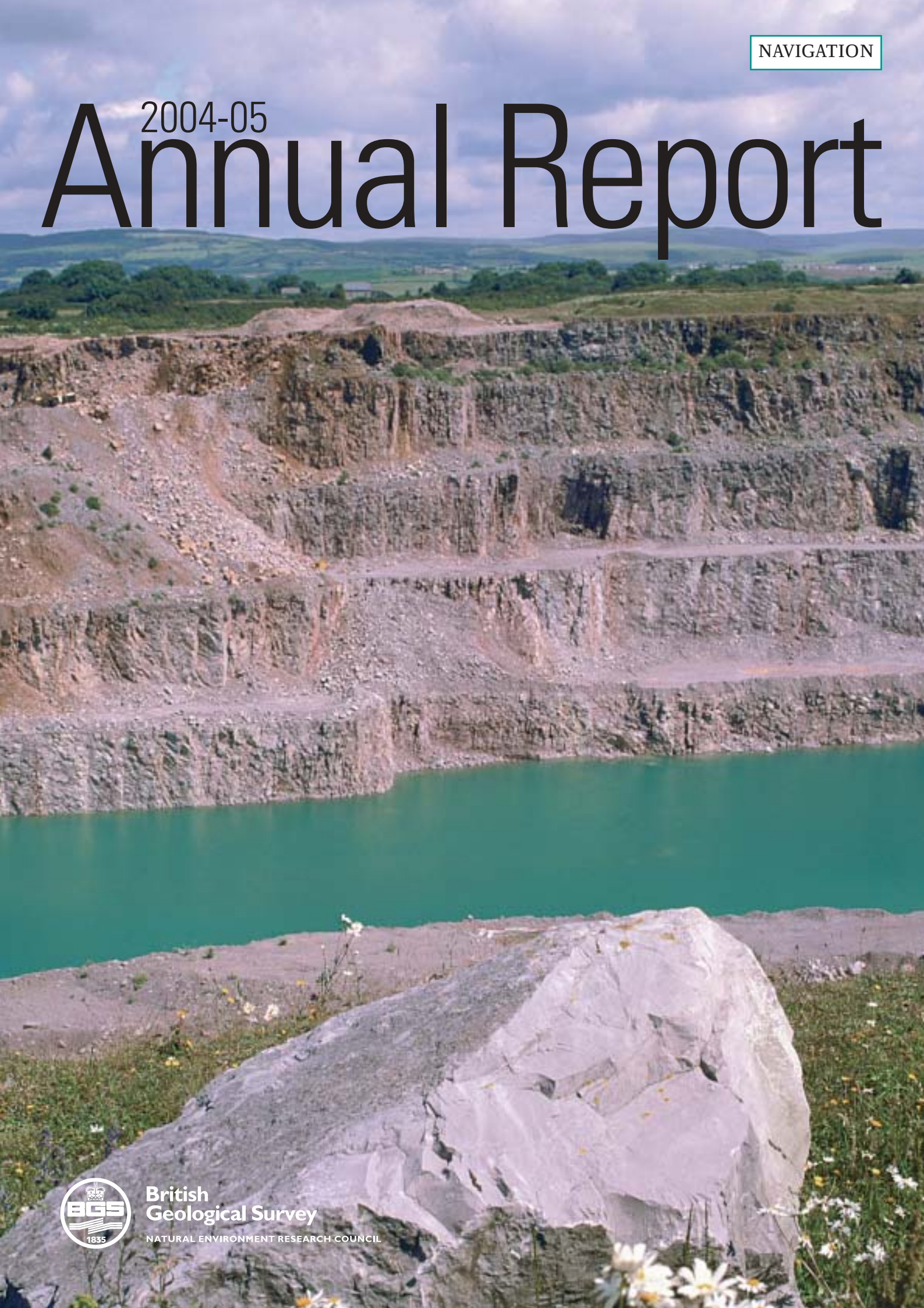
NAVIGATION

2004-05 Annual Report



British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

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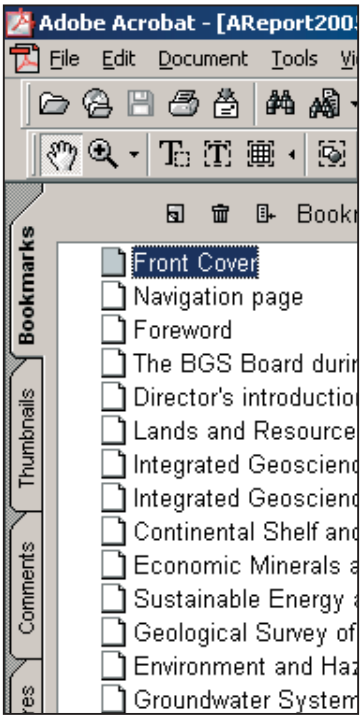

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Bibliographical reference

BRITISH GEOLOGICAL SURVEY, 2005.
Annual Report of the British Geological Survey 2004–2005.
(Swindon, Wiltshire: Natural Environment Research Council).

Printed in the UK for the British Geological Survey by Hawthornes, Nottingham C30 09/05
Cover: Quarry at South Cornelly near Porthcawl, South Wales. Graham Bell, BGS © NERC

ISBN 0 85272 524 8

Editor: David Bailey
Design & Production: Amanda Hill, Adrian Minks
Print Production: James Rayner
Reprography: Jayne Kmieciak

NATURAL ENVIRONMENT RESEARCH COUNCIL

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 around £325 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;
- to provide effective national and international leadership for the environmental sciences; and
- to ensure that the NERC is a flexible, fit-for-purpose organisation that achieves excellent service delivery and customer focus.

To deliver these science priorities effectively, the NERC invests in a broad spectrum of research from non-directed 'blue skies', through a range of directed investments, to more applied and long-term strategic research and survey activities, which underpin national and international needs.

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

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British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

THE MISSION OF THE BGS IS TO:

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

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

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

FUNDING BGS SCIENCE

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

CORE STRATEGIC SCIENCE

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

COMMISSIONED RESEARCH

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

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Foreword

Mr Derek Davis
Chairman of the BGS Board

I first knew the BGS over fifteen years ago when I had charge of oil and gas at the Department of Energy and DTI. It has been a real pleasure for me over the past year to renew the association and to discover how effectively the Survey has responded to the challenges of a changing world: in leading-edge geological research, in the practical application of geology, in the maintenance, exploitation and dissemination of the nation's data archive, in the development of new products and, not least, in the manner of earning one's living.

The BGS remains a highly successful research organisation, is renewing the data archive imaginatively and decisively for the twenty-first century and has become a growing business, in traditional areas and new ones as diverse as insurance and tourism. It is regularly in the public eye, whether helping us understand in real time the Indian Ocean tsunami disaster and assisting in the aftermath, or making geological techniques available to archaeology so that ancient migration patterns can be accurately traced, or obtaining the earliest core samples yet from the Arctic with proof of a once much warmer climate some 50 million years ago.

As you will see in the pages that follow, 2004/05 has been a positive year for the Survey on all these fronts. During the year the BGS's new science programme received very strong endorsement in NERC's review processes but, in the event, the funding available for environmental science proved more limited than hoped. It is particularly regrettable that we have had to put our planned new programme of collaboration with the wider geosciences research community on hold. The BGS's business result for the year has been encouragingly positive.

I cannot end this first Chairman's foreword without paying tribute to my immediate predecessor Geoff Robinson who contributed so much to sharpening focus during his term of office. Frank Curry, Head of Administration and Finance, who retired during the year was a support to both of us and to the organisation who will be sorely missed. We have a highly able and resilient team working to build on what has been achieved. I look forward, with confidence, to the next stages.

The BGS Board during 2004/05

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 David Falvey; Council's Chief Executive or his nominee, in 2004/05 this was the NERC Science & Innovation Director Dr Steven Wilson, 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 up to a further four years. Dr Brian Marker of the Office of the Deputy Prime Minister sits on the Board as an Observer.

Board Members: non-executive

Mr D Davis	(Chairman), formerly of the DTI.
Dr O Bavinton	Senior Vice-President, Exploration, Anglo American PLC.
Professor P Styles	President of the Geological Society; Applied and Environmental Geophysics, Keele University.
Professor L Warren	Board member, Environment Agency.
Mr J Smith	Managing Partner, Wardell Armstrong.
Dr R Scrutton	School of Geosciences, Edinburgh University.
Mrs R Johnson-Sabine	Chevron Texaco.
Dr G Robinson	Former Director General of the Ordnance Survey.
Dr S Wilson	Director Science & Innovation, NERC.
Dr B R Marker	Office of the Deputy Prime Minister (Observer).
Professor A Rogers	Former MP for Rhondda, and External Professor, University of Glamorgan.

BGS Executive Committee

Dr D A Falvey	Executive Director.
Mr F G Curry	Head of Administration and Finance.
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.
Dr D J Morgan	Head of Geoscience Resources and Facilities.
Mr D C Ovadia	Director of Marketing, International and Corporate Development.
Professor J A Plant	Chief Scientist.

Secretariat

Miss R U Leader, BGS.

Changes during 2004/05

Dr Lynn was replaced by Dr Wilson.

Professor Rogers left in December 2004.

Dr Robinson was replaced as Chairman by Mr Davis in January 2005.

Professor Plant retired in February 2005.

Mr Curry retired in March 2005 and was replaced by Mr J Parker.

Remit

The BGS Board replaced the original Programme Board in January 1998. It advises and supports the Executive Director and the executive team in the management and furtherance of the Survey's mission, vision, aims and objectives; and on matters of efficiency, effectiveness, economic use of resources and business strategy. The BGS Board also approves the annual business and operational plans prior to submission to NERC Chief Executive; and monitors the scientific and resource balance between the core strategic and commissioned research work programmes.

The BGS Board, March 2005: *(l to r)* back row: Miss R U Leader (Board Secretary), Mr J Parker, Mr D Ovadia, Dr O Bavinton, Dr D J Morgan, Mr J Smith, Dr B R Marker, Mr I Jackson, Dr S Wilson; front row: Mrs R Johnson-Sabine, Mr D Davis (Chair), Professor L Warren, Dr D A Falvey, Dr G Robinson, Mr F G Curry, Professor P Styles. Other members (not in photograph): Dr M K Lee, Mr D C Holmes, Dr R Scrutton.

Director's introduction

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

I am delighted to introduce the BGS Annual Report for 2004/05. This year marks the completion of the latest five-year science programme agreed with our parent body, the Natural Environment Research Council (NERC), and is one in which we have continued to deliver world-leading science through many exciting initiatives. Through its science programme, the BGS has delivered many new products and participated in a number of significant achievements, information on which you will find below and throughout this report. The BGS has also been involved in extensive planning for the new science programme for 2005 to 2010.

As I reported last year, the BGS science programme for 2000–2004 received high praise in the Science and Management Audit. That SMA made a number of recommendations concerning future funding and increasing the level of university collaboration, which we brought forward in our 2004 'New Programme' proposals. The proposal identified eight new 'science themes'. All received very strong support from the independent, external review process, and form the basis of the current 2005–2010 science programme. However, funding constraints within the NERC will affect delivery of some elements for the time being.

Probably our biggest 'high profile' achievement in 2004/05 was the recovery of sediment core up to 425 metres beneath the seabed of the Arctic Ocean in water depth of 1100 metres, just 240 kilometres from the North Pole. This was accomplished by the BGS in its role as the science operator of the European component of the Integrated Ocean Drilling Program. Analysis of the core has subsequently provided valuable information on climate change over the past 50 million years, and will increase our knowledge on predicting changes in the future.

We played a significant part in the response to the Asian Tsunami and our public profile was raised considerably as a result. Staff have collated available data and information, studied remote sensing images, and made contact with various colleagues internationally.

Our important work overseas has continued. Notable achievements this year have been institutional strengthening of the Afghan Geological Survey, where BGS staff have helped re-establish infrastructure and train local staff in a range of basic geological survey activities directed towards encouraging and supporting mineral exploration by the private sector.

In a joint initiative with the Finnish Geological Survey, we have purchased a Twin Otter aircraft, and have successfully carried out an airborne survey of an area of environmental concern and geological interest in Ayrshire, Scotland.

The five-year Digital Geoscience Spatial Model (DGSM) project was successfully completed and the new three-dimensional visualisation facility at Keyworth officially opened. This is the culmination of many years of work at the BGS and has enabled geologists and others to view the structure of the United Kingdom landmass in three dimensions for the first time.

Professor Sir Keith O'Nions, Director General of the Research Councils UK, opened the new Environmental Materials Facility building at the Keyworth site. This facility addresses NERC's legal obligation to adopt a consistent risk-focused approach to the preparation, analysis, storage and disposal of material arising from its growing portfolio of investigations.

During 2004/05, we have been successful in gaining ISO 9001:2000 from the British Standards Institute, HMSO Information Fair Trader status (the first non-trading fund to achieve such recognition), as well as renewal of our Investor in People status.

I hope this introduction has given you an insight into our achievements during 2004/05. I believe that they, and many others, will contribute to our growing reputation for scientific excellence and relevance. The following pages of this report contain further exciting examples of our work, both in the UK and overseas, which I have not been able to mention here. The work undoubtedly reinforces the relevance of the Survey to the prosperity and sustainability of the UK and global society. I hope that you, after reading it further, will agree that BGS, the oldest geological survey in the world, is very much a part of the twenty-first century, through the relevance of its geoscience, its focus on delivery, and its future vision.

In 2004/05 the BGS's work programme was organised around three Programme Directorates: 'Land and Resources'; 'Environment and Hazards'; and 'Information Services and Management'. These programmes managed and delivered the operational science programmes (coherent packages of related projects).

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

Essential cross-Directorate support was 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**
Geoscience National Information	**Digital Geoscience Spatial Model**		**Training and Career Management**
Administration and Finance Directorate			
Personnel and Administration	**Facilities and Infrastructure**		**Finance, Accounts and Contracts**

Lands and Resources

The Lands and Resources Directorate (LRD) operates through six multi-disciplinary programmes designed to define the 2D and 3D geology (onshore and offshore), provide information on energy and mineral resources and carry out research on the sustainable use of the land, seabed and natural resources. A major component of our work is concerned with strategic survey, modelling and research in the UK, supported by mixture of BGS funding, commissions from government and its agencies, and industry-sponsored research consortia. We also operate in Europe and worldwide through international research projects and commissioned contracts. LRD generates many of the mainstream BGS publications and provides the basic layers of information for the rapidly expanding range of digital products and services delivered through the Information Services and Management Directorate. We also provide the geological, geophysical and geochemical baselines that directly underpin the work of the Environment and Hazards Directorate.

A major highlight of the year was the successful completion of the Arctic Coring Expedition on the Lomonosov Ridge, in ice-covered waters of the Arctic Ocean, for the Integrated Ocean Drilling Programme (IODP). The deepest hole reached the pre-Cainozoic and a cored interval was recovered across the Paleocene–Eocene boundary. On a more sombre note, the expertise of the marine team was called upon in aftermath of the Indian Ocean tsunami of 26 December 2004 and staff played a major role in the follow-up HMS Scott expedition, which produced dramatic images of submarine thrust ridges and slides across the earthquake rupture zone.

The first year of the Wales Rapid Mapping initiative (the GeoCymru Project) was highly successful. Productivity more than doubled, resulting in the completion of two high quality maps in record time. In Scotland, new methodologies have led to better understanding of the regional glacial history and geomorphology. Geoheritage activities have continued to expand and raise the profile and relevance of geoscience in the tourism, education and conservation sectors. Examples include Geodiversity Audits and Action Plans for the North Pennines and Durham, supported by the Aggregates Levy Sustainability Fund, and the publication of two *Landscape Fashioned by Geology* booklets in collaboration with Scottish Natural Heritage.

Commissioned research grew and widened in scope. A notable achievement was the launch of TELLUS in Northern Ireland: a major geochemical and airborne geophysical mapping project, funded by the Department of Enterprise Trade and Investment (DETI), aimed at providing key information to underpin protection of the environment, sustainable land use and sustainable development of natural resources. Other important commissions included investigations related to the decommissioning of Dounreay, 3D geological modelling for the Environment Agency and water companies to aid their understanding of the shallow geosphere, and new 'environmental sensitivity and sustainable development' tools for the minerals sector.

In the sustainable energy sector, the BGS-led European Network of Excellence on the geological storage of carbon dioxide (CO_2GeoNet) was successfully launched. The team has also continued to work with the DTI to support development of the government's Carbon Abatement Technology Strategy, and it is now widely recognised that underground carbon dioxide sequestration has a role to play as part of UK strategy for reducing greenhouse emissions. At the other end of the scale, the use of low enthalpy geothermal resources has been given a boost by the launch of an online 'GeoReport' service for those considering the installation of ground source heat pumps for space heating, following work co-funded by the Carbon Trust.

(Opposite) The *Sovetskiy Soyuz*, the *Oden* and the *Vidar Viking* in operation during the Integrated Ocean Drilling Program's Arctic Coring Expedition (see page 14). Photograph, Heiko Pälike, IODP.

New high-resolution airborne geophysical survey capability

The BGS and the Geological Survey of Finland (GTK) have formally established a Joint Airborne-geoscience Capability (JAC) to provide both partners with a cost effective, state-of-the-art facility for acquiring high-resolution airborne geophysical data for their respective national strategic science programmes. The rationale is to share the cost of ownership, maximise the use of the facility, share the cost of technical R&D and maximise collaborative scientific opportunities.

The survey aircraft, a de Havilland Twin Otter, is owned by NERC/BGS and is equipped with GTK instrumentation comprising a dual frequency electromagnetic (EM) system, a multichannel gamma spectrometer and a magnetic gradiometer. The first survey under the auspices of the JAC was successfully carried out over an area of environmental and geological interest in Ayrshire.

Joint Airborne-geoscience Capability: the NERC/BGS owned de Havilland Twin Otter survey aircraft *(below)* and the JAC logo *(bottom)*.

JAC

Joint Airborne-geoscience Capability

Geological Survey of Finland/British Geological Survey

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 Moffat and progressed in the Glasgow, Assynt, Aviemore, Crianlarich, Hexham, and Montrose districts. Fifteen 1:50 000 scale and two 1:25 000 scale maps were delivered along with one Regional Guide, one Memoir, 26 papers and articles, 22 internal reports and the supervision of eight studentships.

Grampian Highlands — new insights into bedrock geology and superficial deposits

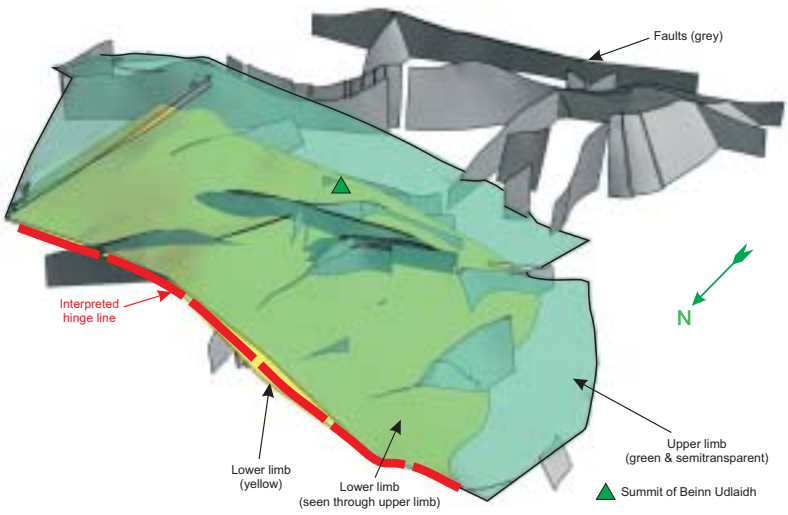
Bedrock and superficial deposit mapping was completed over 400 square kilometres in the Crianlarich and Killin areas. Major omissions in Dalradian stratigraphy were demonstrated where Easdale to Crinan subgroup strata adjoin the Lochaber Subgroup across a non-orogenic overstep unconformity. Section logging, X-ray diffraction analysis of till, and landform mapping has revealed a more complex distribution of superficial deposits and provided further constraints upon the flow direction and maximum surface altitude of the Loch Lomond Stadial icecap. In the Cononish area analysis of landforms favours an icecap deglaciation model against valley-style glaciation.

Funding to the University of Glasgow through the BGS–University Collaboration Scheme has aided the development of three-dimensional structural models using the GoCAD package. These provide a methodology for analysing complexly folded strata using constructed subsurface interpreted data. Recumbent kilometre-scale folds exposed on mountainous topography around Beinn Udlaidh in the Glen Orchy–Glen Lochy area of the Scottish Highlands have been constructed using structurally accurate cross-sections linked in three dimensions. These constructions identify surfaces that capture and constrain the fold form and provide the geologist with significantly improved model viewing, evaluation and interrogation tools.

Northern England — integrated field and desktop mapping

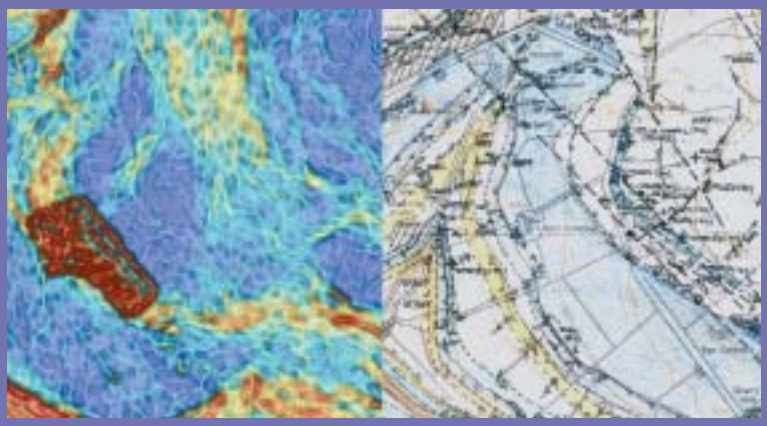
NEXTMap Digital Surface Model (DSM) data have been used in conjunction with traditional 1:10 000-scale field survey and aerial photograph interpretation to complete the resurvey of 65 km^2 of the Dinantian and Namurian Yoredale successions on the northern margin of the Alston Block in the Hexham district. Slope gradient and rate of change of gradient data were derived from the DSM to produce a slope analysis map. This highlighted many of the landscape features related to bedrock lithology and structure, and the nature and form of the Superficial Deposits. The precise location of the landscape features enabled efficiency gains in the survey process, particularly in areas of open fell country where there is little interference from buildings and trees.

New 1:10 000 scale maps combined with detailed mine plans are being utilised to construct 3D models for the Alston Block and to improve our knowledge of the sandstone architecture and structural geometry of faults and mineral veins. These will inform interpretative mineralisation models and will improve our understanding of the environmental impacts of mining in this Area of Outstanding Natural Beauty.



Grampian Highlands: the Beinn Udlaidh fold structure (preliminary model) showing both limbs of the overturned fold.

Northern Britain



Northern England: slope-angle and break-in-slope information derived from NEXTMap data *(left)*. Colours show slope angle (steep in red, shallow in blue). Corresponding 1:10 000 geological field slip *(right)*. Carboniferous strata comprising, limestones (blue), sandstones (yellow), and siltstone with subordinate sandstone (unshaded).

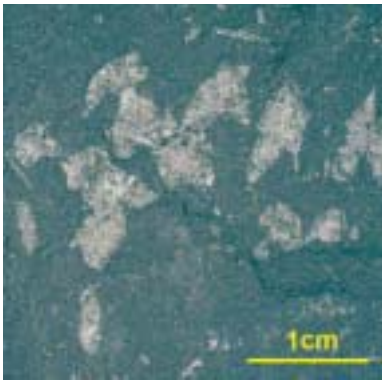
South of Scotland — revised interpretations of the development of the Lower Palaeozoic Basin and the regional glacial history

Completion of the resurvey of the Moffat district has resulted in exciting new discoveries and interpretations of the development of both the Southern Uplands Lower Palaeozoic Basin and the regional glacial history and geomorphology.

Combined whole rock geochemical, G-BASE and faunal evidence indicate the presence of a hitherto unrecognised succession of turbiditic strata, thrust-faulted into the sequence. In addition, an exceptionally well-preserved Silurian graptolite, conodont and 'Dawsonia' fauna in a unique palaeoecological assemblage is under investigation by palaeontologists at the BGS and the University of Leicester.

In southern Scotland fast-flowing ice streams existed in the British Ice Sheet during the last (Late Devensian) glaciation. These ice streams left behind distinct geomorphological signatures, or land systems. In the Moffat area new radar interferometry data (NEXTMap) reveal large-scale highly streamlined glacial landforms comprising megadrumlins, megaflutes and channels that probably formed beneath a fast-flowing glacier feeding into the Irish Sea palaeo-ice stream. Further south in the Solway lowlands new stratigraphical and geomorphological interpretations have revised our understanding of the interaction and timing of palaeo-ice streams from the Southern Uplands and the Lake District massif. A landform classification that allows improved characterisation of slope deposits and glacigenic landforms was developed with the University of St Andrews, funded through the BGS–University Collaboration Scheme.

South of Scotland: articulated remains *(below)* and artist's impression of the enigmatic animal 'Dawsonia' *(bottom)*.



South of Scotland: a view down the steep sided and glaciated Blackhope valley in the Southern Uplands showing glacial landforms and paraglacial talus deposits in the foreground. Thin head and peat mantle the rounded mountain tops.

Integrated Geoscience Surveys

Programme overview

The programme undertakes systematic multidisciplinary geological surveys of Southern Britain,as part of a long-term strategy to provide onshore coverage which satisfies user needs and, in particular, enhances our understanding of the three-dimensional geology of the UK landmass. The programme provides the basic underpinning framework for many of the applied geological, geophysical and geochemical activities undertaken within other BGS programmes, and also ensures the maintenance of a local and regional geological knowledge base (the District Geologist network). During the year, a total of 3220 square kilometres were surveyed, and nine 1:50 000 scale geological maps were published, together with three Sheet Explanations and two Memoirs.

Mapping the Variscan Belt: view of Wheal Golden, Penhale Sands. Photograph courtesy of Simon Camm of Camborne School of Mines, University of Exeter in Cornwall.

Rapid mapping in Mid-Wales

The new rapid mapping survey of Mid-Wales commenced in Spring 2004, with a concerted field campaign covering 1000 square kilometres in the Llangranog and Newcastle Emlyn districts. Innovative techniques, such as the use of orthorectified radar images, have aided the interpretation of the regional geology and enabled efficient traverses to be undertaken. The mapping has covered the Llanvirn to Caradoc succession north of Carmarthen, a classic area of British Ordovician geology.

The project has been successful in delimiting the geometry of the Central Wales Syncline; a major first-order fold and fault plexus preserving the youngest strata in the district, which was active during deposition, and which controlled facies distribution within the area. The survey also revealed a lack of Quaternary glacigenic deposits across the area, and a landscape largely dominated by river evolution suggesting that much of the Newcastle Emlyn district lay beyond the margin of the Late Devensian ice sheet. The field survey programme was completed in record time and by March 2005, first proof 1:25 000 scale maps were already available.

Global cooling in Norfolk!

Geological surveying and analysis of the complex succession of superficial deposits in north-east Norfolk has provided evidence that the area was over-ridden by ice-sheets on five separate occasions during the past 800 000 years. This long sequence of glacial events is unique in the UK, and provides important information on recent major natural climate change prior to anthropogenic influence. Recent fieldwork has been centred on Aylsham, an area last geologically surveyed in the late nineteenth century. In addition to providing information on past climate change, the superficial deposits of this area also overlie, and in places protect, the Chalk bedrock, the main aquifer in the region.

The importance of the superficial deposits in the Aylsham area was recognised by the Environment Agency, who provided funding for the BGS to drill twenty-four 20 metre percussion boreholes during the summer of 2004. A large number of samples were collected and are currently being analysed by staff and research students in the Department of Geography at Royal Holloway College of the University of London, as part of a long-standing collaborative research programme with the BGS. The results are enabling a much-needed detailed characterisation of the superficial deposits, and are facilitating three-dimensional modelling of the shallow subsurface.

Mapping the Variscan Belt in Cornwall

The spectacular coastline around the popular seaside resort of Newquay provides much more than a backdrop to the rolling waves. In this part of the Variscan belt, a mountain chain formed across Europe as a result of the collision of continental plates in the late Devonian and Carboniferous, fine cliff exposures provide the key to unravelling the complex geological history. Detailed study of the geological structure has revealed that three regional fabrics (S1, S2, S3) are present across the area, each related to a pulse of deformation, the first of which affected the entire south-west peninsula.

Southern Britain

A pilot study is under way to discover whether a novel use of argon–argon analysis on muscovite grains extracted from the S1 foliation can provide temporal and spatial resolution of fabric formation across the area, to determine whether successive closure and inversion of basins from south to north accompanied mountain-belt formation. Equally important are the biostratigraphical studies being undertaken, using palynomorph and acritarch analysis, which may reveal the time-frame of basin evolution. A rapid increase in the population around Newquay is pressurising the existing infrastructure and driving the need for new development. The survey of the district includes studies of the superficial deposits and mining data: these will provide us with products to meet modern demands, while revealing new insights into the intriguing geological past.

World's oldest fossil macrofauna

An important part of the ongoing scientific work of the East Midlands Integrated Survey continues to be the geology and geochronology of the Late Neoproterozoic (Precambrian) Charnian Supergroup, which forms the basement rocks of Charnwood Forest in Leicestershire. The project is currently collaborating with other researchers in the field who are studying enigmatic bedding-plane impressions in volcaniclastic strata, near to the base of the exposed sequence. It is anticipated that these will turn out to be among the world's oldest fossil macrofauna, although little is known about their precise biological affinities. The picture is complicated, because geochemical analysis indicates that volcanic grains in these fossiliferous sediments may have been derived from a different source to that supplying the younger Charnian strata of the Maplewell Group. In this group there is a lateral transition westwards, from fine-grained subaqueous tuffs that preserve delicate shards of volcanic ash, into spectacular volcanic breccias. These show features indicating that they are the deposits of lahars and pyroclastic block flows derived from collapsing volcanic edifices — processes that were recently seen on Montserrat in the West Indies.

World's oldest fossil macrofauna: holotype of *Ivesheadia lobata* viewed as a shadow-illuminated latex cast made by the BGS Corporate Collections section. The specimen is approximately 14 cm in diameter.

Dudley to the Welsh borders — a geological roller-coaster

The countryside between Dudley and the Wyre Forest records a fascinating tale of climate change in rocks that represent over 400 million years of geological history. New mapping has revealed fuller details of the northward migration of the region from an arid environment developed south of the Equator during the late Silurian to Devonian, through humid equatorial conditions during the Carboniferous and a gradual return to an arid climate, culminating in desert sand dunes during the Permian. Landforms created by glacial meltwaters indicate extremes of cold in the geologically recent past. Superimposed on this natural landscape are the relicts of an industrial revolution fuelled by coal, ironstone and brick-clay from the coalfields of the Wyre Forest and South Staffordshire.

The project has met the challenge of distinguishing rocks representing a range of environments and climatic types. Arid, semi-arid and humid swamp environments have been recognised and can be distinguished at all scales, from thin-section petrographical studies, in quarry and stream exposures, and at basinal scales in geophysical logs.

Dudley to the Welsh borders: sustainable housing! Holy Austin Rock Houses, Kinver, cut in Permian sandstone.

Continental Shelf and Margins

Programme overview

The Continental Shelf and Margins programme is concerned with all aspects of offshore geology of the UK, from seabed sediments to the deep crustal structure and is also involved in important aspects of international geoscience, particularly with respect to geological hazards and global climate change. Studies around the UK include support for hydrocarbon exploration and marine landscape mapping.

Martin Jakobsson © IODP

IODP Arctic drilling: the drilling vessel, *Vidar Viking*, in ice.

Martin Jakobsson © IODP

IODP Arctic drilling: drilling operations in the Arctic aboard the *Vidar Viking*.

IODP Arctic drilling

The BGS led the first successful drilling of the Lomonosov Ridge in the ice-covered waters of the Arctic Ocean. The Arctic Coring Expedition (ACEX) was part of the Integrated Ocean Drilling Program's (IODP) schedule of international scientific ocean drilling projects. The BGS is the Science Operator for the European Consortium for Ocean Research Drilling (ECORD), a group of seventeen mainly European countries, which implements mission-specific platform expeditions for IODP.

ACEX involved the use of three ships. The drilling vessel was a temporarily converted Baltic-class icebreaker, the *Vidar Viking*. Ice protection was provided by the Russian nuclear icebreaker *Sovetskiy Soyuz* and the Swedish research icebreaker *Oden*. The latter also acted as the main science base and fleet command vessel.

The expedition drilled to a depth of 428 metres below the seabed in almost 1300 metres of water to recover a Cainozoic section dating back to the late Paleocene, as well as sampling Late Cretaceous rocks beneath an unconformity. The Cainozoic section holds the climatic and environmental history of the Arctic Ocean over the past 56 million years, and is now being studied by an international scientific team.

Offshore regional report for Rockall

The BGS is to publish a new offshore regional report for the Rockall Basin sponsored by the Rockall Consortium, which includes a number of oil companies. The report covers the area between the Outer Hebrides and Rockall Bank. It draws strongly on recent data acquired for the consortium. Boreholes drilled on top of Rosemary Bank Seamount penetrated five thin lava flows, each with a rubbly, and locally reddened top. The irregular holes (vesicles) confirm that gas bubbles were present in the lava at the time of extrusion and some are elongate and subparallel suggesting alignment with the direction of flow at the time the lava cooled and solidified. The lava is classified as a phono-tephrite and was probably derived by a small degree of partial melting of lithospheric material beneath the continental crust.

In partnership with the Faroese Geological Survey, we have also commenced a new report focusing on the Faroe–Shetland Basin and its surrounding area. The new publication will, for the first time, present a comprehensive geoscientific overview of both the UK and Faroese national sectors. All of the major oil companies active within this region are supporting the project, through sponsorship, data provision and steering committee membership.

Marine landscapes

A recent marine survey in the Firth of Forth, around the road and rail bridges has produced stunning images of the seabed, revealing for the first time the detailed morphology of the area. Using modern, digital multibeam sonar equipment, the entire area was surveyed in two days using a catamaran. In

Marine landscapes: Firth of Forth seabed morphology.

addition to the high-resolution bathymetry, magnetic field and 2D high-resolution seismic data were also collected. These data are being combined and used to develop a better understanding of the marine landscape by looking at the processes involved in forming the various bathymetric features. This work is being carried out in conjunction with land geologists who have for years been using aerial photographs and digital elevation models as an aid to interpretation and mapping. This form of collaboration will make optimal use of the new data and produce more integrated maps and 3D models that will be of use to developers and managers of the marine environment.

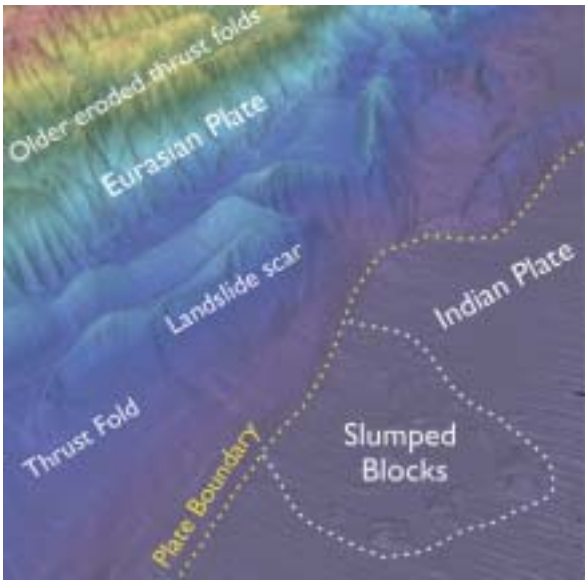
Indian Ocean tsunami disaster

The Indian Ocean tsunami disaster of 26 December 2004 led to an enormous increase in public awareness of tsunami events. As a result our scientists were called upon to explain why tsunamis occur, to provide information on previous events and to explain whether they could happen elsewhere, particularly in the UK. Our studies on previous tsunamis have been used for estimating the frequency of these rare but devastating events as part of future risk assessments. Research on the devastating Papua New Guinea tsunami of 1998 led to our staff playing a leading role in the first high-resolution bathymetric survey of the December 2004 earthquake rupture area offshore of Sumatra.

The survey was conducted by HMS *Scott* and produced dramatic images of submarine thrust ridges and submarine slides. The results from this survey will be used to direct future studies in the area, currently at the planning stage, and will also contribute to a better understanding of the sedimentary processes in subduction zone environments.

Offshore regional report for Rockall: Phono-tephrite lava core samples from Rosemary Bank Seamount.

Indian Ocean tsunami disaster: High-resolution bathymetric survey image of the earthquake rupture area offshore of Sumatra showing a submarine landslide on the Sumatra plate margin. The displaced blocks on the right originated from the scar on the accretionary thrust fold in the centre of the image. They have travelled up to 13 km from their source. The largest blocks are 100 m high by 2 km wide. The landslide is recent, but probably not caused by the earthquake of 26 December 2004.



Economic Minerals and Geochemical

Programme overview

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

Building stones and the built heritage

We have set up a building stones project in response to increasing stakeholder interest in, and recognition of, the pivotal role that geology plays in determining the character of Britain's stone-built heritage and modern urban environment. The local vernacular building styles of cities, towns and villages in Britain are a strong influence on our living and working environment. Historical buildings require repair and maintenance and new buildings are increasingly being built in sympathy with local building styles and materials. It is therefore important to develop a UK-wide knowledge of building stone resources in terms of source areas, lithological and mineralogical characteristics and the ideal building applications of a specific stone resource.

We are developing databases that are a repository of this knowledge and are currently applying our expertise in building stones in Glasgow and the West Midlands by identifying heritage building needs, defining stone character and identifying stone resources. The BGS is a key player in UK building stone geoscience, working in collaboration with bodies such as the Scottish Stone Liaison Group, Historic Scotland, English Heritage and the Natural Stone Institute. One recent report drafted by the building stone project team is the Scottish Executive-sponsored volume on *Building with Scottish Stone*.

Minerals geoscience research for the Office of Deputy Prime Minister

The Office of Deputy Prime Minister (ODPM) has worked closely with BGS for many years. We have provided technical advice and assistance to ODPM on minerals and planning issues in particular. In common with most world economies, the UK has a high requirement for a wide range of minerals. Some mineral commodities are domestically produced. Examples include sand, gravel, crushed rock, cement-grade limestone, gypsum, rock-salt, potash, china clay, ball clay, silica sand, and fluorite.

It is becoming increasingly challenging to locate areas of the UK which contain high-grade, economically viable minerals and which can be consensually worked in line with modern principles of planning and sustainable development. The ideal is to work minerals with maximum benefit to society and the economy, and the minimum negative impact on society and the environment. While local communities rarely welcome mineral workings, it is helpful to the planning debate if the general public can be made more aware of the importance of minerals to quality of life. To this end ODPM has commissioned the BGS to publish a range of awareness-raising brochures entitled *Mineral Matters* which summarise the links between our quality of life and issues such as house construction, road building, recycling, global trade and sustainable development.

Building stones and the built heritage: Cullalo Quarry, Fife, once an important producer of high quality sandstone, has now reopened and is supplying a range of products from walling to finished ashlar both for repair and new build. The BGS played an important role in assessing this indigenous resource whose mineralogical characteristics are almost identical to those of the famous Craigleith Sandstone. Both sandstones were used extensively in Edinburgh's early nineteenth century New Town.

Baseline

Geochemical baseline mapping: the extent of G-BASE sampling of drainage (stream waters and sediments in purple) and soils (in green).

Geochemical baseline mapping

Geochemical mapping is one of our core survey activities and is carried out under the Geochemical Baseline Survey of the Environment (G-BASE) project. Sampling in East Anglia has been completed and only southern England remains to be sampled. Geochemical mapping is carried out using a range of sample media (drainage sediment, soil and steam water) systematically collected at a relatively high sampling density of at least one sample every two square kilometres. The project publishes a range of outputs including geochemical atlases (the Humber–Trent atlas is currently in press) and peer-reviewed literature. Geochemical data are placed in the corporate BGS Geochemical Database, along with comprehensive site information, and this is available for use under licence. Much of the demand for environmental geochemical data is driven by legislation: an example of our work was recently filmed by the BBC where historical contamination by an old forge in a Suffolk village required investigation under the local authority's duty to identify contaminated land. The G-BASE team is also actively supporting the regional geochemical mapping work being carried out in Northern Ireland by the Tellus Project.

Working with universities

EMGB has an active research collaboration programme with universities on minerals and geochemical projects. Projects are based in the UK and internationally. One Ph.D. project is researching copper porphyry style mineralisation in the Gobi Desert of Mongolia and is modelling mineralisation in terms of terrane accretion, crustal genesis and evolution, geological history and structure. This project has already received two awards from the Geological Society of London's Mineral Deposit Study Group. A second Ph.D. project is focusing on a high-Na calc-alkaline stratovolcano in Solomon Islands and ore-element concentration processes within the volcano's geothermal field. Prime Minister Kemakaze of Solomon Islands is taking a keen personal interest in the progress of this particular research, which will generate research outcomes for volcanic hazards as well as mineralising processes.

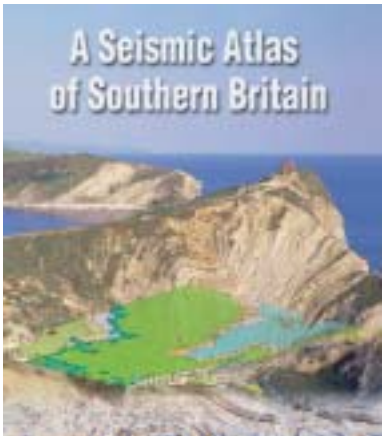
Working with universities: mineralised tourmaline breccia pipes, Gobi Desert, Mongolia.

Working with universities: Investigating mineralisation processes within the solfatara of a stratovolcano, Solomon Islands.

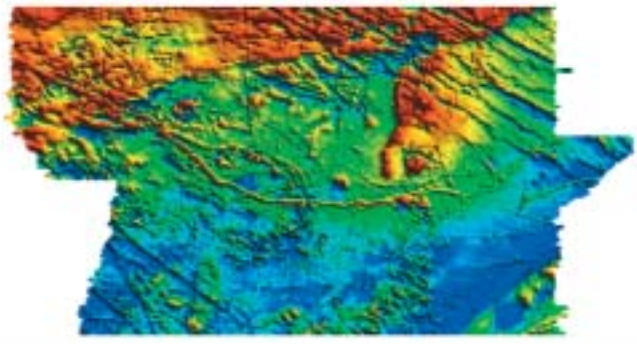
Sustainable Energy and Geophysical

Programme overview

The Sustainable Energy and Geophysical Surveys programme provides research and information to support many of the objectives of the Energy White Paper (2003), and to deliver NERC strategic science priorities (for example, Towards a Sustainable Energy Economy). These include technologies for securing a 60% cut in carbon dioxide emissions by 2050, coupled with finding and using affordable, reliable and 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 environmental applications and core research.



Seismic Atlas of Southern Britain: the Atlas is available in book form and as a CD-ROM.



HiRES in Ayrshire: image of new high-resolution aeromagnetic data over part of Ayrshire acquired during the first survey undertaken by the BGS/GTK Joint Airborne-geosciences Capability (JAC). The image covers an area of around 40 x 25 km, survey line spacing was 200 m.

Seismic Atlas of Southern Britain

The latter part of the twentieth century saw the acquisition of large amounts of seismic reflection data in the UK, mostly in search of hydrocarbons. These data vividly illustrate the subsurface nature and development of many of the principal structural features of Britain. They have transformed our understanding of basin evolution and provided fascinating images of igneous intrusions, major basement structures and the deep crust. We have now reviewed this unique database and published the Seismic Atlas of Southern Britain to illustrate a selection of subsurface geological features. The Atlas features structures both onshore and in the adjacent nearshore areas, which have particular merit because of the image quality or in illustrating UK geological history. The Atlas is available in book form and as a CD-ROM.

Underground gas storage

The UK's North Sea gas reserves and production are forecast to decline sharply, to the extent that the UK will be a net importer of gas by early 2006. Britain has only twelve days underground gas storage (UGS) capacity, while France and Germany hold 55–60 days stock. UGS will become increasingly important, acting as a buffer against surges in demand or interruptions to supplies. During 2004, we increased our involvement and expertise in the rapidly emerging UGS sector. Our staff helped organise a two-day international conference in Aberdeen — The Future Development and Requirements for Underground Gas Storage in the UK and Europe — at which the BGS Onshore UK Hydrocarbons geographical information system was demonstrated. This enables rapid identification of suitable sites for UGS relative to major producing areas, pipelines, consumers and markets. We also submitted written evidence to a House of Lords European Union Committee reporting on Gas: Liberalised Markets and Security of Supply.

Geophysical maps

A new series of geophysical maps has been completed, covering the UK and surrounding areas at a scale of 1:1 million. The maps display variations in the Earth's gravity and magnetic fields, providing important insights into the concealed geology; for example, the form of sedimentary basins and igneous intrusions. There are eighteen maps in total (nine gravity and nine magnetic) and the series spans a region extending from 12°W to 6°E and from 48°N to 66°N.

Ground source heat pumps

Ground source heat pumps (GSHP) harness heat from the shallow subsurface by circulating refrigerant in pipes placed in the ground. The pipes may be installed either horizontally in a shallow trench or vertically in boreholes. These take up heat that is released by a heat pump at a higher temperature for use in space heating. Conversely, heat can be removed from the building into the ground. This low-enthalpy, geothermal energy is renewable, produces negligible carbon dioxide emissions and results in savings in conventional energy use. Estimating the potential performance of a system requires a geological prognosis for a site. During the year we launched a new online GeoReport that generates site-specific information for a GSHP assessment. Included are descriptions of the geology, mean

Surveys

annual air temperatures, estimates of shallow subsurface temperatures of the rocks, and estimates of mean thermal properties, such as thermal conductivity and diffusivity. This project was co-funded by the Carbon Trust. Work also commenced on estimating thermal conductivities from the extensive suite of downhole logs held by the BGS for a wide range of British rocks. This method has the advantage of producing in situ values that are often more accurate than those derived from laboratory measurements.

HiRES in Ayrshire

The Joint Airborne Capability (JAC) recently established between the BGS and the Geological Survey of Finland (GTK) carried out an airborne geophysical survey of the Ayrshire coalfield and adjacent areas in October 2004. Just over 6000 line-kilometres of high-resolution magnetic, gamma spectrometric and electromagnetic data were acquired across an area of 40 by 25 kilometres. These data will be used to generate interpretation products for the benefit of public and private development in the environmental and resource sectors. The Ayrshire Coalfield's industrial past has left a legacy of abandoned mine workings, spoil heaps and opencast sites, creating challenges to redevelopment, landscape quality and pollution management. The HiRES survey will help to elucidate the extent and influence of these features and have relevance to the Ayrshire Joint Structure Plan. It will also provide improved information on the extent of lava successions, igneous sills and dykes and faulting.

CO_2GeoNet

The BGS is an international leader in underground carbon dioxide storage research and co-ordinates the European Network of Excellence devoted to this subject (www.co$_2$geonet.com). Co-funded by the European Commission, it was launched in April 2004 and comprises thirteen research institutes from six countries with the aim of strengthening European research through the alignment and development of joint research activities. CO_2GeoNet partners, including the BGS are working with BP at its In Salah carbon dioxide underground storage project in the Algerian Sahara. Here a total of 1.2 million tonnes per annum of carbon dioxide is stripped out of natural gas produced from a geological structure nearly two kilometres below the desert surface. The carbon dioxide is injected back into the structure, demonstrating the ability to deal with emissions at an early stage in the energy supply chain.

Next Generation Capture and Storage project

The Grangemouth refinery and petrochemicals complex near Edinburgh, Scotland produces around four million tonnes of carbon dioxide annually. The BGS has been involved in a European Community project investigating the potential to store underground (sequester) around half of the carbon dioxide emissions as an alternative to emitting this greenhouse gas to the atmosphere. Our partners in the Next Generation Capture and Storage project (NGCAS) are BP, IFP and ECL. Various sites, both on- and offshore, were considered. However, numerical simulation studies indicated that injection of the carbon dioxide into an underground oilfield could provide sufficient increased oil production to be economical. Consequently, the Forties oilfield in the UK sector of the North Sea was highlighted as the best potential sequestration site for these emissions. A risk assessment process was then undertaken, which concluded that the risks of carbon dioxide escaping through the cap rock above the Forties oilfield were negligible.

HiRES in Ayrshire: the Ayrshire airborne survey calibration flight over Loch Lomond.

Next Generation Capture and Storage project: Grangemouth refinery and petrochemicals complex near Edinburgh.

Geological Survey of Northern Ireland

Northern Ireland

The Geological Survey of Northern Ireland (GSNI) is part of the Northern Ireland Department of Enterprise, Trade and Investment (DETI). It is staffed by BGS scientists under contract to DETI, which allows the GSNI to avail itself of expertise from other parts of the BGS. The GSNI carries out work for other Northern Ireland government departments and collaborates closely with the Geological Survey of Ireland (GSI) on cross-border projects. In October 2004, the GSNI moved from College Gardens to Colby House in the Stranmillis area of Belfast. The Ordnance Survey of Northern Ireland is the main tenant in the building and a strong symbiotic relationship is forming between the two surveys. The move affords the GSNI increased space and a better working environment compared to the former premises.

Tellus project: soil sampling as part of the Tellus geochemistry programme.

Tellus project

The Resource and Environmental Survey of Ireland was rebranded as the Tellus Project (named after the Roman goddess of the Earth). Ministerial approval was secured and work commenced on the collection of soil samples across the western part of the country with some 50% of sites visited. Detailed planning of the airborne component of Tellus has progressed on schedule. Extensive outreach activities are informing the stakeholder community and general public about the project. The data collected will be relevant and of value to environmental monitoring, geohazard identification, agriculture and mineral exploration.

Minerals and energy resources

Mineral and petroleum rights are vested in the DETI. The GSNI act as advisor to DETI and monitors technical aspects of the licence holders. The newly implemented mineral and petroleum promotional strategy attracted three natural resource exploration companies to Northern Ireland for the first time. Increased interest was shown by hydrocarbon companies assessing the potential of the Fermanagh and north Antrim areas.

Mineral exploration remained focused on gold, and work continued at the Cavanacaw and Curraghinalt deposits in County Tyrone and at the Cargallisgoran project in County Armagh. Cavanacaw is expected to be in production by 2006 and Curraghinalt is undergoing Environmental Impact Assessment prior to submitting a planning application. The GSNI participated in a gold metallogeny study of the Armagh area with a view to evaluating the potential for Carboniferous gold mineralisation.

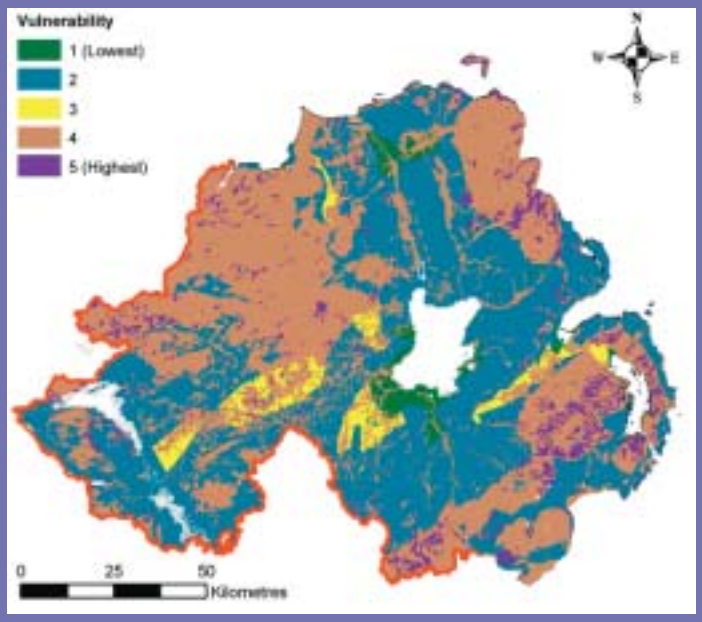
Environment

The GSNI continued to provide the DETI with geological support with regard to Northern Ireland's legacy of abandoned mineral workings. The Abandoned Mines Database contains information regarding mine shafts and adits throughout Northern Ireland. During the year 400 localities were inspected and a number of potentially hazardous openings were identified. The GSNI then prioritised and instigated a systematic programme of closures. Options for the infilling of the collapsed salt mine at Maidenmount were explored with the regulatory authorities.

Geological input was provided to the Belfast Metropolitan Area Plan (BMAP) and other regional plans. The GSNI and the BGS reviewed the datasets and methodology required to construct a geologically focused geographical information system to complement the BMAP initiative. Since 2001, the number of planning consultations submitted to the GSNI has grown enormously. Applications for wind farm developments and mineral aggregate extraction accounted for the majority of Planning Service consultations.

The GSNI continued to provide hydrogeological and groundwater technical support to the Northern Ireland Environment and Heritage Service. Geological and hydrogeological datasets were compiled and reinterpreted at 1:250 000 scale in support of groundwater assessment for the EU Water Framework Directive.

Advice was also provided on significant engineering projects within Belfast, including the large-scale dewatering programme associated with redevelopment of Victoria Square in the city centre.



GSNI © Crown Copyright

Environment: new groundwater vulnerability map for Northern Ireland.
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Landscape heritage and public awareness of science

The work of the landscape and heritage sector is among the most publicly visible functions of the GSNI. Over the next three years the GSNI, through participation in various EU-funded activities, will be engaged in projects exceeding ¤6 M. The major success of the year was the award of the 2006 International Geoparks conference to Northern Ireland, to be staged in the Waterfront Hall. Field trips associated with the event will visit the north and south of Ireland as well as Great Britain and Europe. Work continued on the successful cross-border Briefne project with plans well advanced for the production of state-of-the-art guidebooks and DVDs. The GSNI continues to co-operate with Fermanagh District Council at the Marble Arch Geopark and have employed a dedicated geologist to enhance the visitor experience.

Mapping and publications

GSNI's most recent publication, *The Geology of Northern Ireland — Our Natural Foundation*, was launched in Parliament Buildings, Stormont, by Bruce Robinson (Permanent Secretary, DETI) and David Falvey (Executive Director, BGS). Sales of the book exceeded 850 in the first year and reviews continue to be highly complimentary. Preparation of 1:50 000 scale maps for the Lisnaskea area necessitated close liaison with the GSI to ensure matching of data across the border. This level of co-operation will continue as many of the maps remaining to be published in the 1:50 000 series are in border areas. Fieldwork, allied with air photo interpretation continued in the Cushendall and Strabane districts.

Mapping and publications: launch of *The Geology of Northern Ireland* book. Garth Earls (Director, GSNI), David Falvey (Executive Director, BGS) and Bruce Robinson (Permanent Secretary, DETI).

GSNI © Crown Copyright

New premises: the new GSNI offices at Colby House, Stranmillis, Belfast.

GSNI © Crown Copyright

Environment and Hazards

The Environment and Hazards Directorate operates through five programmes to deliver a wide range of science information on how the rocks beneath our feet impact on us and on our environment. The Electrical Tomography Service utilises an important geophysical technique to investigate and monitor the near-surface in a non-destructive way. Our aim is to understand better 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 people as they go about their business.

The Groundwater Systems and Water Quality programme continues to produce high quality research on processes and information relating to both groundwater resource and quality. A multidisciplinary approach dramatically increases the understanding of how aquifer systems work and how they interact with surface-water bodies. This information aids better sustainable management of finite water resources. Work on understanding how aquifers operate on the West Bank is helping decision makers in the area. Emphasis is being placed on managing underground water resources. This includes augmenting natural recharge and understanding changes in water quality. Novel modelling techniques, developed in co-operation with others, is helping to integrate hydrological and ecological sciences.

The Seismology and Geomagnetism programme continues to monitor and disseminate valuable information on seismic events and geomagnetism. A long-term project to update instrumentation is under way. Research into fracture anisotropy and fluid content, exploited by the hydrocarbons and water industries, has advanced significantly. Industry consortia continue to grow, ensuring that the quality and usefulness of the science is maintained. The Sumatra earthquake of 26 December 2004 has been studied intensively using novel methods. Significant interest in tsunamis has resulted by governments and the media. A near real-time monitoring of space weather is proving its worth with power generators.

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

The third year of the Environmental Protection programme has resulted in the development of a wide variety of activities in the areas of geochemistry, mineralogy, geophysics and hydrogeology. A facility to measure very low flows of gas generated by radioactive waste has been installed underground in Sweden and, operated remotely from the UK, is working well. A major multinational project to research the bioremediation of industrial organic compounds has instrumented a site in the UK. Remote sensing is greatly aiding the study of the environmental impacts of abandoned mines. The experience is being used abroad to solve environmental issues associated with clusters of small mines.

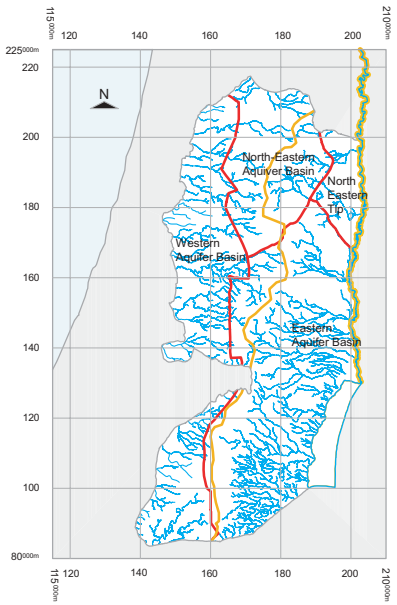
The Coastal Geoscience and Global Change Impacts programme aims to understand past and present patterns of erosion, transport and storage of sediments (and associated materials including pollutants) in order to predict and better manage future change. Marine habitat maps in the eastern English Channel were produced. Options for carbon dioxide sequestration in deep-water sediments using hydrates has required the development of innovative laboratory methods.

(Opposite) Rescue services in action at the height of the Boscastle disaster 16 August 2004. Photograph © www.apexnewspix.com

Groundwater Systems & Water Quality

Programme overview

The programme provides underpinning science and survey data and information to support policy and operations in the sustainable management of the water environment in UK and overseas. Significant outputs for the year have included the completion of nitrate trend analysis work for the UK water industry and government. A major new study into the economic impacts of deteriorating groundwater quality was published and has raised considerable interest. Another first was the publication of the Hydrogeological Map of the West Bank and modelling of groundwater resources of the West Bank with BGS's new object-oriented distributed recharge model. The groundwater modelling group launched its innovative ZOOM3QD software and ran the first course for consultants and Environment Agency staff. After a successful science and management audit major efforts were made to develop a vibrant new programme for the next five years.



Hydrogeological Map of the West Bank: the West Bank aquifer basins.

Hydrogeological Map of the West Bank

The *Hydrogeological Map of the West Bank* describes an aquifer system which is the focus of political debate regarding the equitable apportionment of groundwater on both sides of the Green Line separating Palestine and Israel, and is intended to inform those involved in discussion. The map is also of considerable technical interest as it was created electronically from a geographical information system format database. We carried out a remote sensing geological and hydrogeological interpretation of the West Bank aquifers, which was an important element of the work. The map has recently been published on behalf of the Palestinian Water Authority through the Sustainable Management of West Bank and Gaza Aquifers (SUSMAQ) project (www.ncl.ac.uk/susmaq). The map is printed at a scale of 1:250 000 and conforms with the standard UNESCO legend for international hydrogeological maps. It includes a number of inset diagrams portraying various aspects of the geological framework, hydrogeology, hydrochemistry, climate and other details, as well as comprehensive notes on the characteristics of each groundwater unit. The project was funded by the UK Department for International Development.

Groundwater quality degradation impacts

The United Kingdom Water Industry Research, the Environment Agency and the BGS funded the project 'Implications of changing water quality for water resources and the UK water industry'. This included a national survey of water-supply utilities which showed that groundwater quality problems in the UK have cost the industry £754 million (at 2003 prices) since 1975, mainly in capital investment. This has been largely for mitigation of nitrate, pesticides, *Cryptosporidium*, arsenic and hydrocarbons/solvents. It reflects a combination of deterioration in groundwater quality and the introduction of more stringent regulatory standards for drinking water. About 2450 Ml/d, almost 50% of the groundwater used for public supply, was found to have been degraded. Extrapolation of current trends showed that future capital investment costs could be at least £73 million and possibly as much as £180 million for each five-year asset management programme. By 2027, the volume of water that might have to be treated or replaced may have doubled with almost all groundwater needing treatment. Clearly curtailment of water treatment under the Water Framework Directive could have serious financial and regulatory implications with potential capital costs of the order of £2 billion for development of new sources of water.

Groundwater modelling: ZOOM at home and overseas

In conjunction with the Environment Agency and the University of Birmingham, we have been developing a range of object-oriented groundwater models. In 2004, the models had reached a stage whereby they were ready to be used by the wider hydrogeological community. Therefore, to promote the ZOOM models, a public release took place in Burlington House, the home of the Geological Society in London. The launch meeting was instrumental in attracting participants to the inaugural ZOOM training course held in September 2004. Course delegates included consultants and Environment Agency staff. The course fee included a licence for the ZOOM software. As part of our work with object-oriented groundwater models, we have been developing a distributed recharge model which incorporates run-off routing as well as various rainfall recharge mechanisms. The model has been applied to estimate the water resources of the aquifers underlying the West Bank, Palestine. This is one of the first applications of a process-based recharge model to the area. One

of the challenges of understanding recharge processes in the West Bank is the range of climatic conditions from humid to semi-arid within a short distance (50 to 100 kilometres). A suitable semi-arid recharge mechanism was added to the model to enable better simulation in these conditions. Runoff routing proved important in simulating flows in the wadis, which can provide indirect recharge to the groundwater system. The recharge model has been successfully applied in regional studies in both Scotland (Dumfries Basin) and in England (north-west Kent). In both cases, the recharge model was used in conjunction with ZOOMQ3D (groundwater flow model), to test the conceptual model of groundwater flow.

Augmenting groundwater resources by artificial recharge

Over recent years managed aquifer recharge (MAR) has been seen as the solution to replenishment of overexploited aquifers in rural areas of India and hundreds of thousands of schemes have been implemented as part of watershed management. We have carried out a three-year project funded by UK Department for International Development to improve knowledge of the impacts of MAR in different physical and socio-economic settings and to provide guidance on the scope and effectiveness of MAR for implementers, funders and policy makers. Work was undertaken with local partners at three research sites in India to synthesise knowledge generated into guidance on the types of MAR that are likely to be 'effective' in terms of:

- impacts on the water cycle, in particular groundwater storage;
- management approaches and institutional arrangements; and
- their contribution to supporting and strengthening livelihoods.

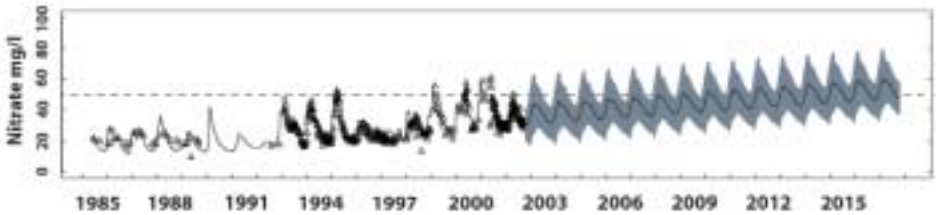
The large range of climatic and hydrogeological conditions combined with complex socio-economic environments make a single management approach inappropriate.

Augmenting groundwater resources by artificial recharge: managed aquifer recharge is increasingly seen as the solution to replenishing overexploited aquifers in rural India.

Detecting trends in groundwater quality

Among the objectives of the European Water Framework Directive and the associated Groundwater Directive is the establishment of good chemical status for groundwaters. Sustained and significant upward trends in groundwater quality threatening good status must be identified and reversed by appropriate pollution control measures. Work has therefore been undertaken for both UK Water Industry Research and the Department for Environment, Food and Rural Affairs to develop simple, robust methods of trend detection. The Water Framework Directive also introduces the concept of estimating trends for a body or group of bodies of groundwater rather than for individual monitored sites, which means developing methods of aggregating data. A novel, automated 'median trend' approach that determines trends at individual sites and then finds the median of these trends was developed and tested on nitrate time series provided by the Environment Agency. Further, an automated procedure based on nonlinear regression has been developed for detecting changes and reversals in trends. Existing monitoring networks were evaluated and found to require significant improvements to meet the objectives of the Directive.

Detecting trends in groundwater quality: nitrate levels in groundwaters are predicted to show a sustained and significant upward trend.



Seismology and Geomagnetism

Programme overview

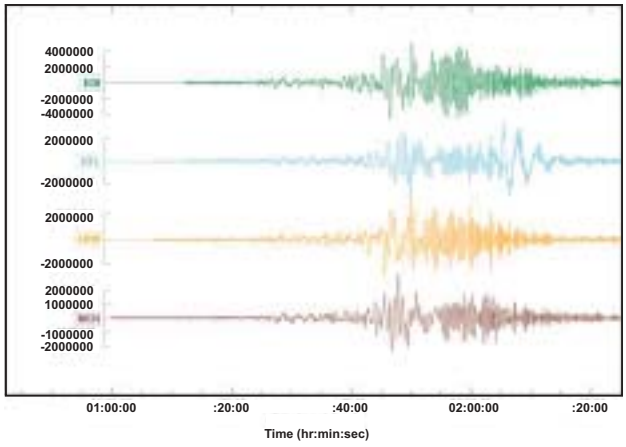
The Seismology and Geomagnetism programme provides critical monitoring data from the UK seismic network and magnetic observatories. Earthquakes and magnetic storms have a significant impact on people and infrastructure in the UK and worldwide, and these attract considerable public, government, industry and media attention. Rapid analysis and interpretation of seismic and geomagnetic datasets ensures the provision of prompt objective information on such events. The programme serves the oil industry through both fundamental and applied research into seismic anisotropy to determine the properties of hydrocarbon reservoirs, and by providing magnetic data enabling wells to be drilled accurately to seismically imaged targets.

Sumatra earthquake

Following the magnitude 9.3 earthquake, and the resulting devastating tsunami on 26 December 2004, we dealt with over 200 media enquiries. The earthquake was caused by a rupture on the subduction zone between the Indian and Burma plates that extended from a point off the north-west coast of Sumatra where the earthquake started, to the Andaman Islands over 1200 kilometres to the north. The width of the fault rupture was about 100 kilometres and the maximum slip on the fault plane about 20 metres; most of this was concentrated in the southern 400 kilometres of the rupture. The rupture took several minutes to propagate from the epicentre of the initial event to the northern end of the fault. Over 300 000 people are estimated to have lost their lives. In the weeks following the disaster, we provided advice on earthquake hazard and the underlying science to several government departments and to the Natural Hazard Working Group. We also led a multidisciplinary consortium on a study commissioned by the Department for the Environment, Farming and Rural Affairs (DEFRA) to evaluate the tsunami risk to the UK.

National Geomagnetic Service

We monitor variations in the Earth's magnetic field to provide data serving a wide variety of academic and private sector interests and run magnetic observatories in the UK and overseas, providing data to support mathematical modelling of the geomagnetic field. The project is supported by funding from several organisations, including mapping agencies and the hydrocarbons sector. We also operate a World Data Centre for geomagnetism and play a leading role in INTERMAGNET (the international programme for the rapid exchange of geomagnetic data). In 2004 the UK regional magnetic model was updated to provide accurate magnetic information for Ordnance Survey mapping products. The geomagnetic field is widely used by the oil industry as a directional reference for drilling production wells. Near real-time data from our observatories have been used to support directional drilling in numerous fields around the UK over the past several years. We also maintain and provide quality control for the observatories established by the oil industry in Prudhoe Bay, Alaska and Sable Island, offshore Nova Scotia that provide data for local drilling operations.



Sumatra earthquake: ground displacements (in nm in the plot) of the order of 5 mm were recorded by BGS broadband seismometers across the UK at Edinburgh, Hartland, Lerwick and Michaelchurch.

Edinburgh Anisotropy Project

The Edinburgh Anisotropy Project (EAP) carries out research into the effects of rock anisotropy on seismic waves. A specific area of world-leading expertise is in understanding the properties of the shear waves generated when a P-wave (a compressional seismic wave) is partially reflected at an interface between different rock types. These 'converted waves' can be used to improve the imaging of subsurface structures and to characterise fracturing. Application to industry datasets has shown that converted wave processing can produce results in difficult cases where conventional methods fail. Significant progress has been made in understanding how the attributes of P-waves can be used to deduce rock properties. Theoretical developments in rock physics are opening up the possibility to predict rock type, the type of fluid contained in the fractures, the scale length of fracturing, and rock permeability using seismic data. For many years EAP ideas have been tested by

application to state-of-the-art datasets provided by the consortium of oil industry companies supporting the project. This year laboratory experiments were started using synthetic rock samples with known properties.

Attenuation of seismic waves

Understanding seismic wave attenuation (the decay of seismic wave amplitudes with distance) is fundamental for seismic hazard assessment. Average Lg-wave attenuation for the crust under the UK has been estimated using data from larger British earthquakes, and, for the first time, lateral variations in attenuation in the UK have been investigated. Lg is one of the many waves that make up a seismogram but because it is often the most prominent phase recorded, it is ideal for investigating attenuation. The results suggest that attenuation in the UK is similar to central France, and higher than in Scandinavia. Using tomography, Lg-wave attenuation has been modelled in two dimensions revealing regional variations, which correspond to variations in the nature of the crust. A striking feature of the results is a region of relatively high attenuation that coincides with the Midland Valley Graben in southern Scotland. This may be due to the presence of a layer of highly attenuative sediments several kilometres thick, but may also be attributable to some physical anomaly within the crust.

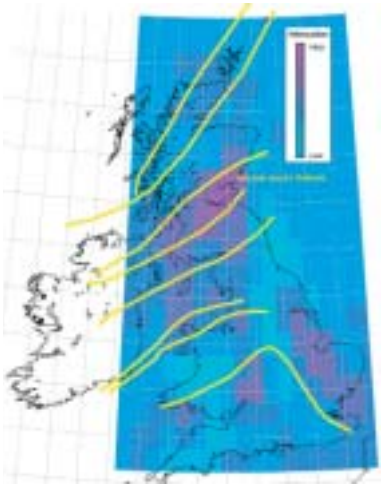
Global magnetic field models

We collaborated with the US National Geophysical Data Center to complete the five-yearly revision of the World Magnetic Model (WMM). This is the standard geomagnetic field model used in UK Ministry of Defence and US Department of Defense navigation and attitude reference systems, and it is also built into many civilian navigation systems. The model is used to derive the magnetic information portrayed on most nautical charts and includes estimates of the rate of change of the geomagnetic field, enabling the charts to be used for a five-year period. The BGS Global Geomagnetic Model (BGGM), widely used by the oil industry, was revised using the latest satellite and ground magnetic measurements. In May 2004 the European Space Agency (ESA) agreed to fund a constellation of magnetic survey satellites, called Swarm, planned for launch in 2009. We carried out an 'end-to-end simulator' study to help determine the optimal constellation. We also contributed candidate models for the revision of the International Geomagnetic Reference Field (IGRF), which is the model most commonly used by the scientific community.

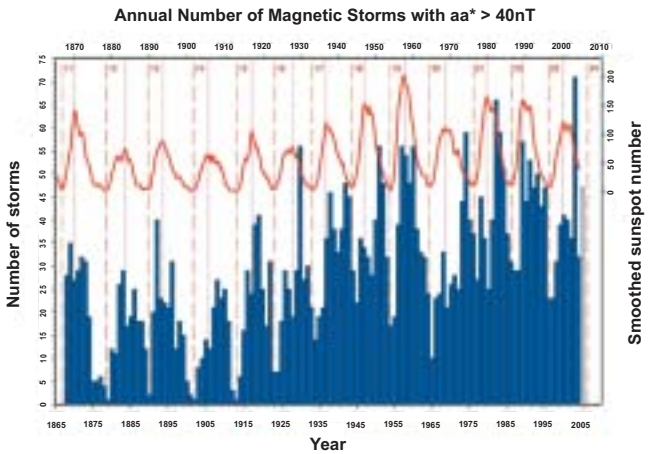
Space Weather

During the year we participated in a number of European initiatives concerned with the development of a space weather plan for Europe, with EU and ESA support. Our geomagnetically induced current (GIC) web server entered full-time service, providing near real-time monitoring and analysis of GIC hazard to the power grid of Central Scotland for the first time. The web service was also successfully demonstrated at ESA meetings and to National Grid Transco, which now has responsibility for the entire UK power grid. Magnetic storms were fewer and less severe than in recent years. Solar activity, which drives magnetic storms, is close to the low point in its normal cycle. However the risk of major geomagnetic storms is only slightly reduced, as compared with the high point in the solar cycle.

Attenuation of seismic waves: Results of the tomographic inversion for seismic attenuation at a frequency of 8 Hz. The yellow lines indicate the boundaries between the major tectonic provinces in the UK. Dark blue indicates higher attenuation, as seen across the Midland Valley of Scotland, for instance.



Space weather: The annual number of geomagnetic storms *(blue bars)* counted using the three-hour *aa* global activity index and smoothed monthly sunspot numbers *(red curve)* showing the (approximately) eleven-year solar activity cycle.



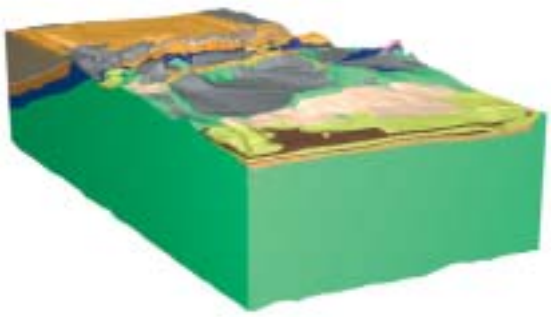
Urban Geoscience & Geological Hazards

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.
- Assessing the likely occurrence of geological hazards.
- The geotechnical and engineering characteristics of rock and soil formations.
- Measuring the chemical, physical and mechanical properties of subsurface materials.

Rapid site characterisation: acquisition of shear wave profile of Quaternary brickearth deposits using the BGS designed and built shear wave probe.



Thames Gateway: 3D geological model of part of the Thames Gateway area.

Thames Gateway

Most development projects in the Thames Gateway will necessitate construction on ground that would be classed as 'difficult' in engineering terms. Compressible soils, high groundwater levels and contaminated brownfield sites are typical of problems that will be faced. Environmental issues such as sustainable urban drainage, biodiversity, flood control and foundation conditions remain important considerations, for which an understanding of the geology is critical. We have begun a new interdisciplinary project in the Thames Gateway (which includes the main site for the Olympics in 2012), focused on making geoscientific information more accessible, relevant and understandable to the wide range of users involved in the regeneration and development of the area. Recent rapid developments in 3D modelling software are now being used to develop new ways of presenting geotechnical and hydrogeological information in 3D.

Rapid site characterisation of superficial deposits

Field trials of a suite of mechanical and geophysical probes have been undertaken. The probes are designed to identify lithological sequences and characterise material properties of near-surface superficial deposits. The probing suite comprises a dynamic portable cone penetrometer, resistivity probe (designed and built in-house) and *in situ* moisture probe. Readily handled by a two-person team, each probe can be rapidly deployed. A shear wave probe has also been developed and employed to assess stiffness variations in fine-grained deposits. Lithological and material properties are difficult to assess from individual profiles. However, viewed in combination the profile suite provides a characteristic 'footprint' profile of the penetrated lithological sequences. Once calibrated against a borehole log or trial pit section, 'footprint' profiles can be acquired across other areas of a site to determine the lithological and depth variations of the logged sequence. The probing suite can also be employed to rapidly field-check inferred subsurface lithostratigraphical boundaries in 3D geological models and to characterise the variability of weathered zone materials.

Modelling future flood risk in Welsh river catchments

Recent high magnitude flood events affecting many parts of the UK have focused attention on the methodologies used to determine which parts of river valleys are liable to inundation or may become so in response to predicted changes in UK climate. We are investigating the combined use of innovative flood modelling software, developed by the University of Aberystwyth, and BGS geological data in the catchments of the rivers Dee, Dyfi, Teifi and Severn. The work is co-funded by the Welsh Assembly Government, the Environment Agency and the Countryside Council for Wales. The modelling methodology factors in the realistic potential for both lateral and vertical changes in river channel morphology and the flux of river sediment within individual catchments. Detailed geomorphological maps have been produced, coupled to a programme of carbon-14 dating of alluvial surfaces. This has established a detailed picture of the form and evolution of specific reaches within each catchment. BGS DiGMap data, allied to information on land use and vegetation cover, underpin water budget, sediment budget and run-off calculations. Together, these data are helping to predict the consequences of various climate change scenarios.

Dissolution hazard

Ground subsidence caused by the dissolution of soluble rocks (salt, gypsum, limestone and chalk) affects many parts of the country and gives rise to the landscape known as karst. Subsidence information has been collected systematically and stored in a networked geographical information system linked to a spatial database. This information helps to identify the risk posed by subsidence and other geological hazards in areas underlain by soluble rocks. The national distribution of karst features and dissolution-related subsidence, combined with digital geological map data, enable us to create zoned hazard maps of areas susceptible to dissolution, which have been incorporated into the BGS GeoSure dataset. The detailed information on the occurrence of karst features and the zoned areas inform householders, planners, developers and insurers about the likelihood of natural subsidence affecting properties.

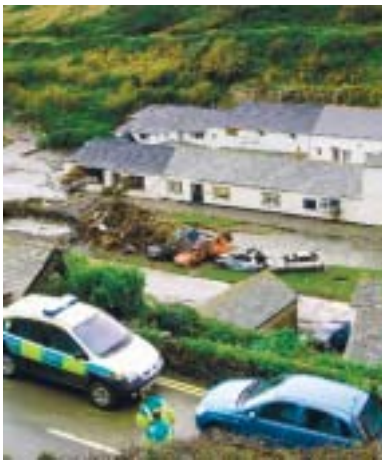
Responding to geohazards

We gather information about new geohazard events as they occur across Britain. As in previous years, there were several landslides, including rock falls on the Isle of Skye, and undermined and damaged roads in Yorkshire. However, geohazard occurrences were dominated by extreme rainfall events and their impact upon towns and villages. In August 2004, a localised storm caused flooding which devastated Boscastle in north Cornwall. In the same week, debris flows blocked the A85 between Lochearnhead and Stirling, in central Scotland, trapping over 50 people in their vehicles. In both instances it is thought that the presence of poorly permeable bedrock and pre-existing gulleys exacerbated the effects of heavy rain, channelling water rapidly down slope. In the case of the debris flows at Lochearnhead, localised landsliding and ancient mass-movement deposits further complicated the position. Understanding the interaction between extreme climatic events, geology and geomorphology is crucial to improving the management and reduction of the impacts to vulnerable communities.

Environmental Information System for Planners

The Environmental Information System for Planners (EISP) is a web-based system, developed by a BGS-led consortium (including the Centre for Ecology and Hydrology and the University of Nottingham) in collaboration with five local authorities. It has been built as a 'proof-of-concept' system to demonstrate the value to urban planning of making information on environmental issues more widely accessible. The research was sponsored jointly by the NERC, through its URGENT Thematic Programme, and the Office of the Deputy Prime Minister (ODPM). The system aims to incorporate relevant research outputs from URGENT and research directly commissioned by the ODPM. The EISP has been designed to support local authorities in carrying out pre-planning enquiries, development control decisions and strategic planning. The system incorporates eleven environmental topics, including air quality, shallow undermining, flood risk, land contamination and natural and man-made heritage. The design framework is based upon a series of decision flow diagrams, each covering one of the environmental themes. These decision flows take account of current planning procedures and link where environmental topics overlap. The system will enable enquirers to identify quickly those environmental issues that are relevant to strategic planning and planning applications. The system also provides advice to enable planners make environmentally appropriate decisions.

Responding to geohazards: an extreme rainfall event devastated Boscastle in north Cornwall in August 2004.

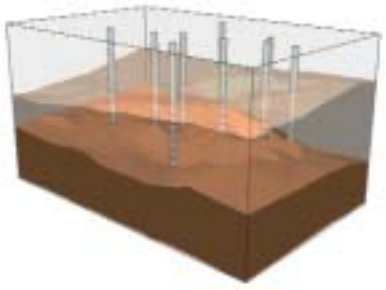


Responding to geohazards: debris flows blocked the A85 near Lochearnhead trapping over 50 people in their vehicles following heavy rain in August 2004.

Environmental Protection

Programme overview

The Environmental Protection programme undertakes research across a wide spectrum of environmental projects covering human health, waste disposal, groundwater contamination, and contaminated land. Commercially commissions have been undertaken for a range of external organisations ranging from local and central government, industry and also internationally. The aim is to consolidate and enhance programme core activities through these commissions.



Pollution, migration and mitigation: integration of trichloroethene concentration into the 3D geological model. Coloured rings on boreholes define proportional concentration.

Radioactive waste disposal: the BGS gas laboratory (Lasgit project) under construction.

Environmental impacts of abandoned mining

Parys Mountain mine on Anglesey is a site of historical and mineralogical importance with mining dating back to the Bronze Age. We used hyperspectral imaging spectrometry to characterise mine waste and SWIR Imaging Spectrometry to map associated vegetation stress. The HyMap data used for this study were flown as part of the SAR and Hyperspectral Campaign (SHAC) in 2000. Mine site characterisation was undertaken using Spectral Angle Mapper (SAM) classification techniques. SAM is a physically based spectral classification that uses an n-dimensional angle to match pixels to reference spectra. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified. The classification results have been backed up with geochemical analysis for verification of the spectra observed both in the field and the image data. Historical geochemical and spectral data from the Parys mountain deposit have been used for comparison purposes.

Pollution migration and mitigation

Chlorinated solvents are dense non-aqueous phase liquids (DNAPLs) which are used in large quantities and account for a large proportion of groundwater pollution incidents. Poor handling practices and inappropriate disposal in the past have contaminated the subsurface, which contributes to a significant decline in groundwater quality in the UK. Novel remedies are required to address this widespread problem because traditional techniques are time-consuming and expensive. Project SABRE (Source Area BioREmediation) is the flagship project of the DTI LINK Bioremediation programme. It tests the hypothesis that enhanced anaerobic bioremediation using reductive dechlorination can be effective in treating chlorinated solvent DNAPL source areas. Our contribution includes: mapping the spatial distribution of the DNAPL source zone; monitoring the performance of the biostimulation and bioaugmentation experiments; and developing future guidance for the characterisation of contaminated sites that will help us to assess risk, target remediation technologies and quantify performance assessment. We are using novel techniques, including 4D electrical tomography, and the combination of contaminant and geological data via GSI3D visualisation software. The project supports a Ph.D. study on the roles of low permeability materials as contaminant sinks and source zones and an M.Sc. study on hydrogeological heterogeneity.

Radioactive waste disposal

The Swedish waste management company SKB has commissioned us to design, monitor and interpret results from a large scale gas injection test or 'Lasgit'. Lasgit is a full-scale demonstration project conducted at the Äspö Hard Rock Laboratory in Sweden at a depth of 420 metres. We designed and assembled a 'gas laboratory' which houses state-of-the-art experimental monitoring and control systems. We are able to control and monitor the test remotely from BGS Keyworth using a customised graphical interface. Lasgit will provide the industry with important new information on the mechanics of gas flow in buffer bentonite. The numerical data will be used in the development and validation of process models aimed at repository performance assessment. The deposition hole was sealed and the experiment started on 1 February 2005. We have also undertaken a detailed experimental programme on behalf of the Mont Terri Consortium examining the consolidation and rebound properties of Opalinus Clay. This fully drained state-of-the-art experiment will provide information to help assess the long-term evolution of the geological barrier.

Electrical Tomography Service

This year ETS has continued to enhance existing techniques such as electrical resistivity tomography. New survey design and array optimisation schemes have been developed to improve image reconstruction, particularly for 3D cross-hole scanning applications. These advances were supported by a commission from the Coal Authority to critically assess a range of known geophysical techniques for detecting buried mine entries. Research has also continued to further develop emerging and interrelated techniques such as:

- Capacitive Resistivity Imaging (CRI) for imaging below engineered surfaces in the built environment;
- surface-to-hole Self-Potential Tomography (SPT) for detecting cavities;
- Complex Resistivity Tomography (CRT) to discriminate between aqueous and non-aqueous phase contaminants; and
- Automated time-Lapse Electrical Resistivity (ALERT) to monitor temporal variations in subsurface electrical properties arising from the impact of climate change, land-use and/or anthropogenic pollution.

ETS research has involved extensive collaboration with both academia and industry. A long-standing link has been established with the University of Thessaloniki and two BGS funded Ph.D. studentships are ongoing with the University of Lancaster and the University of Nottingham. A legal agreement has been signed by NERC and the venture capitalist Rainbow Seed Fund to develop a business plan to spin-out a company based on ETS know-how, technology and software. A NERC patent has been filed to protect the CRI technology.

Automated time-Lapse Electrical Resistivity

A major effort has been expended to develop Automated time-Lapse Electrical Resistivity (ALERT) technology for the sustainable management of water resources and to monitor leachate and gas generation within landfills. This work is funded by research commissions from the Onyx Environmental Trust, English Partnerships, and the European Commission. Our ALERT system allows the automated 4D time-lapse monitoring of sensitive sites, to provide early warning of leakage through containment barriers, incipient physical hazards or subsurface hydrodynamic changes; thereby reducing the time-frame for remedial action. Permanently installed instrumentation allows imaging 'on demand' from the office, using telemetry, global systems for mobile communications, or satellite data transmission. This generic technology could have far-reaching implications for future environmental monitoring, physical hazard prediction, and the understanding of earth processes. The survey concept and technology is attracting significant interest from industry.

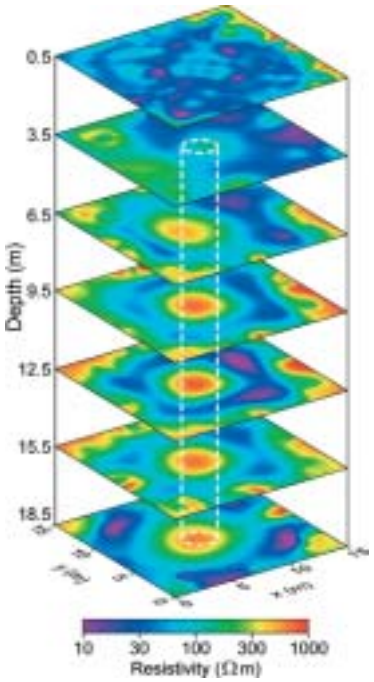
Cross-hole Electrical Resistivity Tomography

Further advances have been made in cross-hole Cross-hole Electrical Resistivity Tomography (ERT) imaging to detect cavities (both natural and man-made) and pollution plumes. In the built environment engineered surfaces or infrastructure (such as roads, pavement, houses) often prevent electrode emplacement. However, large volumes of ground can still be scanned beneath buildings if tomographic measurements are made between two or more boreholes using cross-hole, single in-hole and surface-to-hole electrode arrays. New 3D tomographic survey, data optimisation and inversion schemes have been developed which have significantly improved detectability, image resolution and the accurate recovery of target geometry.

Electrical Tomography Service

The Electrical Tomography Service (ETS) develops leading-edge technologies for the non-invasive electrical imaging of the subsurface. The techniques developed by ETS are used to underpin various BGS activities including core research, geological mapping, pollution studies, geohazard detection and groundwater sustainability, for a range of public sector and commercial clients.

Electrical Tomography Service: horizontal depth slices showing the tomographic imaging of a buried, air-filled, mineshaft by cross-hole ERT survey. Detection was only possible using the new array optimisation scheme. Conventional cross-hole scanning failed to detect this shaft.



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.

Organic geochemical records of changing land use in Swaledale: sampling alluvial sediments to gather evidence of changing land use and deforestation in Swaledale.

Eastern English Channel seabed habitat map: Seismic boomer equipment being deployed on the survey.

Eastern English Channel seabed habitat map

As the proposed exploitation of aggregate resources within an area of the Eastern English Channel requires baseline data, the BGS in partnership with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the Joint Nature Conservation Committee (JNCC) and Marine Ecological Surveys (MES Ltd) is mapping seabed habitats covering 7200 square kilometres of the Eastern English Channel. The mapping is funded under the Marine Environment Protection Fund of the Aggregates Levy Sustainability Fund and includes data provided by the East Channel Association. It uses an interdisciplinary approach, integrating geological, geophysical and biological data and interpretations. Surveys are being conducted using modern high-resolution geophysical systems, including multi-beam, digital sidescan and sub-bottom profiling. New and existing data will be integrated to provide a comprehensive interpretation of the distribution of marine species and habitats within the project area. The map output will provide information on the distribution of sensitive species or habitats and any relationships or correlations between these and physical environment will be investigated and assessed. The data, interpretations and maps produced will support the integrated management of seabed resources in the area and provide a better basis for marine spatial planning, now and in the future and will also help resolve conflicts regarding seafloor use.

Organic geochemical records of changing land use in Swaledale

Records of carbon cycling and land use at local scale are provided by the chemical structures, concentrations, functionality and isotopic compositions of organic matter in the alluvial units of the river Swale, Yorkshire. Evidence of changing land use at Reeth and Isles Bridges were inferred from *n*-alkane proxies, cellulose and lignin specific molecules as well as organic geochemical screening methods such as Rock-eval pyrolysis, bulk carbon isotopes and carbon to nitrogen ratios. The strong odd *n*-alkane preponderance as well as aquatic/emergent and terrestrial macrophyte proxy values showed that the sediments contain an abundance of terriginous organic matter. Pyrolysis and elemental analysis suggested that the vegetation cover changed at two intervals from mixed woodland to grassland as indicated by a marked decrease in carbon to nitrogen ratios. By contrast the stable carbon isotope compositions remained unchanged, this being entirely consistent with indigenous grasses and woody plants. Lignin signatures also showed the effects of changes in woodland and grass cover on the composition of organic matter in the alluvial units. The use of organic geochemistry to identify plant origin of soil organic matter not only facilitates better management of this when it is nutrient rich, but also identifies distinct historical deforestation events and thus is a valuable tool for understanding past land use.

CO_2 gas hydrates

Various concepts for the underground sequestration of carbon dioxide (CO_2) in different parts of the Earth's crust are being investigated. One possibility that we are studying with the University of Leicester is storage within deep-water sediments, where pressures are high and temperatures are low. Under these conditions CO_2 can be trapped as a relatively dense liquid phase below an impermeable cap rock,

dissolved in water filling pores within the rock, or as solid phases such as calcite and CO_2 hydrate. The latter is of particular interest, because this white, ice-like solid can form very rapidly, only needing the presence of water and CO_2. If liquid CO_2 was injected into the sediments, then it is possible that a 'cap' of solid CO_2 hydrate may form in the sediments above a 'pool' of trapped CO_2, enhancing the sealing of any pre-existing cap rock. Such natural self-sealing processes would contain stored CO_2. Recent investigations have focused on both large- and small-scales. Large-scale maps have been produced of potential CO_2 hydrate stability within offshore sediments for western Europe. At a smaller scale, the growth of CO_2 hydrate between sediment grains has been studied in laboratory experiments.

CO_2 gas hydrates: synthetic CO_2 gas hydrate.

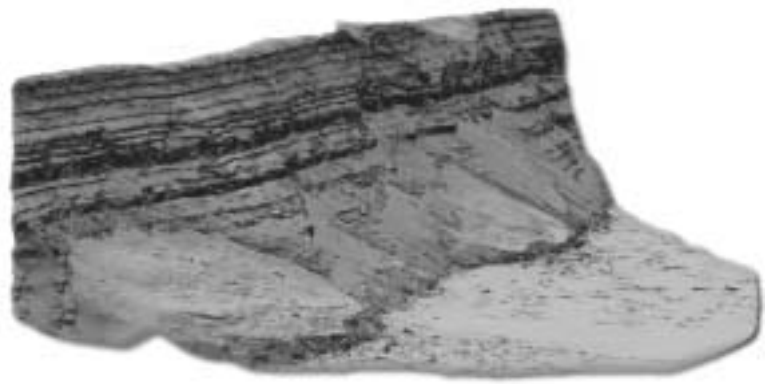
Intertidal substrate mapping

We have been working with the Maritime and Coastguard Agency (MCA), Department for Environment Food and Rural Affairs (DEFRA) and Scottish Executive at a strategic level in their oil spill contingency planning. We have supplied data for geographical information systems to provide a regional scale snapshot of the distribution of sediment and rock in the intertidal zone of England and Scotland. This new, approximately 1:25 000 scale, dataset was generated by the interpretation and integration of a variety of data sources, including: 1:10 000 scale aerial photographs, Ordnance Survey mapping and existing BGS geological mapping. This was further enhanced using expert knowledge and data gained through other projects that we had undertaken, including FutureCoast and ICZMap (see past BGS annual reports). In consultation with MCA we decided to create a simple coastal polygon for diagrammatic depiction of the extent of the sediments. This fulfilled the criteria that the presence of a sediment type was more important for this application than its precise extent within the intertidal zone. As part of the project these data have been made available to all by DEFRA though its MAGIC website.

Brotton cliff survey

Network Rail commissioned us to investigate the stability of Hunt Cliff on the Cleveland coast near Brotton. A single-track mineral railway serving Boulby potash mine and Skinningrove steel works passes close to the cliff edge. Here the cliff is 100 metres high and formed in Lias Group mudstones and sandstones. Currently, instability is confined to minor rockfalls, particularly from the Staithes Sandstone Formation. However, the debris from a large landslide (38 000 cubic metres), at least 150 years old, is found on the platform. We carried out geological and geomorphological surveys, and a desk study, designed to form the baseline for a programme of monitoring using a combined laser scanning and global positioning (GPS) technique, developed at the BGS. The 3D model produced by the survey allows accurate volumetric data and cross-sections to be produced. This model will act as the basis for comparison with subsequent monitoring surveys, and hence quantification of cliff stability and recession.

Brotton cliff survey: 3D computer model of Hunt Cliff.



Information Services and Management

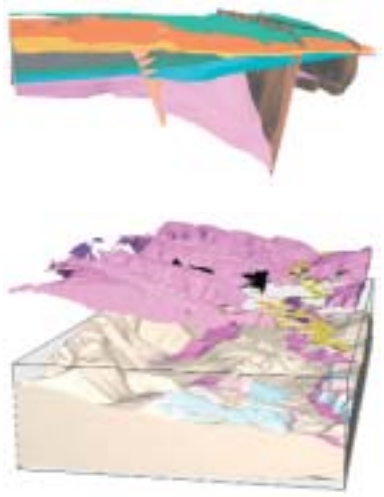
The successful retrospective review of the BGS by the Science and Management Audit in 2003 was followed in 2004/05 by submission and external review of the 2005–10 BGS Programme. The Geo-information proposal (one of eight BGS proposed themes) received the highest mark in this review (an alpha 5). Regrettably, the increased funding initially allocated to deliver the new BGS programme did not materialise and at the time of writing review and revision of the Information programme and associated budgets are being undertaken.

The year saw the successful conclusion of the five-year Digital Geoscience Spatial Model project (DGSM). Three- and four-dimensional modelling is pivotal to the BGS's future work programme and the DGSM project's achievements means we can move to a corporate operational modelling platform. At the end of the project we commissioned and installed a three-dimensional visualisation facility at Keyworth. The facility is already a huge success, allowing geoscientists to share and review their work dynamically, and non-geoscientists to more easily understand the complexities of the ground beneath their feet.

Work on further developing and upgrading our digital geohazard databases took precedence during the year and in particular the work on natural subsidence datasets, as these data are a priority for many clients. The BGS was represented on one of the Homebuyer's Information Pack Working Groups set up by the Office of the Deputy Prime Minister (ODPM) and natural ground stability information was recommended to be authorised for inclusion in the new Pack. Our ongoing collaboration with the Coal Authority to deliver a combined coal mining and natural ground stability report is key to achieving this.

The individual programme reports that follow describe the year in more detail, but of note is our attainment of HMSO Information Fair Trader Scheme accreditation, the corporate implementation of the new ISO standard for metadata and the complete re-development of our website. A major scanning exercise that digitally captured several terabytes of legacy map and borehole records was concluded; while the contract to do this was not without its problems, the records are now securely backed-up and we are now in a position serve the digital versions internally and externally.

Digital Geoscience Spatial Model project: examples of output from the Nottingham–Melton activity. GoCAD model showing the thickening of the Carboniferous succession into the Widmerpool basin *(below)*. There is a major fault on the right side of the model and the basin is clearly a half-graben feature. GSI-3D model of the River Wreake valley and surrounding area *(bottom)*. This is an exploded view, with the Oadby Till (pink) and younger lithologies displaced upwards by 150 m allowing the subcrops to be visualised.



(Opposite) The new three-dimensional visualisation suite at Keyworth allows 3D output from projects such as the Digital Geoscience Spatial Model to be reviewed dynamically by geoscientists and more easily understood by non-geoscientists.

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.

Critical collections: recently donated borehole core from Parys Mountain, Anglesey, showing polymetallic sulphide mineralisation.

Critical collections

Scientists acknowledge that 'if they have seen further it is by standing on the shoulders of giants'. In the earth sciences, this frequently means going back to material studied by earlier workers. Collections such as the National Geological Materials Collections play an essential part in this. They fulfil the fundamental quality assurance requirement that published interpretations have a basis in fact. Holding the original materials means that they can be inspected and observations and measurements can be repeated and validated. More importantly, samples can be studied using new techniques and frequently for completely different aims. Drilling a deep borehole is an extremely expensive undertaking, well beyond the reach of most projects, yet many studies depend on access to borehole samples obtained for completely different purposes.

BGS metadata moves to ISO 19115

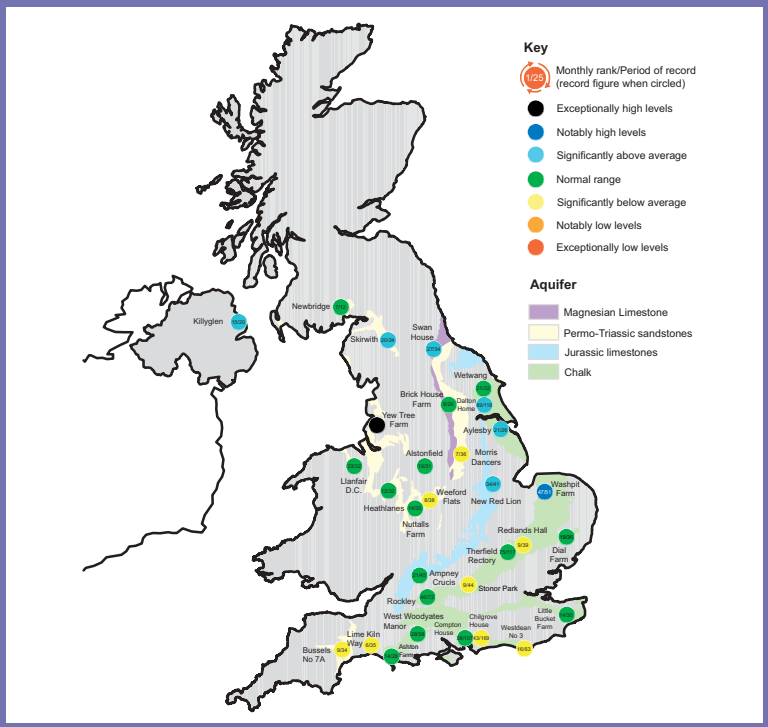
The International Organization for Standardization's standard for 'Geographic information — Metadata' was issued on 1 May 2003 after several years' consultation. The BGS wanted to update its metadata to the new ISO standard in order to be able to expand access to our data holdings via the Internet, to maintain compatibility with national and internal initiatives such as Gigateway, e-GMS and PSIgateway. A database design for the core requirements of the standard was developed in Oracle. This core database and application design was extended to include both ISO non-core and BGS-specific requirements to meet our additional needs.

Groundwater Level Archive

Working in partnership with the Centre for Ecology and Hydrology, the BGS operates the National Groundwater Level Archive. The archive comprises data on fluctuating water levels across Britain's major aquifers. By combining these data with information on river flow we are able to publish monthly hydrological summaries that are used by government agencies, the media and the water industry. The database of water levels that has been built up is a unique and invaluable resource,

Critical collections: 'fossils reunited' — proximal fragments of *Normalograptus persculptus* (inset) collected a century ago by O T Jones have been 'rescued' from the former Department of Geology at the University of Wales, Aberystwyth and reunited with his field slips, which were already housed in the NGDC.

BGS metadata: working on the new database design for BGS metadata.



Groundwater Level Archive: map showing groundwater levels in December 2004 (outcrop areas are coloured according to BGS conventions.

with many records spanning 100 years. It is being enhanced by the development of GIS with gridded water level surfaces, using a combination of archive data, records from the WellMaster Hydrogeological database and modelled data. These national datasets are the basic starting point for groundwater resource assessments and work on groundwater flood risk.

Promoting the National Geoscience Data Centre

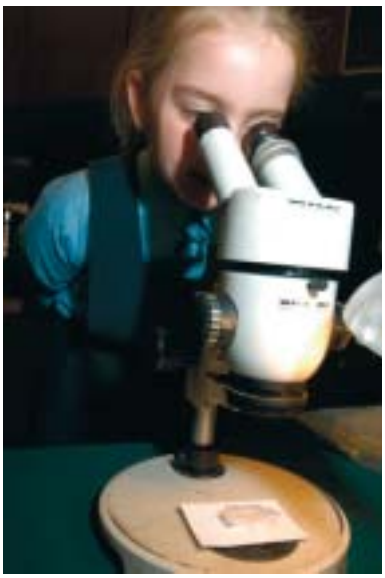
The National Geoscience Data Centre (NGDC) is the largest collection of geological data and material in the UK — it is a resource available for use by the whole community. Users from across the world come and access the materials and information. We have been actively raising the profile of the NGDC through new publicity material, presentations and exhibits at scientific meetings, lectures and tours. We took an active part in the national Archive Awareness Campaign in 2004, organising a series of tours and displays attended by many visitors. Presentations demonstrated the impact of the geology on the landscape, the availability of mineral resources and the development of local communities. The NGDC has featured in a number of television documentaries during the year, including the BBC's *British Isles: A Natural History*. As part of National Science Week, the NGDC hosted a Rockwatch event at Keyworth, aimed at children and providing an exciting range of activities, including gold panning, generating an earthquake, making fossil replicas, and 'behind the scenes' tours.

Promoting the NGDC: during a break in filming the BBC TV series *British Isles:A Natural History*, Alan Titchmarsh was presented with a framed photograph of a 300-million-year-old fossil seed fern, *Sphenopteris incurva* by Jeremy Giles, manager of the NGDC.

National Geoscience Information Service

Programme overview

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



Science and Society: young visitors investigating ancient bones and gold mineralisation at the 'Fossil and Rock Show'.

Electronic Dissemination of Information

Following the major consultation with external and internal stakeholders in 2003 about what they want from a BGS website, we redesigned our main Internet site, and relaunched it in September. The new site has been very well received and at the end of 2004/05 visitor rates were 45% higher than at the end of 2003/04. We enhanced the BGS Internet Bookshop by making additional products and services available for online purchase, and launched a new online shop, Historical Ordnance Survey Maps, in September. The BGS Intranet is a core element of our scientific and administrative operation and continues to grow. It now has over 60 000 static pages, images and documents together with over 5000 scripts. Over the year, there has been a substantial increase in the availability of BGS reports to view internally online (via the Report Management System) and to download from the main Internet site.

Library

We expanded the level of services to our scientists and the public considerably during the year through electronic access to more information. Online journals and electronic access to scanned images of 1:10 560 maps and field slips have proved very popular with staff and a new server for GEOLIB (our public access catalogue) substantially increased access speed to our data as well as allowing new facilities to be added. Increased participation in a number of events such as World Book Day and, for the public, the National Archives Awareness Month campaign, raised the Library profile significantly. Substantial numbers of donations of photographic and other material continued and the appointment of a new Archivist has allowed us to begin to exploit our extensive historical collections on the history of the Survey. Digitisation of our back catalogue of publications continued and our expanded volunteer scheme greatly speeded up scanning of photographs.

Science and Society

We promote the earth sciences and publicise our work to a wide audience. We contribute to many national and regional popular science events. Our Edinburgh office held an Open Day and Schools Week in September 2004 as part of Cockburn Association Doors Open Day. In England we celebrated National Science Week in March 2005 with several events: at Keyworth over 900 children attended our annual 'Fossil and Rock Show' and we hosted a 'family' day on behalf of the children's geology club 'Rockwatch'. BGS Wallingford, with the Centre for Ecology and Hydrology, held a 'Water Detectives' event. Following the relaunch of our website, visits to the Popular Geology and Education section have increased significantly; a new web application, 'Make-A-Map', is very popular. We contributed geological materials and information to the HLF-funded 'Xplor Active' gallery at Mansfield Museum, which highlights environmental issues. There are now 24 BGS 'Science and Engineering Ambassadors' working with the DTI-sponsored organisation SETNET to promote science in schools. For the second year we supported the Engineering Education Scheme, working with a team from Loughborough Grammar School to develop a large-scale powder-processing machine. We are also active in adult education, promote the earth sciences at public exhibitions and educational conferences and provide geological information boards and flyers for public sites.

Sales

The Sales Desk network disseminates publications and products to BGS customers. Sales also provides a route through which customer feedback on publications can be

channelled back into the Survey. The success of the guide *Exploring the landscape of Assynt* is testimony to the benefit of talking to customers about book content and design. During the year we utilised the new sales management system to analyse customer groupings and better target marketing activities. Sales revenue increased by over 8% on last year to reach a record high. Our Internet Bookshop continues to perform strongly, with annual income via this route increasing during the year by almost 20%. Online sales now contribute around 11% of total sales income and we continue our drive to make more supplementary publications information available to Internet Bookshop customers.

Enquiry Service

The Enquiry Service continued to meet its customer response targets and handled 7700 enquiries by members of the public, a 20% growth over 2003/04. The commercial side of the service also continued to perform strongly, dealing with over 12 000 enquiries. The GeoReports automated report-generating service was highly successful, with 30% of orders now being made through the online shop. The service was recognised as a Best Practice case study in a high-profile DTI report on Knowledge Transfer from Public Sector Research Establishments. The GeoRecords service, which provides copies of the National Geoscience Records Centre collections, grew strongly and customer service was further improved through use of scanned records and an improved online ordering service. Revenue from commercial enquiry services rose by over nearly 8% on last year to a record high.

Copyright and Data Licensing

We continued to offer guidance on intellectual property matters on the use of BGS materials. In October 2004 the Intellectual Property Rights section took the lead in helping the BGS become the first non-Crown body to be awarded accreditation under HMSO's Information Fair Trader Scheme (IFTS). There was another significant rise in the demand for the use of our data: revenue from digital data licences, copyright fees and royalties rose by over 30% on last year to a record high. To increase the user base and market penetration for our data we introduced a new type of value-added business agreement, the Licensed Data Supplier (LDS) scheme. An LDS, via their agents, enables the reuse of geological data for the provision of a range of services, for example location-based risk evaluations, in diverse market sectors.

DiGMapGB

DiGMapGB is the national set of digital geological map data in vector GIS format at a range of scales from 1:625 000 to 1:10 000. During the year we extended and improved these data, which are firmly established as the key reference for much of our work and the basis for important derived datasets, such as GeoSure ground stability data. Systematic reviews and rationalisations of DiGMapGB-50 (1:50 000 data) were completed, with major revisions to the nomenclature of the Superficial deposits and Carboniferous Bedrock. The revised dataset was approved for release as Version 2. Work at 1:10 000 scale started to assume greater importance and DiGMapGB-10 now has over 700 (5.9%) 5 x 5 km tiles released and another 1200 (10.2%) in preparation. We released a revised 1:250 000 scale onshore bedrock dataset with a new data structure, as DiGMapGB-250 Version 4. Preparation of the new DiGMapGB-625 (Bedrock) from the DiGMapGB-50 dataset was started, and these data will be the basis for a new national 1:625 000 map to be published in 2006.

Enquiry Service: our GeoReport service offers independent advice to developers and others who are investigating ground conditions prior to building, including information on geology, hydrogeology and related subsidence or radon hazards. GeoReports are backed up by the national geological archive of over a million borehole logs, site investigation reports, digital maps and geologist's manuscript field slips covering England, Scotland and Wales.

DiGMapGB: DiGMapGB data draped over terrain model with vertical exaggeration.

Publications Production

Programme overview

The Publications Production programme publishes the BGS's formal output: maps, books and reports. It is a major contributor to our digital data holdings, in particular the Digital Geological Map of Great Britain (DiGMapGB) and images for the National Archive of Geological Photographs. It also designs and produces marketing and promotional materials such as multimedia products, web pages, posters and brochures. Publications Production's cartographic service protocols were a key element in gaining compliance for the ISO 9001:2000 Quality Management System. The programme partnered the BGS Information Systems programme in the development of AEGIS, an advanced geo-cartographic geographical information system (GIS) which is integral to the SIGMA project (*see page 46*).

Cartographic production

For many years now the BGS has used geographical information systems (GIS) to capture spatial geoscience information and input comprehensive attribution to build digital spatial databases (DiGMapGB, *see page 38*). Customised interfaces and operating procedures increase the efficiency and provide quality controls for these processes. The digital map data are published at a variety of scales and reflect output from a wide range of scientific surveys. This year they included *Exploring the Landscape of Assynt*, the winner of the Ordnance Survey Award for creativity and innovation in map design.

Graphic design and publishing

A range of high quality books and print-on-demand reports have been published, including Sheet Explanations and Sheet Descriptions that accompany 1:50 000 scale maps, special publications such as *Earthwise* magazines and *Murchison's Wanderings in Russia*. Many reports are converted to digital form in portable document format (PDF) and made available as free Internet downloads. Demand for the internal graphic design service has grown especially for multimedia titles such as the *Britain beneath our feet* website and CD-ROM and the *Foundations of the Peak* website.

Reprographic and Photographic Services

A digital camera policy and image database was introduced to secure and improve the accessibility of BGS's digital photographic images. A photographic/reprographic digital imaging laboratory was established and is a key part of the evolution to 'born-digital' processes.

Photographic Services: a digital camera policy was introduced to ensure geologists have available the most appropriate photographic equipment for field use.

Checking map products in the new cartographic suite in Murchison House, Edinburgh.

Output in 2004/05

Digital map and book data and printed media include:

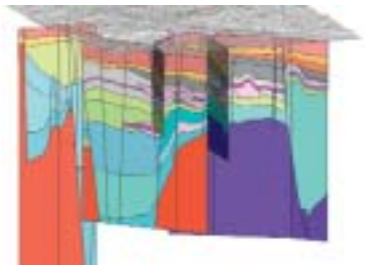
- Additions to the 1:50 000, 1:25 000 and 1:10 000 scale map databases. 1:10 000 scale map data now stands at 6.1% GB coverage (722 5 x 5 km tiles.)
- Ninety-three maps approved for print-on-demand at 1:10 000 or 1:25 000 scale.
- Twenty-five maps printed and published at 1:50 000 scale.
- Two maps approved for print-on-demand at 1:1 000 000 scale.
- Additions to the horizontal sections database for the Digital Geological Spatial Model project.
- Three Geological Memoirs.
- One Sheet Descriptions.
- Three Sheet Explanations.
- Five annuals.
- Four 'special' publications.
- Three titles in the popular publications series.
- Thirteen multimedia CD and website original designs.
- Fifty 'projects' in the posters and brochures series.

Examples of output from the Publications Production programme during 2004/05 *(below and bottom)*: publications include technical reports, brochures, geological maps and sheet explanations, websites, and multimedia presentations for internal and external customers.

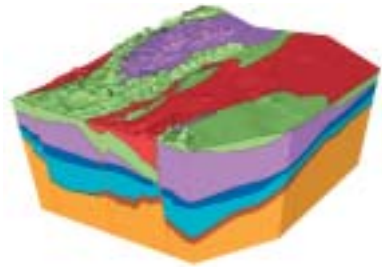
Scanning photographs in the digital imaging laboratory at Keyworth.

Digital Geoscience Spatial Model

The new 3D visualisation suite: at Keyworth demonstration the UK regional model developed by the DGSM.



DGSM: Polygonal cross-section data shown beneath a draped surface layer. The data contain attributions based on DiGMapGB 'lex-rock' values. A layer of separate fault lines are also available for use by modellers and scientists.



DGSM: A model of the Weald viewed from the south-west of the Isle of Wight, illustrating the inverted sedimentary basin and the major reversed fault controlling the Isle of Wight monocline.

Digital Geoscience Spatial Model

For the past five years the Digital Geoscience Spatial Model (DGSM) project has been developing the infrastructure, protocols and systems to build three- and four-dimensional models, not just on a research and development basis, but operationally. This was the final year of the project; the funding for which was provided by the NERC Science and Innovation Strategy Board. The funding has been matched by the BGS in initiating projects that feed into, test and benefit from the modelling methods developed. The core principle in the design and development of the DGSM has been to ensure that it is 'future-proofed' and to achieve this it has been built on the corporate data standards developed by the earlier BGS-geoIDS project. The DGSM project has two main elements, the 'Framework' and 'DGSM UK'. The Framework has developed the technical infrastructure for modelling and the necessary standards and methodologies. DGSM UK has undertaken modelling of specific areas of the UK to test that the data structures and procedures are appropriate for a range of geological environments and resolutions.

Key elements of the Framework are:

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

The following DGSM UK activities have been completed during the year:

- Methods for describing the uncertainty of a model.
- Geological cross-sections on all 1:50 000 scale maps have been digitised with full spatial referencing ready for inclusion into models.
- Midland Valley of Scotland — merged onshore models and offshore models of both the Firth of Forth and Clyde.
- Atlantic Margin — an integrated model for much of the area west of Shetland.
- UK national model — a model showing the major surfaces and faults at a national scale is being used extensively in demonstrating the achievements of the DGSM.
- Nottingham–Melton area — detailed models of 1:50 000 scale data.
- South-east England — the Weald has been added to the national model and hydrogeological models of parts of the South Downs are available.
- Lake District — the western part of the Lake District batholith.
- Glen Lochy — complexly folded rocks in the South-west Grampian Highlands.
- Central Wales — heavily faulted and folded Lower Palaeozoic basinal rocks near Rhayader.

Geoscience National Information

- Suffolk/Essex — High definition models of superficial geology and aggregate distribution for 400 square kilometres of terrain.
- West Midlands — Permo-Triassic sandstone aquifers in a geologically complex region.

To allow the full visualisation and sharing of these and other models, we have installed and commissioned an immersive visualisation suite at Keyworth. This '3DVF' visualisation facility and the models it can display have already had a major impact on both our geoscientists and our clients.

The systems and methodologies developed by the project are now being fully integrated into the our overall work programme. A major element of BGS's new five-year programme will take full advantage of the DGSM protocols and continue to develop them. Further details of the DGSM project and its components have been published in a BGS Occasional Report.

Geoscience National Information

Digital geoscience information is being used increasingly by government, business and the general public. We hold and generate a huge amount of geo-environmental information but, in the past, much of it has been neither user-friendly nor national in cover. Building on the GeoHazarD project, the Geoscience National Information project (GENI) has maintained and continued to develop a series of nationwide geo-environmental data products. High-resolution geoscience information has been reinterpreted and integrated with other data to deliver a variety of datasets and services. These include potential hazards from natural subsidence, radon and methane, rock permeability, thickness of superficial deposits and rockhead models. The ground subsidence layers include shrink–swell clay, running sands, slope instability, soluble rocks, and compressible and collapsible deposits. Pilot studies for the development of a number of novel products were also initiated.

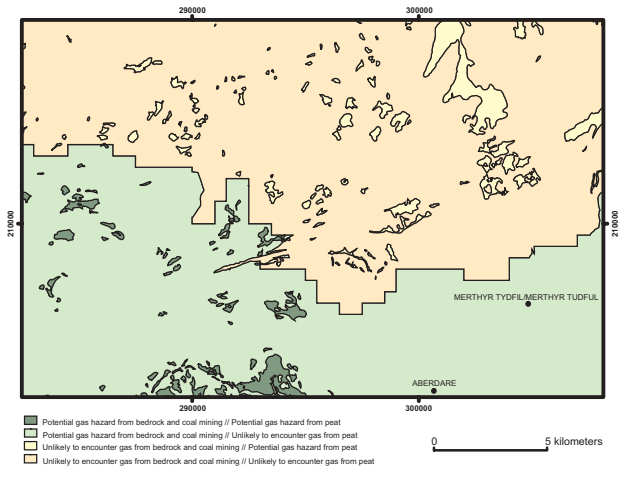
The data products are available as nationwide layers for use in geographical information systems and can also, if required, be cut into specific areas to answer local environmental and construction related queries. The subsidence and radon hazard datasets are used in our reporting system (GeoReports) and a number of commercial data providers incorporate these data within their own high-volume environmental reporting services.

In 2004/05 the GENI project delivered:

- Updated versions of the six natural ground instability layers, incorporating additional data and a refined methodology.
- Updated superficial thickness and rockhead models.
- More than 100 000 scanned geological map documents, including the unique BGS collection of field slips.
- Potential methane hazard.
- Radon potential for England and Wales in cooperation with the Health Protection Agency Radiation Protection Division.
- Groundwater level data that will feed into a future groundwater flooding product.
- Pilot datasets for coastal landslides, soil erosion and shallow mining hazards.

GENI: datasets include information on natural ground instabilities such as this landslide in which an estimated 5000 tonnes of mud and rubble blocked the A9 near Dunkeld in August 2004.

GENI: an extract of potential methane hazard map data for the Merthyr Tydfil area, south Wales.



Geoscience Resources and Facilities

The role of the fourth directorate, Geoscience Resources and Facilities (GRFD), is to ensure that adequate human and physical resources are available to deliver the scientific programme, and to develop scientific capacity in order to ensure that our capabilities remain in line with both our present and future requirements. Scientific staff are managed and deployed by the four Heads of Discipline (HoDs), divided into the subdiscipline groupings of Geology, Geotechnics and Palaeontology; Geophysics and Marine Geoscience; Geochemistry, Mineralogy and Hydrogeology; and Information Systems. A separate HoD is responsible for staff in Administration and Finance.

Pre-planned staff deployment during 2004/05 exceeded 98%, with the unallocated staff resource being used to upgrade legacy data sources critical to our information delivery strategy. A database of staff skills was completed and the information used to inform recruitment and training requirements for the new programme. Increased support was given to publication of commissioned research work in peer-reviewed journals, with over 30 journal papers being submitted through this route. The GRFD funded attendance at more than 50 conferences and meetings, and supported over 40 staff serving as members of external scientific committees and learned societies. Our staff continue to hold high-profile appointments and leadership positions within various scientific and professional bodies, and as editors of both peer-reviewed and popular journals.

Work continued on many projects aimed at developing and supporting our scientific infrastructure, the primary focus being on completing work already in progress in preparation for the implementation of the new five-year programme. A major priority within this was the completion and testing of the SIGMA field-based tool kit. The Environmental Materials Laboratory, a £1.5 million project, was handed over by the contractors, and a mobile laboratory was designed and purchased; both of these will play a significant role in the new programme. A rolling five-year plan for investment in our scientific capital equipment was initiated. Our analytical geochemistry laboratories' accreditation to ISO 17025 was renewed and the current scope of methods extended to include the Environment Agency's Monitoring Certificate Scheme (MCERTS) for soils.

During the year all staff were provided with training in core expectations for NERC employees, performance management and the use of the new electronic appraisal and development-needs system. Courses were also provided covering a range of personal, business and communication skills, with particular emphasis on project management. In the IT sector, training efforts concentrated on supporting the use of 3D visualisation packages and the migration to ArcGIS software. Specialist IT training in a range of emerging IT technologies was provided for developers and the use of more widely-used corporate software was supported with in-house, external and computer-based learning. Scientific training included field–based courses in both lowland and highland Quaternary geology and sequence stratigraphy. A new in-house course in statistics was developed. Training in a variety of health and safety issues was also provided, primarily for staff working in hazardous environments or with potentially hazardous materials and equipment. Workplace coaching for new recruits and those undertaking major job changes continued to receive funding and support was provided for those working towards further education qualifications (ten postgraduate degrees, fourteen undergraduate degrees, two NVQs and eleven other qualifications).

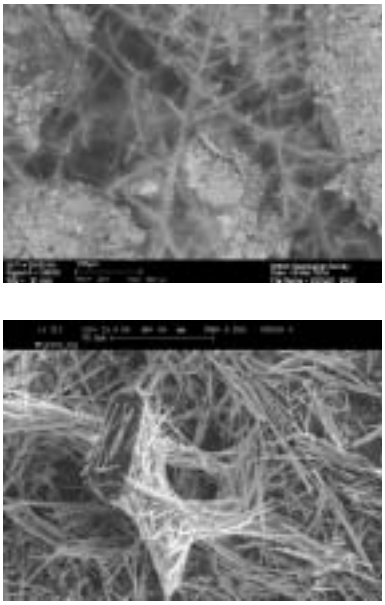
The new Digital Fieldslip application running on one of the latest tablet PCs during field trials.

(Opposite) Geological surveying, a BGS scientist taking a soil sample during the SIGMA toolkit trials.

Development of Capability

Programme overview

The Geoscience Resources and Facilities Directorate (GRFD) carries out strategic scientific research designed to underpin both our Core Strategic and Commissioned Programmes. The Development of Capability programme covers a diverse range of activities and consists of many individual small-scale initiatives, but is managed as a single cross-discipline entity. This emphasises the initiation and assimilation of new scientific ideas and technological developments applicable across a range of our present and future activities. Each scientific HoD takes responsibility for a group of projects within the overall programme. In addition to the projects headlined here, topics included within the ongoing Development of Capability Programme range from the introduction of new methodologies and equipment to cutting-edge research.



Forensic geoscience: scanning electron microscope images of needle fibre calcite illustrating variations in morphology resulting from their formation in different environs *(top)* precipitated on filamentous strands (either bacterial or root hairs) in modern garden soil from Keyworth, Nottinghamshire, and *(above)* in fossil root channel within brickearth deposits from Pegwell Bay, Kent.

System for Integrated Geospatial Mapping (SIGMA)

This was the final year of SIGMA development, aimed at developing and implementing a standardised methodology for onshore geological surveying. The tool kit project developed the enabling IT infrastructure to take the raw data (and interpretation) from the field to the customer. Digital Field Notebook and Fieldslip applications designed to run on palm-top computers were developed and underwent extensive field trials. Hardware developments have resulted in robust tablet PCs becoming available that will allow a fully functional geographical information system to be taken into the field and work is ongoing to integrate this with the new applications. A corporate data model to underpin the entire SIGMA workflow was also developed, and in particular the Geoscience Spatial Database, an application developed in ArcGIS to allow office-based capture of information.

High-resolution measurement of electrical resistivity

A methodology for high-resolution measurement of electrical resistivity linking laboratory measurements on core to downhole images was developed. Key areas of interest include relationships between the slabbed core resistivity and primary porosity, secondary fracture porosity and permeability structure in potential reservoir rocks. Application of conventional contact resistivity methods using a robotised system has been proven to provide images of slabbed core at a similar resolution to downhole ones from the formation microscanner. Measurements on sandstones similar to those found in the southern North Sea reservoirs have revealed the detailed sedimentological structure, which could aid our understanding of reservoir properties, with implications for hydrocarbon recovery and greenhouse gas sequestration.

Quaternary lithostratigraphical framework

Through collaboration with academia and industry, a new scheme rationalising the Quaternary lithostratigraphical framework for Great Britain has been drawn up, for the first time allowing correlation of onshore deposits to group level. This helped to formalise our understanding of Quaternary processes, resource assessment and the impact of fluctuating climates in Britain over the past 2.6 million years. A formation-level scheme to provide a framework for both on- and offshore mapping is also in draft. Similar studies have also been published on the Carboniferous strata, the most economically significant period in Great Britain, including full revision of lithostratigraphical nomenclature and framework at both group and formation level. The new scheme, based largely on lithofacies characteristics, provides a framework for the assessment of natural and man-made geohazards, resources, and for our understanding of this important period of the Earth's history.

Forensic geoscience

When soil-derived material is found on items such as clothing or vehicles in a forensic investigation, it is often crucial to establish the source. UK soils show significant variation in their mineral and organic components, thus chemical, microscopic and physical analysis of soils can yield vital clues concerning their provenance. We have been involved in three investigations in the past year. In one example, using diagnostic minerals and with the aid of our comprehensive mineral archives, it was possible to help confirm that a body had been buried at one location, then removed to a second prior to discovery. In another investigation, scanning electron microscopy was used to assess the morphology of gypsum plaster and soil minerals to link a suspect to the scene of a crime.

NERC Isotope Geosciences Laboratory

Programme overview

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

Seasonal cycle in North Pacific sea surface temperatures and the glaciation of North America 2.7 million years ago

Two oxygen isotope data sets were obtained from a sediment core in the western subarctic Pacific in a joint project with University College London. The data shows that late summer to early winter sea surface temperatures (from $\delta^{18}O_{diatom}$) in the region rose in response to a freshwater-driven stratification 2.7 million years ago, even as the spring surface ocean cooled (from $\delta^{18}O_{foraminifera}$). The late summer/autumn warming would have provided water vapour to northern North America where it could be precipitated and accumulated as snow. Thus, warmer sea surface temperature in the North Pacific combined with globally colder air temperatures probably triggered the Northern Hemisphere Glaciation of North America by maintaining the water vapour source to the continents, even as climate cooling favoured the preservation of snow and ice.

Older granites in remote north Himalayan domes

NIGL is working with the Open University and the University of Wuhan, China on leucogranites within remote north Himalayan domes of southern Tibet between the main Himalaya and the Indus–Tsangbo suture. U–Pb dating reveals ages that span the period 28–14 Ma, including some of the oldest, Oligocene, leucogranites known in the Himalaya. Sr–Nd isotopes also show that these rocks were derived from melting of the Greater Himalayan Sequence derived from India, providing new constraints on models of crustal melting in the Himalayan Belt.

Early Holocene retreat of the George VI Ice Shelf

The recent collapse of several Antarctic Peninsula ice shelves has been linked to rapid regional atmospheric warming during the twentieth century. The NIGL is working with the BAS and the Universities of Durham and Edinburgh on the George VI Ice Shelf. New isotope records of Holocene ice shelf behaviour derived from sediments in an epishelf lake show that ice shelf was absent between 9595 and 7945 calibrated years BP, and that its collapse was associated with the influx of warmer deep water. The collapse of the ice shelf suggests that either Early Holocene atmospheric temperatures in this part of Antarctica were warmer than present, or that ice shelf collapse was caused by sub-ice shelf melting by warm currents, or both.

Atlantic Margin

New Sm–Nd isotope tracer and U–Pb geochronological data have been obtained from Rockall Bank and a transect of the UK continental shelf about 550 kilometres in length. These samples probe the continental crust between mainland UK and Greenland. The data indicate a long history of episodic crustal growth mainly at 2.8 Ga, 2.74 to 2.7 Ga, and 1.8 to 1.74 Ga, younger crust predominating in the south-west, with significant reworking of Archaean crust through time. These data are being used to test and refine both local and regional terrane models, and Proterozoic plate tectonic reconstructions. The project was partly funded by the Rockall Consortium, which comprises a number of oil companies with interests on the Atlantic margin.

North Pacific sea surface temperatures: the diatom *Cosinodiscus radiatus* from the north-west Pacific at the beginning of the Northern Hemisphere Glaciation 2.7 million years ago.

Photograph courtesy of George Swann

Early Holocene retreat of the George VI Ice Shelf: fresh water lakes formed by ice damming embayments along the George VI Ice Shelf in Antarctica.

Photograph courtesy of Dr Mike Bentley

Marketing, International and Corporate Development

The Marketing, International and Corporate Development Directorate (MICD) has a number of cross-survey roles including strategic planning, corporate reporting, supporting the BGS Board and the Executive Committee, liaising with our clients and stakeholders both in the UK and internationally and co-ordinating certain large, multidisciplinary overseas projects. Media and parliamentary relations are important components of the liaison function and are executed through the Press Office. MICD owns the corporate target for commissioned research earnings and, working with colleagues throughout the organisation, undertakes the necessary marketing functions.

A major task for MICD during 2004/05 was the planning and support of the new science programme for 2005–10, which followed the Science and Management Audit of BGS, and resulted in the achievement of very high grades, mainly 'alpha-5' and 'alpha-4'.

International work included several large, long-term projects in the United Arab Emirates, Mauritania, Afghanistan, Mozambique and elsewhere, which are concerned mainly with geological mapping, natural resource exploration and data management. We responded quickly and positively to the Asian tsunami disaster of 26 December 2004, initially through the provision of scientific and strategic advice to the Foreign and Commonwealth Office and the Department for International Development, and later in working with geological surveys in the affected area, to give direct and indirect scientific support. We were invited to sit on the Natural Hazards Working Group, set up by the Prime Minister under the chairmanship of the Chief Scientific Advisor, in the aftermath of the tsunami disaster.

Staff in the Directorate presented several papers at important international conferences and set up exhibition stands at various trade exhibitions in the UK and overseas, including the IUGS four-yearly conference in Florence.

Damage caused in Thailand by the Indian Ocean tsunami of 26 December 2004 *(below, left)* and revealed by maps of the Khao Lak area produced from satellite images acquired before *(below)* and after the tsunami *(bottom and, detail, opposite)*. Maps produced by the German Remote Sensing Data Center (DLR/ZKI), using Space Imaging's IKONOS data processed by the Center for Remote Imaging, Sensing and Processing (CRISP), under the European Space Agency's RESPOND Service Element. Reproduced with permission.

BGS International®

Programme overview

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

Mercury contamination in Tanzania: taking river sediment samples from the Malagarasi River, near Lake Tanganyika.

Assessing mercury contamination from artisanal gold mining in Tanzania

Artisanal gold mining provides income to some of the world's poorest people, but is also a major source of mercury contamination. To extract the gold the miners employ a simple amalgamation process using mercury, some of which escapes into the air, soil and surface water where it poses a significant hazard to the health of miners and other people through eating contaminated fish and other food and inhalation of mercury vapour. In 2003 we were contracted by UNIDO to carry out an environmental assessment in the Rwamagasa small-scale gold mining area of northern Tanzania. Scientists from the Geita Mines Office, the Tanzania Fisheries Research Institute and the University of Dar es Salaam provided assistance. The assessment demonstrated that although the heavy mineral tailings are highly contaminated with mercury, dispersion of this material into streams and on to agricultural soils appears to be restricted. The impact of mercury contamination on fish in the lower reaches of the Malagarasi River and the international waters of Lake Tanganyika, about 400 kilometres downstream of Rwamagasa, is not readily discernible. This is probably because dispersion of mercury is inhibited by the extensive swamps located between Rwamagasa and Lake Tanganyika.

Moving into Madagascar

In partnership with the United States Geological Survey and a local partner (GLW) we have begun work on a major three-year geological and geochemical mapping and mineral assessment project in northern and central Madagascar. The contract is part of a $30 million programme funded by the World Bank with the aim of reforming Madagascar's mining industry and attracting new mineral investment. The main objective of the BGS-led consortium is to provide the Malagasy Government with a modernised database describing the geological framework and mineral potential of the region. The consortium will survey an area of approximately 126 000 square kilometres of predominantly mountainous jungle and marginal savannah at a scale of 1:100 000, while an additional area of 115 000 square kilometres will be studied and sampled at 1:500 000 scale. The region is underlain for the most part by rocks of Precambrian age which are prospective for precious and base metals, chromium, nickel and gemstones. Complementary studies of the petrology, geomorphology, hydrogeology and vegetation for land use and environmental planning are also being undertaken.

Documenting Mozambique's mineral wealth

As part of a larger capacity building project aimed at promoting private sector investment in Mozambique's mining industry, we have been developing a documentation centre and a minerals information system (MIS) for the National Directorate of Geology (DNG), a division of the Ministry of Mineral Resources and Energy (MIREME), with funding from the African Development Bank. The MIS will also be used for planning purposes and as a tool in the social and economic development of the country. With the help of DNG staff, the BGS team is carrying out the recovery of all relevant paper documents at DNG headquarters in Maputo so that they can be classified, digitised and organised into a single management system and database. Geological, geochemical and geophysical data, including those derived from mining companies, will be integrated into a geographical information system. Additional datasets such as topography, and remotely sensed imagery will also be imported into a single management system. On-the-job training of DNG staff has been supplemented by specialist training at BGS headquarters in the UK.

Protecting the Black Sea

In April 1992 the governments of Georgia and five other Black Sea coastal nations put their signatures to the Convention for the Protection of the Black Sea Against Pollution. In the following year the Odessa Declaration specified the need for Integrated Coastal Zone Management (ICZM). Since 2003 a BGS team of experts in geographical information systems (GIS) and remote sensing has been contributing to a project led by the Lowestoft-based Centre for the Environment, Fisheries and Aquaculture Science (CEFAS) carrying out a World Bank supported ICZM project for the Ministry of the Environment in Georgia. The purpose of the project is to establish a coastal environmental quality monitoring and information system that will assist the government of Georgia to meet its commitment to the Regional Black Sea Environment Programme, and thus ensure sustainable economic development along its coastline. We are involved in establishing a pilot GIS with a view to the planned equipping and training of local Georgian staff, and is also preparing an implementation plan for integrating existing and future digital datasets into the GIS.

Protecting the Black Sea: human use of the Coastal Zone of the Republic of Georgia on the Black sea.

Supporting the Afghan Geological Survey

Years of conflict and the recent war in Afghanistan have brought disruption to people's livelihoods and taken a serious toll of the country's economy. Among the casualties of war, the offices of the Afghan Geological Survey (AGS) in Kabul were severely damaged by artillery fire. Although the Survey's staff salvaged and protected many documents, maps and samples — often at great personal risk to themselves and their families — much has been lost. In spite of such set-backs, Afghanistan now stands on the brink of a bright future, but there is an urgent need to attract inward investment in order to rebuild the country's ruined economy. The rebirth of a fully functioning geological survey is a necessary prerequisite to any such development. With this aim in view, the Department for International Development (DFID) has commissioned us to undertake a major capacity building project involving the rehabilitation of the AGS and the promotion of the country's mineral wealth to the international mining community. Work began in 2004 and is due to be completed in 2007. Already it is clear that the country possesses a wealth of energy and mineral resources, in many cases undeveloped, including world-class deposits of copper, iron and gemstones. The development of these resources could provide a much-needed source of revenue.

Supporting the Afghan Geological Survey: lapis lazuli an example of Afghanistan's world-class mineral resources.

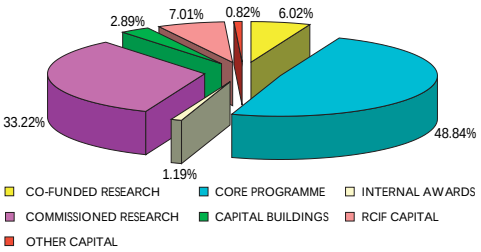
Assisting the Saudi Geological Survey

Since early 2004 we have provided technical assistance to the Saudi Geological Survey (SGS) in a number of areas. One such project has involved the preparation of new content for the SGS website and the provision of advice on its future management in the short to medium term. We also ran a four-week UK-based training course in industrial minerals evaluation for eleven junior staff of the SGS together with two staff from the Yemeni Geological Survey. The course included visits to industrial mineral deposits and quarries (bentonite, feldspar and gypsum) and industrial sites (a glass factory, brickworks and a rockwool factory). Two days were also given over to laboratory evaluation of kaolin samples. A further six-month training course was provided for six SGS staff covering analytical geochemistry, geohazards, environmental geology, and minerals.

Finance

BGS summary of income and expenditure 2004/05

Income	£ million
Science Budget	27.392
Other income	22.907
Total	**50.299**
Expenditure	
Salaries	25.866
Other expenditure	22.791
Total	**48.657**
Excess	1.642



BGS expenditure during the financial year 2004/05.

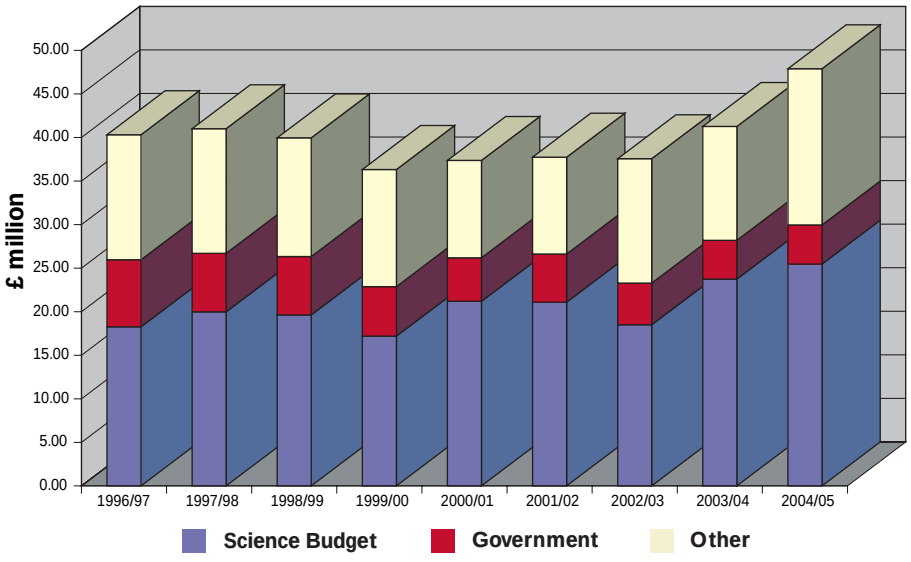
BGS funding

We receive funding from our parent organisation, the NERC, to carry out our Core Strategic programme. This programme encompasses long-term surveying, monitoring, databasing, environmental research and the provision of scientific advice, as well as the public understanding of science. The level of this funding (shown as Science Budget in the sources of BGS income chart below) increased from a low in 2002/03 following an additional £1.5 m allocation towards infrastructure in 2003/04, which was added into the base allocation. The 2003/04 and 2004/05 allocations include significant Research Council Infrastructure funding for capital, which will continue at a lower level in 2005/06. Financial year 2004/05 was the last of the old science programme and a new funding profile has been agreed for the five years from 2005/06.

We earn around 50% of our non-capital budget from research commissioned by external partners and customers, chargeable services, products and data licensing. The Commissioned Research programme enhances the Core Strategic programme through funding, ideas, data and review as well as making a vital contribution to our infrastructure. In 2004/05 the total operating income received from these sources amounted to £22.4 m. This included £4.5m contract income relating to the Arctic Drilling project carried out under the Integrated Ocean Drilling Program. Commissioned research income is shown split into government and other income in the sources of BGS income chart below.

We have an obligation to the NERC to balance our income and expenditure over the government's spending review period (three years). In practice we have adopted a business strategy to build a reserve of £750 000 to allow for variability in commercial income from year to year and to invest in priority services. This reserve was rolled forward into 2004/05 from 2003/04 and remained intact during the 2004/05 year. In fact due to the successful commercial activity during the year the surplus of income over expenditure increased to £1.6 m (£750 000 of which related to the strategic reserve) by the end of 2004/05.

The Capital programme was successfully progressed throughout the year. The Round 1 RCIF projects were all completed including the seabed corer, purchase of new mass spectrometer for NIGL and the development of the Joint Airborne Capability project with the Finnish Geological Survey (GTK). There was good progress on the Round 2 RCIF projects. In addition, the mobile field laboratory was delivered to Keyworth on 8 March 2004. The NERC Hazard Assessment and Environmental Materials Handling Facility is now occupied. The 3D visualisation suite at Keyworth has been completed and successfully demonstrated.



Sources of BGS income 1996/97 to 2004/05 (at 2004/05 prices).

Personnel

Personnel

During the year we continued with our annual graduate recruitment exercise, building on our science skills and long-term staff replacement policy. Further recruitment included senior positions relating to the new structure, due to be introduced on 1 April 2005, and replacement staff for resignations and retirements. Open-ended appointments were applied to the majority of new starters with fixed-term appointments only being made to meet specific short-term needs. Applications from all areas, including people with disabilities and minority groups, continued to be encouraged. In order to help publicise the organisation within the community, personnel staff have been involved in supporting local schools with specific projects and have attended careers events.

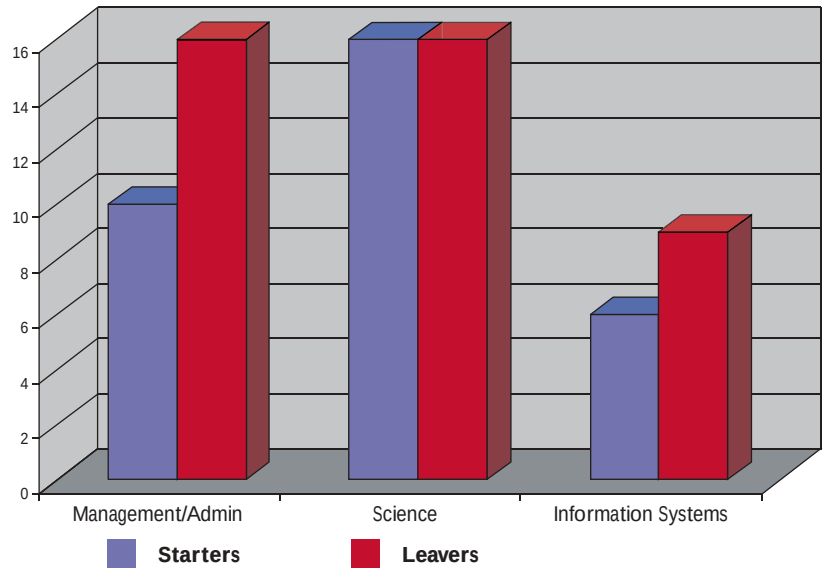
The number of staff resigning remained fairly constant when compared with the previous year, with 15 staff leaving. A further 20 staff retired, although this year saw six staff opting to remain beyond the age of 60 years following the relaxation of the normal age retirement rule. This change is providing the organisation with the opportunity to retain valuable skills for a longer period. Heads of Discipline and Personnel will continue to monitor the situation as the BGS approaches a 'bulge' of staff who are approaching age 60, and who may or may not decide to apply for voluntary retention beyond that age. Proposals for a change to the retirement age and pension benefits will, no doubt, affect individual staff as they plan for retirement.

The previous work on equal opportunities and diversity continued with the appointment of Diversity Officers at the main BGS sites. The individuals appointed will shortly receive formal training provided by an external company. The Diversity Officers will act as an important link between individual staff, Personnel and management. We continue to be sympathetic to requests for part-time working, job sharing, special leave and career breaks for family purposes. Personnel administer childcare support for young families, available to all staff.

In order to be supportive of individual's health needs, Personnel have in place regular occupational health clinics at the two main sites at Keyworth and Edinburgh. The health provision has now been extended to include medical check-ups and appropriate health care advice for staff with a commitment to serve overseas. Work has also continued on stress management to ensure appropriate support is provided.

The NERC introduced an automated e-appraisal system in 2004 and the organisation is about to embark on a second year of appraisal using this system.

Starters and leavers for 2004/05.



Facilities and Infrastructure

Facilities and Infrastructure: the new open-plan cartographic suite at Murchison House, Edinburgh.

Facilities and Infrastructure

This year has seen a high level of activity within the Facilities and Infrastructure department. The injection of increased infrastructure funding has allowed the maintenance and development programmes at Keyworth and Murchison House to be accelerated.

The Estates Committee has been effective in acting as a monitoring body and has taken an interest in the priorities and order of work. As well as the five-year maintenance plans for the major sites there is now a development plan that highlights the development needs and potential of the BGS estate.

Funding, in the main, continues to be spent predominantly on the maintenance and upgrading of the building fabric. The programme of roof re-covering, window replacement, toilet refurbishments and energy efficiency measures has continued with significant progress being made.

In Edinburgh work has been carried out to create a large open-plan area for the cartographic staff. This has resulted in a modern, well-serviced space which ideally suits the work patterns of the cartographers. While the development plan mentioned above initially addressed the Keyworth site, it will subsequently be expanded to cover all the Survey's sites. It will be an active, evolving document and will ultimately form part of a similar plan that is now being proposed at NERC level.

The two capital projects started during 2004, namely the refurbishment of H-Block and the building of the new NERC Hazard Assessment and Environmental Materials Handling Facility (HAEMHF) were successfully completed during the financial year. The H-Block project will be used as an exemplar for the type and standard of accommodation that the Survey would like to provide for all its staff in the future. The HAEMHF was completed at the end of the 2004/05 financial year and will be commissioned during the first part of 2005/06. This laboratory will provide state-of-the-art facilities, which will allow the safe handling and assessment of potentially contaminated samples, not just for the Survey, but for the whole of the NERC community.

Facilities and Infrastructure: the new NERC Hazard Assessment and Environmental Materials Handling Facility at Keyworth which was completed at the end of the 2004/05 financial year and will be commissioned during the first part of 2005/06.

Quality and Environmental management

Following intensive work in recent years the Survey achieved accreditation, through the British Standards Institution (BSI), to the international quality standard ISO 9001:2000. This was a major achievement for the Survey, which is one of the first research establishments in the country to gain accreditation to this standard.

Work continued to prepare for accreditation to the environmental standard ISO 14001. This is progressing well and it is hoped that the BSI will carry out the accreditation audit visit early in 2005/06.

Health and Safety

Health and safety procedures and guidance

Considerable progress has been made on the updating of procedures to ensure that the organisation keeps abreast of the continuous changes in legislation. Examples of this work are the draft procedures for risk assessment and risk management and project health and safety management. There is also in draft a new fire regulations procedure that is being prepared ahead of legislation due in April 2006. The BGS 'Control of Contractors' and 'Transport Manuals' and more recently our 'Permit to Work System' have all received favourable comment from the NERC.

Occupational health

New contracts are now in place with the Queens Medical Centre in Nottingham and the Institute of Occupational Medicine in Edinburgh and both have been used regularly over the past year. The inclusion of extra services, in particular for preparing personnel for overseas projects, has increased the usefulness of these contracts.

Accidents, incidents and near misses

The total number of accidents reported in 2004 was again down on the previous year. Reporting of all accidents means that action can be taken to prevent a recurrence and thus is important to both the Survey and its staff. Of equal importance is the reporting of 'near misses' and incidents where no injury has occurred and there is now a form on the BGS Intranet to encourage this reporting. There was one accident during the year which required reporting to the Health and Safety Executive and this related to a back injury.

Office health and safety

Offices have not been inspected on as regular a basis as in the past, mainly because the housekeeping standards have improved, but this is under constant review and with the change in the fire regulations mentioned above there will be a concerted effort to further improve the tidiness of work areas whether it be offices, workshops or stores and perhaps most importantly passage ways.

Risk assessments

The risk assessment procedure mentioned above will be available later in 2005. The majority of risk assessments that have been submitted over the past year have shown an improvement over those produced when the system was first introduced. This may be part of the reason that accident and incident rates are low. The implication being that the risk assessments are a useful aid to the management of projects and are being followed with a corresponding improvement in the safety of staff.

Health and safety training

The 'first day' induction on health and safety continues and is followed by an in-depth induction course arranged by the Training Section. Manual handling training continues, but the NERC training programme on safety responsibilities and risk assessments has been delayed because the BGS wanted the attendance criteria to be altered slightly. This is now being addressed and courses should start again early in the new financial year. Almost all of the training of senior managers has been completed.

Health and safety: the new laser-guided rocksaw installed in the thin-section preparation laboratory at Keyworth has a number of fail-safe features to minimise the potential for injuries.

Health and safety: a crane has been installed in the workshops at Keyworth to reduce back injuries caused by lifting heavy loads.

British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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