressing need is the identification of areas with a potential for ground movement or contamination.

The GeoHazarD project is providing digital datasets to identify potential geological hazards for the whole of Great Britain. These data will enable the timely provision of information to the general public, commerce and government, aiding their ability to make decisions related to a whole variety of issues from strategic planning and civil engineering to house conveyancing.

The geohazards data are being prepared so that they can be incorporated into geographical information systems and combined with other geographical data to be used as part of a decision-making process. A large number of national datasets have already been delivered including:

- Location of potentially compressible deposits.
- Location of potentially collapsible deposits.
- Location of the potential for running sands.
- Location of potential slope instability.
- Location of potential dissolution hazards.
- A plasticity database for urban areas.
- Location of ground that could be liable to shrink and swell in south-east England.
- Permeability and rock fracture data for rocks.
- Two million scanned borehole logs.
- 1292 BGS publications and 824 technical reports scanned with optical character recognition (OCR); all have text searching functionality.
- Depth to bedrock in 400 000 boreholes entered into a national database.
- Models of the thickness of superficial deposits.

Further work has been initiated to extend the digital baseline datasets from which ground stability and contamination assessments can be made. This work includes the scanning of 1:10 000 scale mapping field slips, and 1:10 000 and 1:10 560 scale geological maps.

GeoHazarD: subsidence crater formed by dissolution of gypsum in Sutton Howgrave, North Yorkshire.

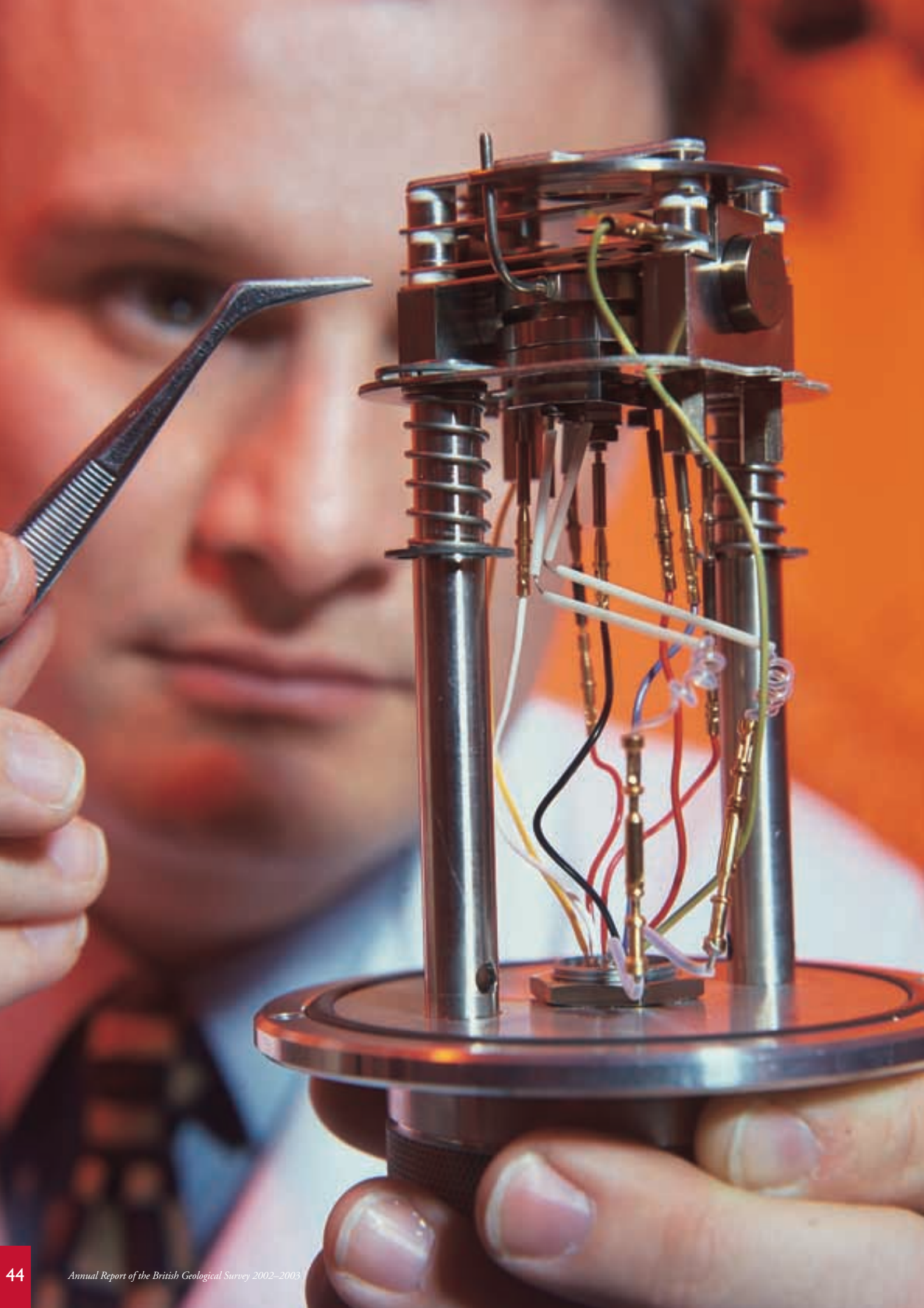


A Cooper/BGS © NERC

GeoHazarD: dormant landslide reactivated after a rainstorm, resulting in a road being cut near Ainthorpe on the North York Moors.



BGS © NERC



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 to the Programme Directorates to enable them to deliver their scientific programmes and to develop scientific capability. 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.

Recruitment during 2002/03 was focused on meeting identified requirements for specific skills in response to identified organisational needs. Many of those recruited were recent first- or higher-degree graduates but, where appropriate, we also made more senior appointments. New recruits are given a two-day induction course and an experienced member of staff, outside their line management, is assigned to mentor them through their first year. The in-house database system for managing staff time and project allocations has been further developed and is now able to track bids in progress and potential staffing requirements for future years. In consequence, it has become a primary source of management information at all levels of the organisation. The BGS has also worked with the NERC at corporate level in developing a skills database and this is in the process of being populated by staff on a 'self-service' basis.

The BGS first obtained 'Investors in People' status in 1996. This accreditation was reviewed during the course of the year and it was confirmed that the organisation continues to meet this exacting standard. Staff are increasingly aware that relevant training and development are accessible to them, and recognise the importance of taking personal responsibility for maintaining and developing their professional skills. The BGS **Training and Career Management** programme has continued to respond to the needs of the BGS programme, and has developed new courses in areas such as carbonate sedimentology, isotope geoscience, and Quaternary geology.

The GRFD funded attendance at 50 scientific conferences and meetings, and supported over 50 staff serving as members of external scientific committees or learned societies. During the year, BGS staff held many high-profile appointments including office-bearers of various scientific and professional organisations, and as editors of both refereed and popular journals.

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

Chief Scientist Prof J A Plant 0115 936 3521 japl@bgs.ac.uk Geoscience Resources & Facilities Dr D J Morgan (Acting Head) 0115 936 3138 djmo@bgs.ac.uk		
Geochemistry, Mineralogy & Hydrogeology Dr D J Morgan 0115 936 3138 djmo@bgs.ac.uk	NERC Isotope Geosciences Laboratory Prof R R Parrish 0115 936 3427 rrp@nigl.nerc.ac.uk	Geophysics & Marine Geoscience Dr J R Evans 0131 650 0213 jre@bgs.ac.uk
Geology, Geotechnics & Palaeontology Dr J H Powell 0115 936 3123 jhp@bgs.ac.uk	Information Systems Dr W Hatton 0115 936 3217 wha@bgs.ac.uk	Training & Career Management Mr M P Hawkins 0115 936 3187 mpha@bgs.ac.uk

Development of Capability

Programme overview

The Geoscience Resources and Facilities Directorate (GRFD) carries out strategic scientific research that is designed to underpin both the Core Strategic and Commissioned Programmes of the BGS. The *Geology, Geotechnics and Palaeontology* discipline supports BGS geoscience in the fields of Quaternary geology, stratigraphy, palaeontology, and the digital capture of field data. The *Geophysics and Marine Geoscience* discipline provides baseline funding to maintain equipment pools used for applied geophysical surveys, onshore and offshore. The *Geochemistry, Mineralogy and Hydrogeology* discipline manages most of the BGS laboratories and sustains development of laboratory-based techniques for analysing a range of natural materials. The *Information Systems* discipline delivers enhanced software solutions and geoinformation processing.

Geology, Geotechnics and Palaeontology

Quaternary science was supported through the Superficial Deposits Advisory Group, which has finalised a revised stratigraphical scheme for the Quaternary of the UK. Stratigraphical research was also underpinned through publication of multidisciplinary information via the BGS web site; outputs include stratigraphical framework reports on the Carboniferous of Great Britain, Lower Palaeozoic igneous rocks of the Lake District, Chalk Group of the UK, and the Llandovery stage. Capability in palaeontology was further enhanced through development of a gallery of Late Palaeozoic spores and pollen to be released as an online, searchable database. Trials using new non-acid techniques for the preparation of palynological samples were carried out successfully.

Geophysics and Marine Geoscience

The BGS Core Programme is closely supported by joint funding of projects in areas such as marine drilling and sampling (with Continental Shelf and Margins), and in electrical tomography (with Electrical Tomography Services). The redesigned rockdrill/vibrocorer was deployed offshore Papua New Guinea for the University of Freiburg and achieved full five-metre penetration in water depths of 2000 metres. Laboratory research has demonstrated that, unlike standard conductivity surveys, Spectral Induced Polarisation (SIP) imaging can detect non-aqueous phase liquids in porous media. New analysis techniques, based on a mix of mathematical modelling and inversion, GIS, and subsurface visualisation, have unlocked the potential for application of airborne geophysical datasets to land and water quality issues (and so sustainability) at both local and regional scales.

Geochemistry, Mineralogy and Hydrogeology

A major project on the investigation and characterisation of fractures has been completed, which drew on skills across the organisational matrix. The BGS Rock Classification Scheme, currently in draft form, now provides a means to name, classify and describe succinctly and consistently a wide range of geological discontinuities at any geological scale. The classification scheme can be adapted to digital use. The potential for using frequency-dependent changes in seismic data to measure fracture sizes has been established, and a series of technical papers has been prepared for external publication. Ongoing projects continue to develop laboratory techniques in areas such as ICP-MS analysis of environmental samples; trace-level radionuclides, such as strontium-90 and technetium-99; SEM studies of gas hydrates; CFCs in groundwater; and geomicrobiological assessment of groundwater.

Information Systems

The programme continues to underpin the System for Integrated Geospatial Mapping project (SIGMA) through the development of key technologies, such as a project workspace environment, which provides a graphical user interface reflecting the SIGMA project workflow and providing access to tools appropriate to each stage of map production. Rapid mapping methods based on remote sensing are increasingly being exploited throughout the BGS programme, applying techniques such as enhanced digital photogrammetry, high spatial resolution satellite data, hyperspectral and thermal analysis, all developed within the Survey. The organisational resources are being further extended through tools such as a fully integrated ESRI-based map production system, and the development (with CSIRO) of GeoSciML, a generic geoscience data exchange language.



T Bradwell, BGS © NERC

Information Systems: digital field survey equipment being used to record a frost-shattered vein on Beinn a' Chreagain, south-west Scottish Highlands.

NERC Isotope Geosciences Laboratory



Nature of the lower crust beneath the Pannonian Basin

New isotope data (strontium, neodymium, lead, hafnium and oxygen) for a suite of mafic lower crustal granulite xenoliths from the Pannonian Basin shed new light on the lower crust in the region. The new data show that the granulite protoliths are considerably older than Tertiary basalt underplating and formed in an oceanic environment as hydrothermally altered mafic rocks. Many of the xenoliths have $\delta^{18}\text{O}$ values less than average MORB and/or mantle peridotite — a situation not observed in any other lower crustal granulite xenolith suite. These values require a period of hydrothermal alteration at high temperature, the most likely location being in the oceanic lower crust.

Landfill ammonium pollution naturally attenuated by denitrification

Investigations of a chalk quarry landfill near Cambridge using innovative gas and liquid analysis demonstrate that anaerobic decomposition of landfill organic matter led to the formation of toxic concentrations of ammonium in the landfill leachate. This was leaching outwards into the more aerobic environment of the surrounding chalk. There was therefore a high possibility that oxidation of the ammonium by bacterial nitrification would lead to nitrate pollution of the chalk aquifer. When chemical data were combined with nitrogen isotope information on ammonia, nitrate and dissolved gases, the processes were revealed. Ammonium is converted to nitrate, which in turn is converted by bacterial processes into nitrogen. This unexpected discovery suggests that pollution by landfill ammonium can, in some environments, be attenuated by a series of natural processes that convert it to a harmless gas.

Zinc isotopes — a possible tracer for industrial pollution processes

In a CASE studentship with Imperial College, the NIGL has investigated the potential of zinc isotopes as a monitor for the source of industrial pollution. Experiments using rice, lettuce and tomato plants grown in soils doped with zinc showed subtle levels of isotopic fractionation from the roots to the shoots of the plants. The level of isotope fractionation was, however, tiny in comparison to the levels of fractionation (nearly 1%) in samples of refined and purified zinc metal. This establishes the feasibility of using zinc isotopes to fingerprint industrial processes and related anthropogenic zinc pollution.

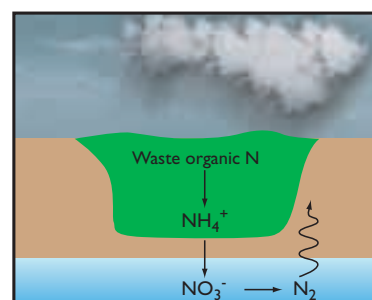
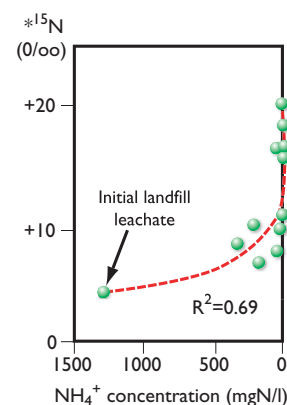
Very rapid tectonic exhumation in the Himalaya

Accessory minerals in ultra-high-pressure eclogite have been dated using the uranium–thorium–lead system in conjunction with petrographical and chemical data, in a joint project with the University of Oxford. During India–Asia continental collision in Pakistan, coesite-bearing eclogite grew allanite during subduction to depths of about 100 kilometres, then crystallised coesite and zircon accompanied by further growth of allanite and rutile, and was followed by retrograde growth of epidote and conversion of clinopyroxene to hornblende during exhumation. Zircon and allanite record dates of 47–46 Ma, defining the prograde to peak-pressure portion, while rutile returned an age of 44 Ma that probably defines the cooling of the rock to temperatures less than 500–550°C. These data allow a calculated rate of exhumation of more than 50 kilometres per million years, amongst the fastest ever documented.

Programme overview

The NERC Isotope Geosciences Laboratory (NIGL) is a comprehensive stable and radiogenic isotope laboratory facility that undertakes environmental, life, archaeological and earth science research for universities, NERC institutes, and external clients. A primary focus is the training of NERC Ph.D. students in a collaborative research environment. The NIGL underwent a quinquennial review by the Services Review Group in 2003, and renewal of funding for the five-year period after 1 April 2004 was secured.

Landfill ammonium: $\delta^{15}\text{N}$ values and concentrations of ammonium in landfill groundwater (below). The negative log-linear relationship conforms to the effects of 'Rayleigh' isotope fractionation during conversion of ammonium to nitrate; one of two steps towards nitrogen attenuation by conversion to nitrogen gas (N_2) (bottom).





Marketing, International and Corporate Development



Marketing, International and Corporate Development Directorate contains **BGS International**[®], which is responsible for BGS's activities outside the United Kingdom; the **UK Business Development** team, which spearheads corporate marketing of BGS projects in Britain; the **Press and Parliamentary Liaison Office** which communicates the activities of the BGS to the media and politicians, and the **Central Directorate Support Group** that supports the Executive Director's office and services the requirements of the BGS Board.

The overall strategy for the marketing and exploitation of BGS science has been to engage with a wide variety of clients and stakeholders, including in co-funding arrangements where these support and enhance the Core Programme. The BGS also undertakes commissioned research (CR) projects that are appropriate to its core science and, by so doing, not only demonstrates the relevance of the science, but enhances the facilities and skills base available to all programmes. CR projects are carried out at full economic cost with no element of cross subsidy from the Science Budget.

The work of **BGS International**[®] is funded entirely by external commissions, principal among them being projects funded by aid agencies and development banks. There was continued growth in such activities during 2002/03. 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. The BGS undertook projects in Africa and the Middle East, Central and South America, Eastern Europe, and Asia and the Pacific. The BGS has also supported the Government's post-conflict reconstruction initiatives in Afghanistan.

The **Press and Parliamentary Liaison Office** continued to communicate the BGS's activities and information to the printed and broadcast media, and to politicians in central, devolved, regional and local governments. It also supported the work of the All Party Parliamentary Committee on the Earth Sciences, at which BGS staff members gave a number of talks.

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

Marketing, International and Corporate Development Mr D C Ovardia 0115 936 3465 dco@bgs.ac.uk			
BGS International	UK Business Development	Central Directorate Support	Parliamentary and Media Liaison Office

BGS International®

Programme overview

BGS International® co-ordinates the overseas activities of the BGS, operating in recent years in over 60 countries, mainly in the developing world. The applications of geoscience, water resource, and geohazard understanding in these countries is often key to their economic and social development and is funded by clients such as the Department for International Development (DFID), the World Bank, and the European Union.



D Harrison, BGS © NERC

Minerals from waste: artisanal miner separating tin-tantalum ore at the former Uis tin mine, Namibia.



K Goodenough, BGS © NERC

United Arab Emirates: mapping harzburgites, north of Khor Fakkan.

Minerals from waste

Mine and quarry wastes from the extraction and processing of mineral ores and rocks commonly occur in substantial volumes in waste heaps or tailings lagoons. Fine-grained waste, in particular, can create environmental problems that remain long after mining has ceased. The DFID-funded 'Minerals from Waste' project aims to improve the sustainability of current and former mining and quarrying communities by investigating ways to utilise mineral waste as a source of construction and industrial minerals. The objective of the research is to develop a waste utilisation methodology which is generic and applicable to developing countries worldwide. Case studies have been undertaken at several mining sites in Namibia and Costa Rica in collaboration with the Ministry of Mines and Energy and Instituto Costarricense de Electricidad respectively. The BGS has also called upon specialist input from the Universities of Exeter and Warwick. The methodology involves an evaluation of the quality of the waste, a market analysis, a financial assessment, and a socio-economic impact assessment. Together, these are essential prerequisites for evaluating the feasibility, and assessing the benefit to a community, of waste reclamation at a mine or quarry site.

Geological mapping and mineral reconnaissance — United Arab Emirates

The BGS has embarked on a major four-year geological surveying programme to produce high quality maps of the mountainous region of north-eastern United Arab Emirates. The mapped area is largely occupied by the Semail ophiolite, but includes Permian to Cretaceous shelf carbonates in the Musandam Peninsula in the north, and Quaternary deposits occupying the desert plain to the west. In addition, the BGS will undertake a reconnaissance industrial and metallic mineral assessment of the region. Ophiolites are widely believed to represent fragments of oceanic crust and mantle which have been thrust on to the continental surface by powerful earth movements associated with subduction and collision. Ophiolite complexes of significant size are rarely preserved on land, however, and the precise details of their origin and mode of emplacement are still disputed. The Semail ophiolite is the largest and best preserved on-land ophiolite thrust sheet complex in the world, but in spite of this, the UAE segment of the complex has received much less scientific attention than its southern extension in neighbouring Oman. Apart from the great scientific interest of ophiolites, they are frequently an important host to economic deposits of chromite and platinum-group minerals, as well as a wide range of other metallic and non-metallic minerals. The current BGS project is expected to make a significant contribution to the knowledge and infrastructure of the UAE and, in advancing our knowledge of the Semail ophiolite in particular, will lead to an improved global understanding of these intriguing fragments of the Earth's lithosphere.

Supporting the mining sector in Papua New Guinea

The BGS has begun work on several projects in Papua New Guinea (PNG) funded under a World Bank Mining Sector Institutional Strengthening Project. The PNG Department of Mining is being provided with technical assistance and training at its headquarters in Port Moresby. Specific components of the project include developing a remote sensing capability; geophysical data compilation and interpretation; and the design, development and implementation of an integrated information system and web site. A training-needs analysis of the Department of Mining was also completed during the year.



Geoscience metadata — a tool kit

The BGS has developed a generic self-help 'toolkit' to enable national geological surveys to compile, digitise, manage and disseminate geoscientific metadata for the benefit of themselves and their external users. The project, funded under the DFID's Knowledge and Research Programme, has been undertaken in collaboration with geological surveys in Korea, Malawi and Mozambique, and in partnership with the Coordinating Committee for Geoscience Programmes (CCOP). Metadata can be defined simply as 'data about data'. In effect, it is a mechanism for describing and documenting data so that a potential user can ensure that it is fit for the purpose for which it is intended. For this project the BGS has designed metadatabase tables in a form suitable for use in widely used database applications. A web-based metadata retrieval application and a toolkit of methodologies and applications for handling geoscientific metadata will be accessible over the Internet.

User-group management of groundwater resources in rural India

There is increasing evidence that the current intensity of groundwater exploitation is not sustainable in many areas of rural India. This is leading to reduced access to groundwater, disproportionately affecting poorer households. The BGS is undertaking a DFID-funded project testing the viability of local user-groups managing their own groundwater resources as a means to address the problem. Issues that the project is exploring include: whether it is possible for a small community of users to 'fence-off' a section of the underlying aquifer so they retain the water they conserve; under what socio-economic conditions will groups of users be prepared to come together to jointly manage groundwater resources; and how does local groundwater management fit in with an approach that promotes less water-intensive livelihoods?

Fluoride in drinking water

Fluorine compounds, or fluorides, are a common constituent of rocks, soils, water and air. Like several other naturally occurring elements, fluorine in compound form can enter the human body via the air we breathe and the food and water in our diets. Studies carried out in the USA and Europe in the 1950s were able to demonstrate a link between improved dental health and the introduction of fluoridated toothpaste and fluoridated drinking water to local communities. In spite of this, scientists are still uncertain whether fluoridation of drinking water is essential for human health. For example, health problems associated with too much fluoride, known as fluorosis, have been widely reported. Fluoride concentrations in the environment are highly variable and are often controlled by particular types of rocks, minerals or water.

In Central Europe, groundwater resources with concentrations of fluoride that exceed minimum guidelines are widespread, leading to associated health problems. The BGS, together with partners from the Netherlands, Moldova, Ukraine, Hungary and Slovakia, has been involved in a project funded by the European Union which aims to improve water quality through reduction of fluoride concentrations in groundwater. The BGS's specific involvement concerns the establishment of a geographical information system management tool that will aid the identification of areas where high fluoride waters and fluorosis may be a problem.

United Arab Emirates: vibroseis trucks at Wadi Zikt. WesternGeco has been subcontracted by the BGS to undertake deep seismic profiling over the northern part of the Semail ophiolite.



K Goodenough, BGS © NERC

Papua New Guinea: the BGS is working on several projects to support the mining sector in Papua New Guinea funded by the World Bank. Tavurvur volcano from Rabaul Volcano Observatory, New Britain island.

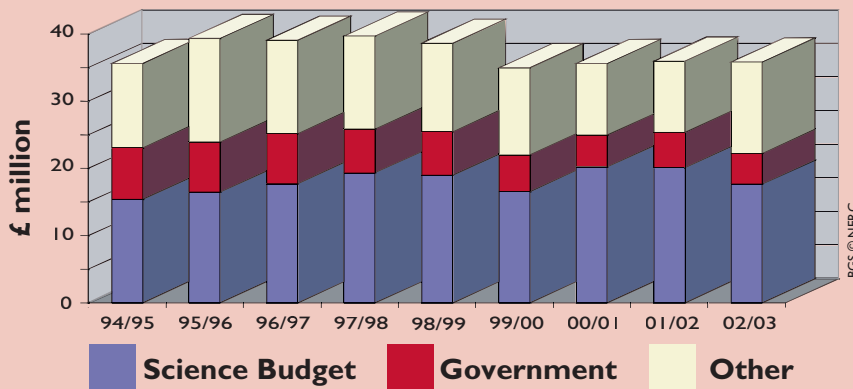


M Stephenson, BGS © NERC

Finance

BGS summary of income and expenditure 2002/03

Income	£ million
Science Budget	18.456
Other income	18.760
Total	37.216
Expenditure	£ million
Salaries	23.263
Other expenditure	13.472
Total	36.735



Sources of BGS income 1994/95 to 2002/03 (at 2002/03 prices).

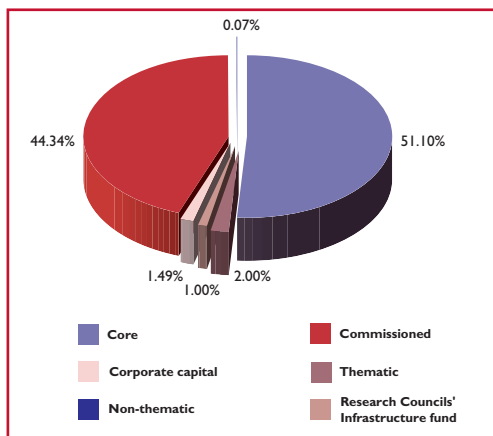
BGS Funding

The BGS receives funding from its parent organisation, the NERC, to carry out its Core Strategic Programme encompassing 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 2002/03 was £18.4 million which includes contributions to infrastructure.

The BGS also earns income via external or Commissioned Research programmes comprising strategic commissions, partnerships and contracts with a wide range of clients which include government departments, 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 the Survey's infrastructure. The value of the Commissioned Research programme rose from £16.2 million in 2001/02 to over £18.7 million in 2002/03, including receipts from the BGS's participation in the NERC's competitive thematic projects.

The BGS has an obligation to the NERC to balance its income and expenditure each financial year. The financial year 2002/03 saw a small surplus made which is to be reinvested as part of the BGS's prioritisation policy. The 23% increase in Commissioned Research receipts since 2000/01 represents a considerable success for the relevance of the BGS's activities to external customers and enables the Survey to look forward with some confidence in the stability of its financial base.

The year also saw the development of the new NERC Corporate Funding Framework, which will be formally adopted in 2003/04. Initial population of the Funding Model demonstrated that the BGS has been comparatively disadvantaged in the support given by the NERC to its infrastructure. This conclusion led Council to approve an increase in infrastructure support for the BGS of £1.5 million per annum for the financial year 2003/04 onwards. Additional NERC funds were also allocated both in 2002/03 and for 2003/04 to specific infrastructure and capital projects. Proposals are also being developed for Rounds 2 and 3 of the Research Councils' Infrastructure Fund.



BGS expenditure during the financial year 2002/03.

Personnel



Financial restrictions requested by the NERC limited the number of recruitment exercises that were undertaken during the financial year 2002/03. This followed two years in which there had been a significant intake of graduates. Recruitment during the year was mainly restricted to appointments relating to replacements for staff who had resigned or retired. There was a decrease in the number of leavers during 2002/03 with 18 staff leaving as a result of resignation. This showed a steady decline from 2000/01 (30 leavers) and 2001/02 (24 leavers). It is intended to resume scientific 'new blood' recruitment in 2003/04.

The majority of new recruits are employed on open-ended contracts and the number of staff employed on fixed term appointments (FTAs) has continued to reduce as individuals move to open-ended status. The number of FTA staff now stands at 19 individuals. Personnel Section has continued to provide support for equal opportunities in recruitment and employment. The BGS has maintained its 'Positive About Disabled People' Standard ('Two Ticks') accreditation and is supportive of those with disabilities. Personnel staff have been active in providing specialist facilities, where required, with the support of outside agencies.

The changes in 'family friendly' employment legislation were fully complied with as Personnel Section continued to support the provision of job sharing, part-time working and career breaks for family purposes, where possible. Other facilities available to staff include flexible working hours, and home working in special circumstances.

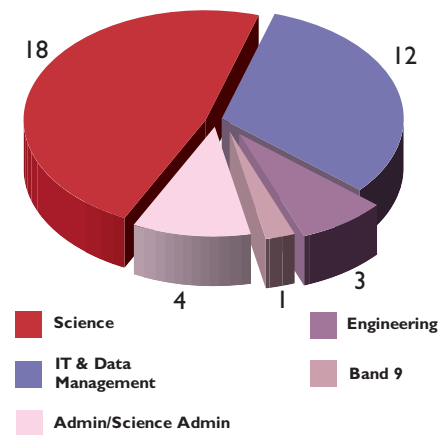
Personnel Section has continued with its important role of providing professional support to the Geoscience Resources and Facilities Directorate (GRFD). Personnel staff and members of the GRFD work closely together on human resource issues.

The NERC Merit Promotion Scheme has continued to provide promotion opportunities for staff within all sectors. Through the new scheme, higher performance levels of staff, in all disciplines, are being recognised (*see chart, top right*).

An upgrade to the Personnel Database allowed further development of this application to take place during the year. The new upgrade has provided the facility for individual staff to gain direct access to their own personal information and allows them to amend certain records. This facility is most important to ensure essential personal information is kept updated.

The upgrade has also provided a valuable management tool. A long-awaited Personnel requirement has been met, as CVs will soon be produced centrally, in various formats, to meet customer requirements in relation to tendering for commercial contracts. The database has been expanded to include publications, memberships and skills. The inclusion of skills is an important planning tool that allows Heads of Discipline to quickly identify which staff match both internal and external customer requirements. BGS staff were introduced to the new system via a series of short courses led by Personnel and are now actively involved in populating the database.

Numbers of staff promoted during the year through the BGS Science Panel and the various NERC Panels.

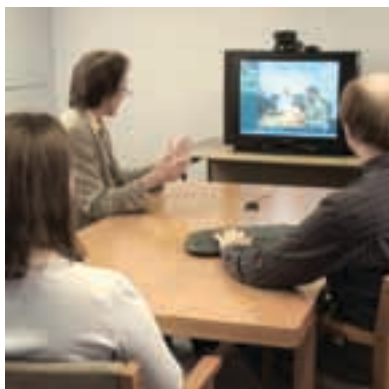


BGS © NERC

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

Administration & Finance Mr F G Curry 0115 936 3157 fgc@bgs.ac.uk		
Personnel Administration Mr J Orr 0115 936 3156 jorr@bgs.ac.uk	Facilities and Infrastructure Mr G S Bowick 0115 936 3243 gsb@bgs.ac.uk	Finance, Accounts and Contracts Mr T Hossain 0115 936 3609 thos@bgs.ac.uk

Facilities Management



C Adkin, BGS © NERC

Improving our environment: to reduce the amount of travel between offices, staff are encouraged to use video conferencing facilities.

Facilities and Infrastructure

The BGS is poised on the threshold of a major upgrade and reinvestment in its estate. During 2002/03 bids were placed with the NERC for two major projects: the refurbishment of H Block (£0.5 million) and the building of a new Environmental Material Handling laboratory (£1.5 million). Both bids were successful and works will commence in 2003/04. Preliminary designs for the refurbishment of meeting rooms and restaurant facilities have been produced and a tendering exercise will be undertaken at the beginning of 2003/04.

The upgrade to the heating controls in Murchison House has continued and should be completed by 2004/05; a new Combined Heat & Power (CHP) plant being purchased by Edinburgh University will supply the primary heating. The reception area will also undergo an extensive refurbishment during 2003/04.

To ensure additional NERC infrastructure funding is allocated effectively, an Estates Committee will operate from 2003/04. A five-year maintenance programme has been drawn up, which has prioritised annual maintenance tasks, resulting in a successful bid for NERC Infrastructure funding. The Estates Committee will monitor progress against the programme, which is expected to increase significantly following Rounds 2 and 3 of the Research Council's Infrastructure Fund.

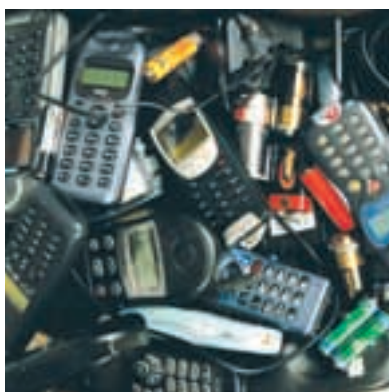
Routine and major maintenance work on buildings and services continued at all BGS sites. At Keyworth, a number of Framework Agreements have been set up with contractors to complete major works by 2006/07, including roofs, windows and WCs. Market testing continues to be undertaken on routine servicing and maintenance contracts to ensure best value for money. Costs have generally held steady although savings have been achieved in some areas.

Improving our environment

The BGS has developed a close relationship with the Nottinghamshire Wildlife Trust during the year and has been providing the Trust with IT assistance, while in return members of the Trust have given a series of lunchtime lectures to BGS staff on wildlife issues, as well as offering advice on how to make Keyworth's grounds more 'wildlife-friendly'. A feasibility study of the 'Earthwise Gardens', a proposed new environmental sciences centre at Keyworth, has to date been very positive, and talks are currently taking place with DEFRA.

The toilets at Keyworth are being refurbished, and many energy-saving features have been included in the specification, such as push button taps; waterless urinals; and automatic light and extractor fan systems. A programme has begun to install energy-saving, 'intelligent' light fittings around the site, while the rolling programme of replacing all the old single-glazed windows with double-glazed units continues.

To reduce the amount of travel, BGS staff are being encouraged to use the video conferencing links between Keyworth, Edinburgh and Wallingford, which is free courtesy of the JANET link. A car-sharing scheme is in place in Keyworth and all newsletters are now only published electronically. There are collection facilities on the Keyworth site for recycling most waste materials; used household batteries and mobile phones can now be recycled, with all proceeds going to the local school.



T Cullen, BGS © NERC

Improving our environment: there are collection facilities on the Keyworth site for recycling most waste materials; used batteries and mobile phones can now be recycled, with all proceeds going to a local school.

Health and Safety



NERC/BGS health and safety procedures and guidance

Work has continued on the production of procedures. Approved procedures this year have included:

- Managing contractors.
- Safety when working overseas.
- Accident reporting and investigation.

Other procedures out for comment include:

- Competence.
- Control of Substances Hazardous to Health.
- Laboratory procedures.
- Noise.
- Fire.

The BGS has produced procedures for Control of Contractors and a Transport Manual in addition to the Fieldwork Guidance which has been distributed to all personnel involved in fieldwork.

Occupational health

Work has continued with the Queens Medical Centre (QMC), in Nottingham, and the Institute of Occupational Medicine, in Edinburgh, on occupational health matters. The service has again been of benefit, with any problems attended to very quickly. At Keyworth, a service on sickness absence with regular clinics has been agreed with the QMC. Analysis of medical statistics has conclusively demonstrated that the Survey's policy of investment in well designed office furniture and good occupational health advice has resulted in a dramatic decline in both work-related upper limb disorders and work-related stress.

Accident, incidents and near misses

The number of reported accidents has remained steady, with Keyworth having the greatest number. Most accidents are at the trivial level and could have been avoided if more care had been taken while going about daily tasks. Two reports were made to the Health and Safety Executive (HSE) during the fiscal year, one in Loanhead and the other in Keyworth. The Loanhead incident, which was serious, was investigated by the HSE and new procedures have been installed to prevent any such recurrence.

Health and safety training

All senior personnel have undergone health and safety courses relating to their legal responsibilities over the past eighteen months, and a lower-key training programme is in preparation which will involve almost all of the rest of the staff.

Office safety

Much emphasis has been placed on improving office safety. Audits and inspections have been used to identify problems, particularly those arising from poor use of computer equipment and general housekeeping. This will continue for the foreseeable future with the aim of reducing risks which could lead to longer term problems.

Occupational health: the Survey's policy of investment in well designed office furniture and good occupational health advice has resulted in a decline in work-related upper limb disorders and stress.



BGS © NERC

Health and safety procedures and guidance: it is especially important for staff working overseas that they receive clear guidance on matters relating to health and safety. A new procedure, *Safety when working overseas*, has recently been approved.



BGS © NERC. This image is a product of the DPID programme of work carried out in Montserrat by the BGS.



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK
Tel: 0115 936 3100 Fax: 0115 936 3200 Web sites: www.bgs.ac.uk & www.geologyshop.com