

Annual Report

2000–2001



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

NAVIGATION

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The British Geological Survey (BGS) is a component body of the Natural Environment Research Council (NERC) — one of the seven UK research councils that fund and manage scientific research and training in the UK. NERC uses a budget of over £200 million a year to fund independent research and training in the environmental sciences. About half its budget goes to universities, and half is invested in its own research centres.

The NERC is the research council that does Earth system science. It is 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 depths of the oceans to the upper atmosphere. Its mission is to gather and apply knowledge, create understanding and predict the behaviour of the natural environment and its resources. We are also committed to using this information to help solve complex problems.

Its current strategic objectives are to focus NERC science on priority issues, to put NERC science to work and to enhance the excellence of the science base for the environment.

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

Bibliographical reference

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British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

THE MISSION OF THE BRITISH GEOLOGICAL SURVEY IS TO:

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

Provide comprehensive, objective, impartial and up-to-date geoscientific information, advice, and services which meet the needs of customers in the industrial, engineering, governmental, and scientific communities of the UK and overseas, thereby contributing to the economic competitiveness of the United Kingdom, the effectiveness of public services and policy, and quality of life.

Enhance the UK science base by providing knowledge, information, education, and training in the geosciences, and promote the public understanding of the relevance of geoscience to resource and environment issues.

THE BUSINESS OF THE BGS IS CARRIED OUT UNDER THE FOLLOWING PROGRAMMES:

CORE STRATEGIC PROGRAMME

This, the principle business task of the BGS, entails long-term mapping/surveying, monitoring, databasing, supporting scientific research and the provision of scientific advice. The Core Strategic Programme contains the underpinning scientific activity which provides geoscientific information in support of decision making by public and private bodies at national to local levels on broad issues relating to resources, land use, geohazards, and the environment. A small, but key, element of the Core Strategic Programme is the promotion of the public understanding of science. The programme's primary funding is from the Science Budget.

PARTNERSHIP PROGRAMME

This is an extension of the Core Strategic Programme, consisting of research activities co-funded by the BGS from Science Budget appropriations, and by partners in the private and public sectors (including the EU). Co-funded projects address surveying and generic research issues relevant to the BGS Core Strategic Programme and to the strategic interests of the co-funding partners. Co-funding helps demonstrate specific customer support for elements of our Core Strategic Programme and is expected to expand in the future.

COMMISSIONED PROGRAMME

These short- and medium-term activities, undertaken in response to direct commissions from customers in both the private and public sectors, are fully funded by them. Projects use and build on expertise developed within the Core Strategic Programme and return knowledge and skills to it. The Commissioned Programme helps the BGS maintain strong scientific depth and expertise.

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Foreword



BGS © NERC

Mr John Mortimer MBA, B.Sc., ARSM, C.Eng., FIMM
Chairman of the BGS Board

It gives me great pleasure to be writing this foreword to the BGS Annual Report 2000/01, the first since I was appointed Chairman in January 2001. I must begin by offering my thanks to my predecessor as Chairman, Dr Eric Hassall, and to Board members Dr Bryan Lovell and Professor Geoffrey Walton, who retired from the Board at the end of 2000 after giving many years valuable service to the BGS. I would also like to welcome Mr Jeff Smith and Dr Geoff Robinson, who took their places on the Board in January 2001. Membership of the Board was expanded in April 2000 to include all the members of the BGS Executive Committee.

The year was a challenging one for the BGS in a number of ways. In April, the two years of Strategic Planning, which began with the arrival of Dr Falvey in 1998, came to fruition. The BGS was transformed from a science-driven, hierarchical organisation, to a user-focused, project management-based organisation. While the BGS is rightly proud of its history, which dates back to 1835, no organisation can afford to stand still and I believe the restructuring has laid firm foundations for the future BGS. As with any major change some unexpected difficulties were encountered and there are minor problems still being addressed. I would like to thank the management and staff of the organisation for their enormous efforts in implementing the restructuring so successfully.

In order to ensure the continued relevance of its science programme, the BGS has introduced a system of programme development groups (PDGs). By engaging the users of geoscience in the development of the programme, the BGS can ensure that the science produced matches the expectations of those who use it. At a time when value for money is high on the Government agenda it is paramount that publicly funded research actually contributes to the public good. The support of the stakeholder community for the PDG system is one way the BGS can demonstrate this contribution.

It was with great sadness that I received the news of the deaths of Dr Steve Robertson and Dr Alice Wain in a road accident. The sadness was in no way lessened by the opinion of the procurator-fiscal that the events leading to the crash were simply a tragic accident. I would like to extend my personal sympathy to Steve's and Alice's families, friends, and colleagues.

I continue to be impressed by the wide range of high-quality science undertaken at the BGS, both in the UK and internationally. The fact that such a high level of scientific excellence has been maintained through a year of enormous change is a testament to the commitment and quality of the entire staff of the organisation and bodes well for the future.

Director's introduction

This year was one of radical change in the BGS, a year which saw the implementation of the new strategy and the accompanying organisational structure. Sadly this was also a year that saw, for the first time in decades, the tragic deaths while on duty of two members of staff. The new financial year began with a complete restructuring of the BGS, moving from a traditional group-based hierarchical structure to a matrix management system for a project-based organisation. As with any major reorganisation, minor problems have been encountered in the implementation. However, the inherent flexibility of the matrix system has enabled corrective action to be taken. While some issues still require more work to resolve them I, along with the vast majority of the staff, am convinced that the foundations for a prosperous future have been laid.

During the year, the most comprehensive Programme Development Group (PDG) to date was completed. PDGs are a means of achieving continuous programme improvement through user consultation. The report of the Onshore Geological Surveys Programme Development Group, *Geology for our Diverse Economy*, was launched at the first BGS Annual Stakeholders' Meeting, held in London on 19th March 2001 and at further meetings in Edinburgh and Keyworth. This report defines the ways in which the BGS will survey onshore geology in the coming years.

We also made major contributions to disaster management work both in the UK and internationally. BGS mapping of modern alluvial deposits proved to be a good indicator of areas of flooding in the Trent Valley following the autumn rains. Following the fatal landslide at Nefyn, we have undertaken a landslide hazard assessment and are working to provide enhanced information on areas at risk of landslides. Among our wide portfolio of international work we continue to manage the Montserrat Volcano Observatory and have worked on assessing and mapping volcanic hazards on Tristan da Cunha.

We have established a world-leading reputation for the management of the geoscience information and data we hold and this year has seen major developments in this area of our work. The first version of DigMap50, the attributed 1:50 000 scale digital geological map of Great Britain is nearing completion. An exciting new project, GeoHazard, will create new national data-sets to address the needs of projects and help answer enquiries relating to geological hazards. The data will include, among others, scanned borehole logs, drift thickness, and hydrogeological characteristics.

Turning to sadder news, I have to report the deaths in service of Dr Steve Robertson and Dr Alice Wain. Both were killed when the BGS Land-Rover in which they were travelling left the road in what the Elgin procurator-fiscal described as a tragic accident. My thoughts and deepest sympathies, and those of the whole of the BGS, are with Steve's and Alice's families.

In this brief introduction I can only give an overview of the major events that have helped to shape the BGS during 2000/01. It has been a year of unprecedented change for our organisation, but one that lays the foundations for a successful future for one of the oldest scientific institutions in the world.

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



The BGS Science Programme



Report of the Programme Development Group for Onshore Geological Surveys (Walton and Lee, 2001)

The PDG carried out an extensive review of user needs and national strategic requirements for geological information in England, Scotland, and Wales. The outcome is a major change in direction towards a much more responsive and multidisciplinary programme that will focus firmly on meeting the need for up-to-date three-dimensional geological information to underpin sustainable development and environmentally sound decisions in a modern diverse economy. There will be an increasing emphasis on collecting, storing, and delivering information in digital form. Regionally-based advisory panels will be established to monitor and re-prioritise the programme on a regular basis. Copies of the report can be obtained from the BGS sales desk or downloaded from the BGS web site: www.bgs.ac.uk.

Land and Resources Directorate (LRD)

LRD comprises six programmes designed to define the surface and subsurface geology, providing information on the distribution of energy and mineral resources, and to carry out research on the sustainable use of the land, sea bed, and natural resources. The programmes were redefined in April 2000 as part of the wider BGS organisational restructuring. The **Integrated Geoscience Survey** programmes bring together the onshore strategic geological, geophysical, and geochemical survey activities and subsurface interpretation projects into two integrated programmes for Northern and Southern Britain, respectively. A major review of the onshore geological survey activities was carried out by a Programme Development Group (PDG) during the year, and a new ten-year strategy was defined to address the evolving needs of the user community. The **Continental Shelf and Margins** programme has developed its industry-sponsored and EU-supported research projects, and has successfully acquired more than 5600 kilometres of high-resolution seismic data over previously unsurveyed parts of the Rockall and Hatton banks. The new **Reservoir Geoscience** programme was established to address issues related to the extraction and storage of fluids and gases in porous and fractured rocks, and has been particularly successful in attracting EU funding for collaborative research into geosequestration of carbon dioxide. The **Onshore Minerals and Energy Resources** programme provides up-to-date information on metallic, industrial, construction, and energy mineral resources, with increasing emphasis on developing solutions for the full life cycle of mineral development. The **Geological Survey of Northern Ireland** is an integrated programme covering all aspects of geoscience on behalf of the Northern Ireland Department of Enterprise Trade and Investment.

Environment and Hazards Directorate (EHD)

EHD operates through five programmes to deliver a wide range of science and information on how geoscience impacts on man and his environment. The aim is to understand the basic science of the many processes that influence the landscape, how and where they occur, and the consequences to man of any interactions as he goes about his business. The **Groundwater Systems and Water Quality** programme produces high-quality research on processes relating to both groundwater resource and quality. A multidisciplinary approach, involving geologists, hydrogeologists, remote sensing, and modelling improved our understanding of how aquifer systems work and can be better managed as sustainable entities. The **Earthquake and Forensic Seismology and Geomagnetism** programme monitors seismic events and geomagnetism and carries out research into fracture anisotropy. A consortium approach maintains the quality and usefulness of the science. Environmental monitoring of atmospheric gases, using the infrastructure of the seismic arrays, is providing valuable information in rural areas. The geohazards and urban components of the **Urban Geoscience and Geological Hazards** programme are new. New protocols have been established for collecting, collating, and establishing risks associated with the hazards of living in cities. Increased rainfall has resulted in an increased frequency of landslides, floods and collapses. Urban studies have shown the value of bringing geoscientists together with planners and developers to improve safe land use. The first year of the **Pollution and Waste Management and Extractive Industries Impacts** programme has resulted in the development of a wide variety of activities in the areas of geochemistry, mineralogy, geophysics, and hydrogeology. Highlights of the past year include dissemination at international meetings of

the containment properties of clays, insights into the environmental behaviour of chiral organic compounds, monographs and reports on issues relating to depleted uranium, and the continued emergence of environmental geophysics as a research methodology and applied tool. 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) in order to predict and better manage future change. Work on climate change is increasing and is showing the importance of geological information in constraining predictive models.

Information Services and Management Directorate (ISMD)

ISMD operates through three Programmes and two major projects. The **Information Management** programme manages all the BGS's Data and Information, as well as managing information for a variety of external organisations. Highlights of the year include the launch of the Internet Geoscience Data Index and the BGS becoming the first PSRE to publish its metadata on the government's premier Information Asset Register. The **National Geoscience Information Service** (NGIS) is responsible for the delivery of information from the BGS's programmes. A significant proportion of non-governmental income comes from NGIS activities. 2000/01 has seen major changes put in place in the NGIS management structure and consequent improvements in the integration and efficiency. Electronic methods for information dissemination are increasingly important. The **Publications Production** programme appointed a new management team. Twenty-seven maps were released for print-on-demand or published as litho-printed maps. Fourteen books were produced, one atlas, and four publications in the PUS series, in addition to a number of books and reports delivered for commercial contracts. The **Digital Geoscience Spatial Model** project started work on building the model framework and exploring modelling methods through a number of pilot studies. Specifications have already been developed to hold model discovery, data discovery, and inference metadata, and a prototype Data Warehouse has been implemented to store spatial models. An assessment of the requirements for modelling software and platforms was completed. A methodology for the 'mark-up' of geoscientific texts has been developed. The **GeoHazard** project was initiated during the year. It will accelerate production of strategically-important geological hazard data for Great Britain so that the BGS is better able to respond to enquiries on the subject.

In addition to the science programmes outlined here, the **Geoscience Resources and Facilities Directorate** operates a generic Development of Capability programme (see pages 38–39).

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+Members of the BGS Executive Committee

From 1 April 2000, the BGS has adopted a matrix approach to the management its activities and services. The essential principle of a matrix scheme is that the management of human and physical resources is separated from the management of work.

Lands and Resources

Integrated Geoscience Surveys

IGS(N) is responsible for providing baseline geological, geochemical, geophysical and rock-mass data for northern England and Scotland. The programme aims are to provide high-quality geoscientific information on the solid and superficial geology; to complete the map coverage; and to provide advice and digital data to facilitate informed decision making and cost-effective development by land-use planners, mineral developers, and organisations involved in conservation, the environment, and education. Strategic and responsive geological surveys were carried out across all parts of Northern Britain, with a total of 552 square kilometres resurveyed.

Strategic surveys

Mapping of coal-bearing strata within the Midland Valley Terrane of Scotland has been revised, digitally captured and visualised in three dimensions to enable non-geologists to see the relationship of solid and superficial geology to the ground surface. Up to ten two-dimensional surface models — including the ground surface, rockhead, selected key geological horizons, and major faults — are combined and modelled. They are then displayed as individual fault blocks, or cut to produce cross-sectional surfaces or backstripped to reveal horizons within the subsurface. When combined with a drape of air photographs (produced in agreement with the Royal Commission of Historic and Ancient Monuments Scotland), the model effectively demonstrates our knowledge of the geology to external users. This approach is now being developed to study the tectono-stratigraphical evolution of contrasting basins across the Midland Valley Terrane.

Within the Southern Uplands, the application of conodont biostratigraphical analysis is becoming increasingly important, especially in the older chert-dominated, graptolite-poor parts of the succession. For the first time an entire conodont bedding-plane assemblage has been discovered in deep marine sediments (the Birkhill Shales) of Caradoc age. In addition, revision of Lower Palaeozoic rocks in the Girvan area has revealed what is probably the oldest brackish water ostracod fauna known anywhere in the world.

Micromorphological analyses of Quaternary glaciogenic sediments highlight the role played in sub-glacial deformation by over-pressured groundwater beneath advancing ice masses. These studies, as part of the Quaternary surveys of the Highlands and Southern Scotland, provide compelling evidence of the polyphase and heterogeneous nature of deformation beneath the soles of Late Devensian glaciers and, in particular, of the role of hydrofracturing and sediment fluidisation. Although both brittle and ductile deformation has been suggested by many studies of modern ice fronts, few have inferred that such disturbance of the glacier bed extends to depths exceeding three metres.

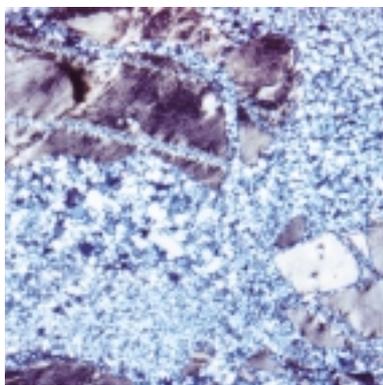
Responsive surveys

Between November 2000 and March 2001 severe subsidence took place in the Gilmerton Limestone affecting large area of Ferniehill, in south-east Edinburgh. Ground collapse above former workings, last mined in 1829, resulted from the progressive failure of mine pillars and roof strata. 34 houses worth over £1.5 million were subsequently demolished. BGS maps, memoirs, geologists' field notes (from an underground inspection in 1940), borehole records, photographs, and database of enquiries were critical to an understanding of the technical and safety problems created by the old mine and associated landfilled quarries. The City has instigated an official inquiry into the event which will involve further collaboration with the BGS.

Revision mapping in north-east England highlights the problems found in areas of former mineral extraction, particularly in respect of future land-use planning. Investigations of wide-spread fissuring in the Permian strata have revealed that:

- Active fissuring and associated damage to land and structures is common throughout the Magnesian Limestone outcrop.

Tom Bain, BGS © NERC



Strategic surveys: hydrofracturing and sand injection in overpressured Quaternary sediments. The photomicrograph shows a deformed Devensian lake deposit, Raits Burn, Speyside (BGS sample number S98557).

Northern Britain

- Landsliding, rock fall, cambering and limestone dissolution do not offer satisfactory explanations of fissure formation.
- Field evidence is consistent with ground movement resulting from reactivated movement along known faults in areas of former underground coal mining, perhaps related to rising groundwater levels.

These examples highlight the importance of interpretation and digital capture of both coal and non-coal mine plans. This information, which is now available for the City of Glasgow, is incorporated in a mining report system developed in collaboration with the Coal Authority for the Scottish Land Information Service (ScotLIS), in part funded by the government's Invest to Save initiative.

A geological survey of the Quaternary sequence in the Dounreay area of Caithness, commissioned by UKAEA, has provided baseline data on the nature, thickness, and extent of superficial deposits in the extended catchment of the Dounreay Burn. This study, undertaken by staff of the IGS(N) and Urban Geoscience and Geological Hazards programmes, enables the role of the Quaternary cover in determining rates of groundwater recharge and discharge from bedrock aquifers within the catchment to be assessed. Modelling is being undertaken by members of the Groundwater and Water Quality programme, in conjunction with staff from CEH Wallingford, as a precursor to decommissioning several facilities at the Dounreay nuclear site.

Geological conservation

IGS(N) staff are involved in geological conservation issues via contracts and collaborative ventures with the Joint Nature Conservation Committee and Scottish Natural Heritage. In particular they have played a leading role in the compilation of several of the Geological Conservation Review (GCR) volumes. These volumes document the scientific case for the conservation of internationally and nationally important geological sites throughout Great Britain. At the local level, BGS staff have been instrumental in the establishment of Regionally Important Geological and Geomorphological Sites (RIGS) and provided advice to the Scottish Executive on the relationship between geodiversity and local biodiversity action plans. As a contribution to practical conservation, BGS staff also play a significant role in developing the Scottish Stone Liaison Group. This multi-organisational group aims to raise public awareness in the built heritage and to revitalise the building stone industry in Scotland through research and by sourcing the availability of indigenous stones (including slate) and encouraging their use in modern buildings.

With the forthcoming designation of the Cairngorms as a National Park a major scientific study has commenced with important implications for conservation and public awareness. This project is focused on the links between bedrock geology and glacial processes and the evolution of a landscape that underpins this internationally valued sub-arctic ecosystem. Aerial photographs, satellite images, and field data have been collated in a Geographical Information System (GIS) linked to three-dimensional modelling software. This software enables the development of a wide range of innovative digital products, including thematic maps and interactive 3D geological and landscape models that are expected to be incorporated into educational products, tourist guides, and exhibits at visitor centres.

Responsive surveys: housing collapse above limestone workings in Ferniehill, south-east Edinburgh.



Fergus McTaggart, BGS © NERC

Geological conservation: the Museum of Scotland, Edinburgh, opened 1998. The cladding is Hopeman sandstone from Clashach Quarry, Elgin.



A A McMillan, BGS © NERC

Lands and Resources

Integrated Geoscience Surveys

This programme undertakes systematic multi-disciplinary geological, geophysical, and geochemical surveys of Southern Britain, as part of a long-term strategy to provide onshore coverage which satisfies user needs and enhances our understanding of the three-dimensional geology of the UK landmass. Geological and geophysical data are brought together to assist in modelling the basins and regional crustal structures of Southern Britain. Geological surveys are active in all regions, whilst geochemical baseline environmental surveys (G-BASE) are currently complete over all of northern Britain, Wales, and the Midlands, with field activities now centred on East Anglia. Airborne geophysical surveys (HiRES) cover the north Midlands, and plans are being made to extend this valuable data-set.

New methods of soil mapping

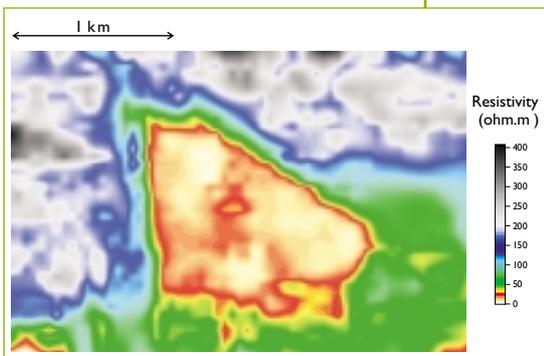
This project is a joint venture with the Soil Survey of England and Wales (SSLRC) and Remote Sensing Applications Consulting Ltd to investigate ways of generating nationwide soil information from currently available databases. A wide range of environmental factors govern soil characteristics, but geological information is a fundamental element. BGS geoscientists have played a key role in modifying 1:50 000 scale geological maps to meet the very-near-surface requirements of soil scientists. To do this, the digital geological map has been reattributed with the lithological characteristics of the near surface. The resulting maps, known as a 'Parent Material' maps, have formed the basis for a series of modelling tests at SSLRC. Modelling of the data-sets has been centred around Melbourne, Derbyshire, where high-quality geology and soil data can be readily compared. In addition, the BGS and SSLRC have been testing the high resolution airborne geophysical surveys (HiRES) data-sets for their suitability in detecting soil characteristics. The radiometric data have proved effective in determining soil texture and, to a lesser degree, bulk mineralogy. The initial results indicate that soil maps can be generated successfully from geoscience data-sets, paving the way for regional-scale trials and a much-needed national data-set of soil characteristics. This will be a significant step in bringing together geology and soil mapping in the UK.

High resolution airborne geophysical surveys (HiRES)

Work has continued on the processing and interpretation of the two UK high resolution airborne geophysical data-sets acquired recently. The onerous task of manually de-culturing some 50 000 line kilometres of aeromagnetic data was completed, while collaborative research into automated techniques of de-culturing involving wavelet analysis was undertaken at the Universities of Nottingham and Keele. A Geographical Information System (GIS) has been produced and populated with images of the airborne data, including a wide variety of transforms and should promote wider use of the data. An image atlas including a limited number of maps has also been produced for promotional purposes. Ground follow-up work has been completed to confirm some of the most significant airborne anomalies and investigate their causes. Isolated radiometric anomalies were found to be associated with power stations, spoil heaps and former industrial sites and a conductive feature associated with a domestic landfill site has been confirmed. Numerous sinuous conductive anomalies extending from the base of spoil heaps were also detected from the air.

Dorset Coast — a proposed World Heritage Site

The Dorset and East Devon Coast is one of the most significant earth science sites in the world and in 2001 was nominated by the UK as a World Heritage Site. The coast includes continuous and accessible exposures of Triassic, Jurassic, and Cretaceous strata, together with internationally-known fossil localities, the largest onshore oilfield in Europe, spectacular landslides, and an array of coastal landforms — all in an area of exceptional natural beauty. The BGS has worked closely with Dorset and Devon county councils in the preparation of the nomination and was able to provide modern stratigraphical and structural syntheses following completion of the new 1: 50 000



BGS © NERC

HiRES: Thoresby Mine spoil heaps and plant are characterised by low resistivities (less than about 70 ohm.m, shown in red and yellow). Conductive zones extending away from the site to the south and east may reflect the presence of pore fluids derived from the spoil drainage (green and pale blue).

Southern Britain

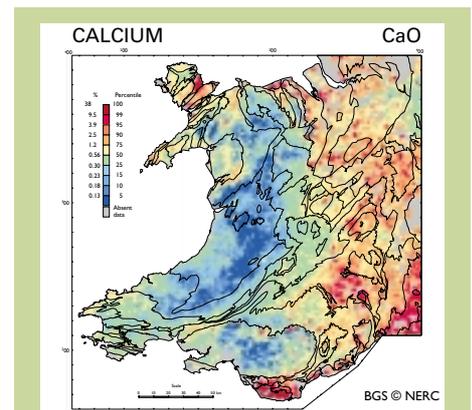
Dorchester, West Fleet and Weymouth, and Swanage maps. The nomination coincides with preparation of a BGS regional memoir that integrates new developments in Dorset geology with a systematic account of the principal coastal exposures. The account also includes the first detailed description of the Palaeogene strata of the Wareham Basin with its important ball clay and gravel deposits.

A new glacial stratigraphy for northern East Anglia

The current primary 1:10 000 survey of north-east Norfolk has resulted in the development of a radical new stratigraphy for the glaciogenic deposits, which replaces the existing stratigraphy developed by numerous workers over many decades. BGS fieldwork in Norfolk has benefited from well-established collaboration with the Department of Geography, Royal Holloway, University of London, which has undertaken much of the analytical work. At the heart of the new stratigraphy is the recognition that the middle of the three tills within the North Sea Drift Formation, previously thought to be of Scandinavian derivation, is actually the lateral equivalent of the Lowestoft Till, deposited by ice that flowed southwards from northern Britain. Previously, the Lowestoft Till was thought to overlie the North Sea Drift Formation. Data indicate that the three tills were deposited during three separate glaciations, whereas earlier workers had concluded that all the tills had been deposited during a single Anglian glaciation — Oxygen Isotope Stage (OIS) 12 — some 400 000 years ago. It is now tentatively suggested that the first till was deposited during OIS 16, the second in OIS 12 and the third during OIS 6. The revised ages, if correct, have a significant implication for the climatic history of the UK during the past one million years.

Basin and regional crustal structure of southern Britain

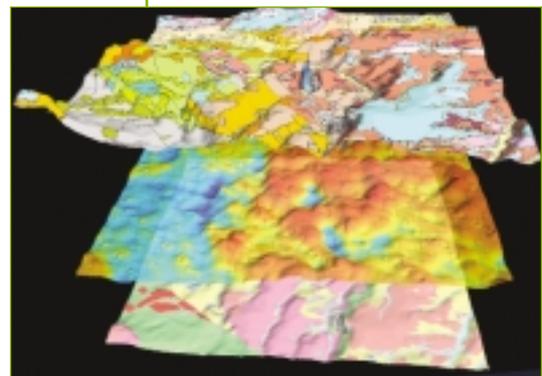
The Cheshire-Staffordshire subsurface memoir, the third in a series, will soon be published. It forms part of a systematic ongoing programme of mapping, analysis, synthesis, and modelling of the subsurface geology of the UK that will lead to the progressive building of seamless subsurface maps, geophysical images, structural cross-sections and models, and regional descriptions of subsurface geology. The memoirs place surface-mapped structures and stratigraphy in their regional context and reveal details of 'buried' structures and stratigraphical variations. This memoir will provide much new information on the distribution, structure, and stratigraphy of both the Upper and Lower Palaeozoic successions below the thick Permo-Triassic Cheshire Basin and surrounding areas. The regional crustal structure of the UK is being investigated using systematic interpretation of the regional gravity and aeromagnetic data. Profile modelling for south-east Britain is now complete. Many of the anomalies can be accounted for by northward-directed Variscan thrusting that has buried Avalonian basement of the Midlands Microcraton southwards. Within the English Channel, a distinctive change in magnetic anomaly signature occurs. A subduction-related suture of Variscan age in the English Channel has been proposed. The region associated with the change in magnetic signature is the likely remnant of the Rheic Ocean, emplaced on to the Avalonian margin by southerly subduction.



Stream water geochemical atlas

This atlas covering Wales and part of west-central England presents data for stream water chemistry from about 13 500 sampling sites, encompassing pH (acidity), conductivity, and major and trace elements. The data highlight a range of water-quality issues including acid mine drainage, heavy metal contamination, nutrient enrichment and acid deposition leading to acidification.

New methods of soil mapping: comparison of high quality geology and soil data-sets around Melbourne, Derbyshire. From top to bottom, the three layers shown are: geology draped over digital terrain model, radiometric (potassium) data from HiRES, and soil 'parent' material.



Lands and Resources

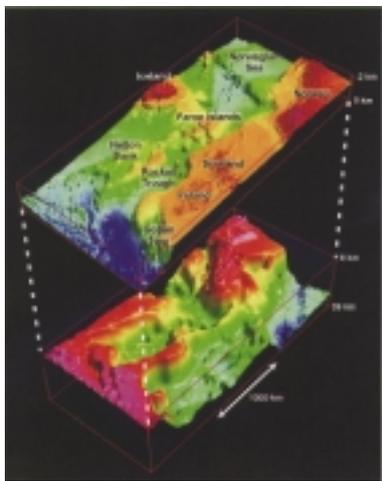
Continental Shelf & Margins

The BGS marine programme is concerned with all aspects of the geology offshore UK and internationally. UK studies include investigations of the crustal structure and sedimentary basins, the Neogene evolution of the western margin, the prospectivity of the hydrocarbon province, and investigations of environmental geology and geohazards.



David Jones, BGS © NERC

Irish Sea pollutants project: collection of sediment cores using a three-metre vibrocorer will enable improved estimates of radionuclide inventories in Irish Sea intertidal sediments to be made.



Geoff Kimbell, BGS © NERC

Passive margins modelling project: illustration of variations in topography (top) and predicted depth of the base of the crust (bottom) in the north-east Atlantic region. Note the thin crust beneath the deep-water basins and the thickened crust beneath regions of elevated topography.

Hatton/Rockall seismic survey

In 2000 the BGS ran a high-resolution seismic survey in the north-east Atlantic across previously unsurveyed parts of Rockall and Hatton Banks. The project was funded by the Rockall Consortium, comprising the BGS and ten oil companies, which was formed in 1992 with an aim of investigating the UK Atlantic Margin. Over 5600 line kilometres of airgun and sparker records were collected along with bathymetry, gravity, and magnetic data. Evidence for significant margin-wide events can be seen on the new data within the Cainozoic section. These tectonic events, and the consequent changes in water circulation patterns which they produced, have caused regional unconformities, prograding deltas, areas of complex contourite sedimentation, and erosional channels and moats. The presence of several early Cainozoic volcanoes has been confirmed and their extensive lava fields mapped. The pre-Cainozoic (pre-Atlantic Ocean opening) geology of Hatton Bank can be shown to be similar to that encountered on the Scotian shelf off Newfoundland, and has marked differences to the geology of Rockall Bank. The new data remain confidential to members of the Rockall Consortium for a number of years, after which they will become publicly available. The results of the data interpretation will be incorporated into BGS maps and publications.

Irish Sea pollutants project

This is a collaborative project with the Proudman Oceanographic and Plymouth Marine Laboratories to investigate pollutants in the Irish Sea. The main focus is on radionuclides from authorised Sellafield discharges, but other contaminants such as heavy metals and organics are also being considered. Detailed analysis of the relationships between radionuclides and a wide range of properties and processes: micro- and macro-biology, sediment structures, mineralogy, and pore water and sediment chemistry are being examined in sediment cores. Cores (up to three metres long) have also been collected from major tidal flats. These have extended our knowledge of the depth of contamination in the sediment and will improve estimates of the inventory of radionuclides in these environments. Experiments show that some burrowing organisms, such as the mud shrimp *Callinassa*, can significantly redistribute radionuclides in the sediments, whereas others have a very limited impact. Three-dimensional water movements in the Irish Sea, being modelled at different scales, emphasise the role of storms in redistributing contaminated sediment.

Passive margins modelling project

The BGS is investigating the structure of the north-east Atlantic margin, from the Goban Spur in the south, to the Norwegian (Lofoten) margin in the north. The project involves the integration of potential field (gravity and magnetic) interpretations with seismic survey and drilling data. A Geographical Information System (GIS) has been established which includes geophysical images and mapped tectonic elements, and a study of rock physical properties has been undertaken. Two-dimensional gravity/magnetic/seismic models have been built along a series of transects across the margin. Routines have been developed for predicting the three-dimensional structure of the crust and upper mantle from isostatic principles, allowing for the influence of factors such as mantle temperature variations and lithospheric rigidity. The base of the crust (Moho) predicted by these methods is compared with the same interface defined

by seismic experiments, and the gravity field computed over the model is compared with observed data. The results are being analysed and the models refined in an iterative process that is leading to a best-fit regional interpretation of the three-dimensional structure and tectonic evolution of the margin.

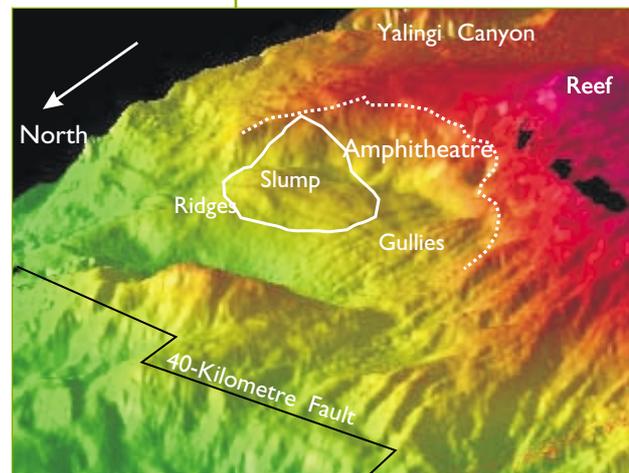
Slumping and tsunami investigations

In July 1998 a massive earthquake, followed by a tsunami wave, struck the north coast of Papua New Guinea (PNG). Over 2000 people died as the wave struck the coast. Following the disaster the South Pacific Applied Geoscience Commission invited the BGS to co-lead the offshore investigations. The Japan Marine Science and Technology Center have funded four surveys collecting seismic data, sea-bed samples and making observations from remotely-operated vehicles and manned submersibles. The results indicate that the tsunami was created by a submarine landslide located 25 kilometres off the coast. The PNG slump also provides a modern analogue to sediment slides being investigated by the BGS off the West Coast of Scotland. Some of these slides were formed during glacial times when ice sheets extended to, or beyond, the shelf break and sedimentation rates were rapid. Other slides are post-glacial in age and here the failure mechanisms are uncertain. The identification of failure mechanisms is important for risk assessment in hydrocarbon exploration. Offshore of Norway, the giant Storegga Slide lies above the newly discovered Ormen Lange gas field. Storegga last failed about 7200 years ago, causing a tsunami which devastated coastal areas in parts of northern Britain. Better understanding of failure mechanisms will help to ensure that development of the gasfield does not trigger further slope failures.

Coring beneath an Antarctic ice shelf

The BGS Marine Operations Team, working with the British Antarctic Survey (BAS) have carried out the first ever high-resolution seismic survey and sediment-coring programme of a sea bed known to have been deposited under an ice shelf. This was possible because of the catastrophic disintegration of the Larsen and Prince Gustav ice shelves in 1995. These small, relatively thin shelves can act as 'early-warning indicators' of climate change, and it was suggested that this was evidence of anthropogenically-induced global warming. Scientists at BAS, however, wanted to investigate possible evidence for similar 'natural' climatic perturbations during the Holocene (the past 10 000 years) and enlisted the help of the BGS. The bathymetric chart produced from the seismic survey revealed deep glacial basins (800–1100 metres deep) near the main glacial outlets, with a relatively smooth sea bed farther offshore at depths of 400–500 metres. The BGS vibrocoring recovered a total of 140 metres of core from 42 sites in conditions which varied from calm and sunny to truly polar, with temperatures of -14°C and driving snow. Subsequent laboratory studies have shown that the extent of the ice shelves has varied in time within the Holocene and that the most recent shelf was about 2000 years old.

Slumping and tsunami investigations: three-dimensional image of the slump of 17th July 1998 from the north-west. The white dotted line marks the top of an amphitheatre that has formed during a number of slump events. The most recent slump is identified in the east.



David Tappin, BGS © NERC

Coring beneath an Antarctic ice-shelf: BGS Vibrocoring on board the RRS 'James Clark Ross' in the Larsen Ice Shelf Area of the Antarctic Peninsula.



Alister Stömmen, BGS © NERC

Lands and Resources

Onshore Minerals & Energy Resources

This programme manages, markets, engages in resource-oriented research, and develops a range of products and services with the aim of increasing the knowledge and understanding of onshore metallic, non-metallic, industrial, and energy mineral resources in both a UK and international context. OMER's mission is to promote environmentally sustainable mineral and hydrocarbon development for the economic benefit of the UK and provide geo-scientific solutions for the full life cycle of mineral development, from exploration and production to management of waste materials and post-mining land use.

Onshore hydrocarbons in the UK

Although the size of the UK onshore hydrocarbons resource base is small compared to the North Sea, it is still significant — Wytch Farm in Dorset is the largest onshore oil field in Europe. The onshore hydrocarbons project aims to identify hydrocarbon targets and assist the exploration strategies, particularly in support of small scale oil companies. This year the project has continued to develop databases and GIS systems containing information on hydrocarbon, coal, and related resources which have already been of assistance to oil companies. One of the main current tasks is the drafting of a Caledonian unconformity map, which shows the effective economic basement beneath which it is unlikely that viable hydrocarbons resources will exist. It is hoped that this map will be published in 2002/03. It is important to evaluate the geological history of potential source hydrocarbon source rocks in any region and assess whether this history is conducive to hydrocarbon generation. Similarly, a detailed knowledge of the subsurface geology and structure is essential for the identification of hydrocarbon structural traps which form the specific exploration targets. This year a combination of the above methodologies has focused on the Cheshire–Warwickshire–West Midlands area.

Minerals GIS application development

MINGOL continues to host and develop the maps and other information produced for the DETR-funded project 'Mineral Resource Information for National, Regional and Local Planning'. Data from four maps, Dorset, Durham, Northamptonshire, and Northumberland have been incorporated to add to the series of 'intelligent' maps that can be used as an aid to minerals planning and sustainable resource management. The Shropshire mineral resources county map has now been designed as a fully attributed web-delivered GIS. It is hoped this GIS will be delivered in the public domain shortly, as a trial for the full-scale development of regional DETR map information on the external BGS Internet site in the coming year. This year saw the completion of a DETR-commissioned GIS for the Wareham Basin of East Dorset. This project incorporates reliable and up-to-date information on the extent of the ball clay resource, existing extraction sites, and the ball clay consultation area and relates these to a wide range of landscape and other conservation designations that may be constraints on minerals development. The system has contributed greatly to the sustainable development issues for ball clay extraction in the area. A similar, but more broadly based study has been carried out on the brick clay resources of England.

Sustainable mineral development

Sustainability is the simple idea of optimising use of resources with minimum adverse impact on the environment, thus ensuring a better quality of life for everyone. Sustainable development objectives will increasingly set the framework for planning for minerals extraction. In doing so, the planning process will need to ensure that economic, environmental, and social goals are resolved equitably. Sustainability means taking decisions in an integrated manner, with consideration of all impacts on all resources, both natural and man-made. In other words, a balance between demand for minerals and social, economic, and environmental cost must be achieved as far as possible, without exporting environmental damage to other countries. Information on mineral resources is essential to the development of planning



David Highley, BGS © NERC

Sustainable mineral development: recovery of by-product fireclay from an opencast coal site in Northumberland.

policies designed to promote both sustainable development, and a sustainable security of supply of minerals to industry. In a number of related DETR- and Science Budget-funded projects, the BGS is bringing together a wide range of expertise, analysis, data on resources, their extraction, and their relationship to other forms of land use. This information is used at national and regional levels to underpin and update planning guidance and advice. At the local level, this work supports the formulation and periodic review of mineral local plans. These plans are key to promoting strategies for sustainable mineral development.

Permian global warming and correlation of reservoir rocks in Oman

The Gharif Formation, which crops out in south-eastern Oman and occurs extensively in the subsurface, is a major target for oil exploration. The formation is a complex of continental fluvial and marine clastic rocks that hitherto have been difficult to correlate. BGS palynologists have shown that the formation records vertical changes in the palaeoecology of terrestrial plants caused by global warming that followed the Permo-Carboniferous glaciation. This warming event, tracked through paleoecological change, culminated in a widespread marine transgression which is marked by marine facies and a unique species of microplankton. Other similar changes appear to occur in coeval Early Permian rocks in Australia that are also, significantly, associated with the same microplanktonic species. The transgression is a significant discovery in that it may mark the first deglacial eustatic transgression of the Early Permian and be the basis of pan-Gondwana correlation in this period, a correlation which has previously evaded stratigraphers. This type of stratigraphical work has led to the establishment of a high-resolution palynological biozonation and to the construction of palaeogeographical maps showing facies distributions. This benefits oil companies because it greatly assists in the understanding of the lateral variability of reservoir sandbodies and intraformational seals.

BGS–DTI Minerals Programme

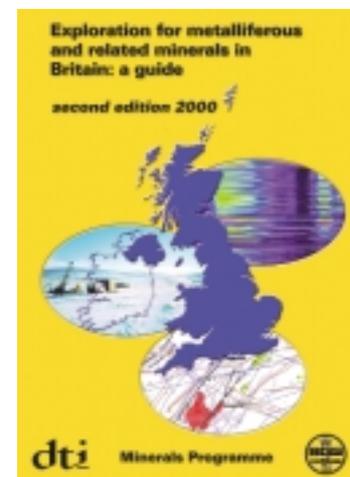
The Department of Trade and Industry (DTI) supports the BGS to develop expertise and information related to economic minerals and the industries these commodities support. Over the years, this programme has evolved in function, reflecting changes in the UK and world mineral markets. Earlier years of direct hands-on mineral exploration have evolved into a programme which synthesises and adds value to minerals information and focuses on key issues relevant to government, industry and planners alike. There have been remarkable changes in primary fuel production within the UK since 1950. The BGS maintains a precise database which allows government and industry to access reliable and impartial statistics to inform decisions and policy development. The data can address questions such as: has the UK achieved the optimum balance in energy supply? And what strategy should be encouraged as oil and gas production falls in the future? In a similar vein the BGS maintains world class databases and expertise over a whole spectrum of mineral commodities for the UK and the world. Other products of the Mineral Programme over the past year include a brand-new exploration guide for metalliferous minerals for the UK, prospectivity analyses for the volcanic rocks of Northern Britain, and gold and base metals in the Lower Palaeozoic rocks of Wales. The Minerals Programme has developed its own highly successful website: www.mineralsUK.com which is becoming an increasingly important platform for information dissemination.

Correlation of reservoir rocks in Oman: geologists from the BGS and Petroleum Development Oman examining sandstones from the Permian Gharif Formation, Huqf area, Oman. These rocks are the outcrop equivalent of oil reservoirs in the subsurface of Oman and can also be traced into Saudi Arabia.



Neil Jones, BGS © NERC

BGS–DTI Minerals Programme: *Exploration for metalliferous and related minerals in Britain: a guide*, published during 2000.



A. Minks, BGS © NERC

Lands and Resources

Reservoir Geoscience

This programme focuses on porous and fractured rocks (reservoirs). Fluids and gases can be extracted (e.g. a producing oilfield), or injected into them (e.g. underground gas storage). All oil and gas reserves are held in such rocks, hence they are of paramount importance in supplying the nation's energy. During the past year, research has focused in particular on the feasibility of underground carbon dioxide sequestration.

Geological storage of carbon dioxide (GESTCO)

GESTCO is funded by the EU Fifth Framework Programme. The project, which started in April 2000 and involves other European geological surveys, was set up to examine major point-source industrial emissions in countries bordering the North Sea and to consider how these sources relate to the oil and gas infrastructure and potential storage sites. GESTCO will help to provide decision support for future EU policy should underground storage of CO₂ in porous rocks — geosequestration — be implemented. Geosequestration has significant advantages over other sequestration strategies (for example biomass and deep ocean disposal): it is verifiable, can accommodate huge volumes, is likely to be secure for thousands of years and does not conflict with land use or have a negative ecological impact. Capture of emissions at point source and removal to a storage site prevents the CO₂ entering the atmosphere, thus avoiding the long residence time that CO₂ has in the atmosphere before it is sequestered by natural processes. Currently global CO₂ emissions from human activity are entering the atmosphere at about twice the rate at which the oceans can absorb them. If deployed, geosequestration is likely to play a significant role in contributing to the 60% reduction of CO₂ emissions required over the next fifty years to stabilise the atmosphere at present CO₂ levels (IPCC report March 2001).

Weyburn

The Weyburn project started in January 2001 and is funded by the EU Fifth Framework Programme. It supports several European geoscience organisations' involvement in an international project based on the Weyburn oilfield in Canada, directed by Canada's Petroleum Technology Research Centre in collaboration with the International Energy Agency (IEA) and several North American research organisations, government agencies, and industrial sponsors. The project focuses on the fate of CO₂ — from a coal gasification plant operated by the Dakota Gasification Company — used in an enhanced oil recovery operation. The project will provide essential knowledge for the sequestration of industrial emissions in an enhanced oil recovery context. The environmental benefits of clean coal gasification technology, which reduce CO₂ emissions from coal by more than 50% (as well as reducing SO_x, NO_x and particulate emissions), are further improved by the enhanced oil recovery. Oil produced in this way has over 30% reduced emissions compared to conventional oil production. Approximately six barrels of oil are produced for every ton of CO₂ injected into this nearly depleted oilfield (operated by PanCanadian). The added oil recovery also contributes to offsetting CO₂ sequestration costs. Deploying this technology in Europe could significantly reduce greenhouse gas and other harmful emissions as well as improve the recovery of remaining oil and gas reserves. Weyburn provides an analogue for such deployment.

Natural analogues for the storage of carbon dioxide in the natural environment (NASCENT)

NASCENT is a new project funded under the EU Fifth Framework Programme to investigate natural underground accumulations of CO₂, many of which are millions of years old. Some of these reservoirs produce very pure CO₂ which is used for a variety of commercial applications, such as enhanced oil recovery and the food and drink industry. Understanding the stability of



courtesy of Geoform Ltd

NASCENT: CO₂-rich water gushing from a wellhead in the French Alps at St Moritz.

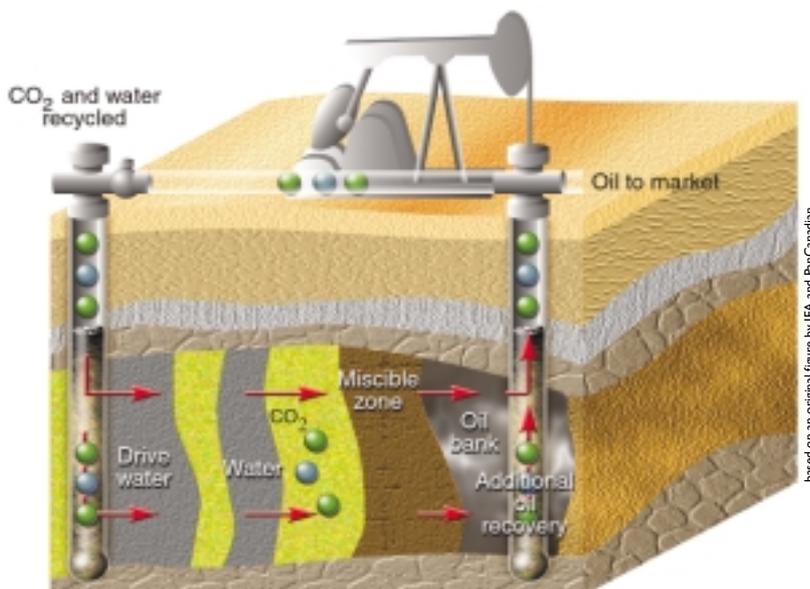
CO₂ stored underground over several thousand years is extremely important for assessing the viability, integrity, and performance of geosequestration sites over the long term. In some parts of the world — mainly volcanic regions — CO₂ leaks naturally to the surface. NASCENT will also look at these sites in order to assess the potential impact of CO₂ leakage from any storage site.

Saline aquifer carbon dioxide storage (SACS)

The BGS plays an important role in this industry- and government-funded project which is monitoring the storage of CO₂ emitted from a gas production platform in a saline aquifer in the Sleipner Field under the North Sea. The BGS's role includes relating the seismic image of the accumulating gas 'bubble' to reservoir performance and integrity, and assisting with modelling the geochemistry of CO₂. Saline aquifers offer the greatest potential storage capacity under the North Sea. At Sleipner alone the aquifer has the capacity to receive the annual CO₂ output of 925 coal-fired, or 2340 gas-fired, 500 megawatt power plants for a hundred years.

Reservoir Characterisation

The BGS continues to be involved with various national and international oil companies in solving non-routine reservoir characterisation problems, particularly in the disciplines of petrology, diagenesis, fluid history, geochemistry, mineralogy, rock mechanics, high resolution stratigraphy/biostratigraphy and seismic anisotropy. Demand from industry for assistance is a reflection of the BGS's world-class analytical and laboratory facilities and the ability of BGS staff to apply specialist expertise gained in non-hydrocarbon activities.



Weyburn: cartoon of the CO₂ enhanced oil recovery process. 5000 tonnes of CO₂ are delivered to Weyburn each day from a coal gasification plant. The CO₂ is injected into the oil reservoir. The extra oil produced will increase the life of the field by 25 years as well as reducing life-cycle emissions of CO₂ by 30% compared with conventional oil.

GESTCO: to sequester the annual CO₂ emissions from a 4000 megawatt coal-fired power station using biomass would require planting a forest 100 by 320 kilometres. After 70 years the forest would have to be cropped, stored permanently and replanted. Geosequestration offers a more secure and verifiable alternative, without any land-use conflicts.



BGS © NERC

Reservoir characterisation: co-existing pale brown oil and colourless water inclusions in a fracture cement — the microscopic 'tell-tale' signs of hydrocarbon potential. The history of fluid movement through a reservoir can sometimes be deciphered through analysing microscopic droplets of geofluids that remain trapped in the rock.



T. Shepherd, BGS © NERC

Lands and Resources

Geological Survey of Northern Ireland

The Geological Survey of Northern Ireland (GSNI) is an office of the Department of Enterprise, Trade and Investment (DETI). It is staffed by BGS scientists under an agency agreement which allows GSNI to draw on expertise in other parts of the BGS.

1:50 000 Map Series

Compilation of the geological linework for the Ballymena area was completed. The sheet has been approved for publication early in the next financial year. The revised edition of the geological map of the Ballycastle area in a style suitable for the tourism industry is nearing completion. Compilation work on the Maghera, Lisnaskea, and Dungiven sheets, and fieldwork on the Dalradian geology of the Newtown Stewart area continued. The revision of the new, restyled version of the *Guide to the Regional Geology of Northern Ireland* is nearing completion. Detailed collaborative studies of the Dalradian in northern Britain and Ireland now involve geologists from the GSNI, the BGS, universities and the Geological Survey of Ireland (GSI). The project is focused on the structure and lithostratigraphical correlation between Scotland and Ireland. New avenues of research include detailed analysis of the sedimentology of key sequences and the petrology, geochemistry, and cathodoluminescence of meta-igneous and metacarbonate marker horizons. A field meeting in Donegal provided a forum for the discussion of new data and for agreement on future collaborative work.

Earth Sciences Conservation Review

The GSNI continued to fulfil the Earth Science Conservation Review under contract to the Environment and Heritage Service (E&HS) of the Department of the Environment for Northern Ireland. This project involved the identification of geological sites throughout Northern Ireland with a view to having them designated as Areas of Special Scientific Interest (ASSI). A network of sites that demonstrate important aspects of the structural history of Northern Ireland have been identified and incorporated into a synthesis of the geological evolution of Northern Ireland. E&HS funding has enabled the NIGL to undertake uranium–lead geochronology of a suite of Caledonian igneous rocks from the Midland Valley Terrane of Northern Ireland. New dates indicate rapid post obduction emplacement closely related to the development of igneous complexes associated with an Ordovician arc system.

Hydrogeology

Funding for the GSNI is provided by Environmental Protection Division (EPD) of the Environment and Heritage Service in conjunction with the BGS to continue its hydrogeological advisory service. This work has focused largely on the implementation in Northern Ireland of the EU Water Framework Directive in January 2001. This legislation necessitated planning for the introduction of new procedures for groundwater protection and abstraction monitoring. A proposal to develop a phased programme of hydrogeological work over the next three years has been accepted by EPD.

Landscapes from Stone

This is a Cross Border project jointly operated with the GSI with the bulk of the funding being supplied by the EU Special Support Programme for Peace and Reconciliation. Its aim is to provide resource material and promote landscape-related tourism in the northern Twelve County Region of Ireland (Northern Ireland and the six border counties in the Republic of Ireland). Under the brand name 'Landscapes from Stone' the project produced seven Drives



© GSNI

GSNI, BGS, GSI and university researchers investigating the sedimentology of Dalradian rocks in Donegal. Collaborative field workshop organised by Dr Mark Cooper and lead with Dr Barry Long (GSI).

Leaflets and three Walks Packages. A comprehensive digital quarry directory was produced giving detailed information on quarry locations and commodities within the Twelve Counties.

Minerals promotion and development

Databases of mineral occurrences, minerals and petroleum licence work reports, regional geochemistry, and quarry information were updated and continue to form a valuable data resource for potential explorers. The GSNI represented DETI at the annual convention of the Prospectors and Developers Association of Canada in Toronto and shared a joint display with the Department of the Marine and Natural Resources (Exploration and Mining Division) representing the Republic of Ireland. The potential for gold mineralisation around the margin of the late Caledonian Newry Granodiorite Complex were identified by a geochemical reconnaissance programme undertaken in collaboration with BGS staff. In addition to the existing licences, applications for four new mineral exploration licences were received by DETI.

Petroleum exploration: promotion and development

This year was one of contrasting fortunes for licensees in the two main petroleum exploration play areas in Northern Ireland. The GSNI monitored the final phases of the work programme for the last remaining active licence over the Antrim Plateau and assessed the technical merits of an application for a new licence in East Antrim. In the Carboniferous 'tight gas sand' play in the southwest, the GSNI liaised with the licensees as they worked towards an exploration drilling programme. GSNI staff presented a review of the petroleum exploration scene onshore Northern Ireland for the Irish Branch of the Petroleum Exploration Society of Great Britain.

Information systems and database development

The GSNI continued with its programme of digital capture of geological map data and index level geoscience database development. Significant advances included the acquisition of digital versions of the 1:250 000 scale Quaternary, Hydrogeology, and Groundwater Vulnerability maps of Northern Ireland and the digitisation of a suite of 1:50 000 scale geological maps. The DIGMAPNI programme will continue next year with the geological attribution and verification of maps from the GSNI 1:50 000 map series. Database developments included the delivery to the Health and Safety Executive (NI) of a browser for the Northern Ireland Shafts and Adits database and design work on enquiries, downhole geology, and petroleum exploration databases. Map-based indexes to a range of GSNI data-sets were published on the World Wide Web via the BGS Geoscience Data Index (GDI).

The Resource & Environment Survey of Ireland (RESI)

The proposed RESI project aims to provide total geochemical and airborne geophysical coverage of the whole island of Ireland, and will be the largest single advance in geology in Ireland. The project is supported by the GSNI, GSI, BGS, and the United States Geological Survey. The final funding has yet to be agreed but it is hoped that parts of the project will be commissioned in the near future.

The joint GSNI/Exploration and Mining Division stand at the 'Prospectors and Developers Association of Canada' conference in March 2001, Toronto.



© GSNI

Advisory Service

Demand from government departments, companies, and education for earth science data and advice remained buoyant throughout the year. Developments in the GSNI databases and geographical information systems (GIS) have streamlined the process by which clients are provided with borehole and other site-specific data. The GSNI continued to advise the Planning Service in Northern Ireland under the terms of a service level agreement. This work involved making geoscientific inputs at strategic, regional, and local level. The GSNI contributed to decision making in planning policy, minerals planning, and environmental impact assessment for a range of developments. GSNI continued to advise the DETI exploration licensing programme with a range of geological data enhancement and promotional activities in support of their statutory regulation of the minerals and petroleum licensing regime.

Environment and Hazards

Groundwater Systems & Water Quality

This programme is built around Core Programme activities and has been defined in consultation with a wide variety of UK and international organisations, including the Environment Agency, UKWIR, English Nature, Water Companies, and the Centre for Ecology and Hydrology, as well as the academic community. Internationally the programme works with DFID, WaterAid, Oxfam, Save the Children Fund, and other NGOs involved in international development as well as international development banks. The BGS is a WHO Collaborating Centre and a UNEP GEMS Collaborating Centre. The GS&WQ programme comprises about 50 projects: several of which are described here and on pages 42–45.

Mathematical hydrogeology

The aim of the project is to maintain and develop expertise in the numerical modelling of groundwater flow and the movement of pollutants. A report has been completed on the development of radial flow modelling software, which was created to support major aquifer studies. The report describes the construction and validation of a two-dimensional radial flow model. A prototype recharge model has been created with the aim of linking the calculation of a soil moisture deficit model with spatial data held in a Geographical Information System (GIS). A comparison of different solute transport codes was undertaken to aid the understanding of the application of sorption mechanisms to modelling contaminant transport. A novel, coupled geochemical reaction and groundwater flow model (PHAST) was trialled as part of this work. Other highlights include the sponsorship of an M.Sc. project investigating the interaction of a chalk aquifer with a tidal river. A paper presented by the M.Sc. student, Simon Mathias, was runner-up in a young authors competition held by CIWEM. Further promotion of groundwater modelling was undertaken in a seminar held to disseminate the results of a joint BGS–Environment Agency project to develop an object-oriented groundwater flow code. Held at BGS Wallingford, this meeting involved an invited audience of BGS, Environment Agency, water industry, and consultant-based hydrogeologists and groundwater modellers. The seminar was well attended and the potential benefits of object-oriented groundwater modelling was appreciated by the audience.

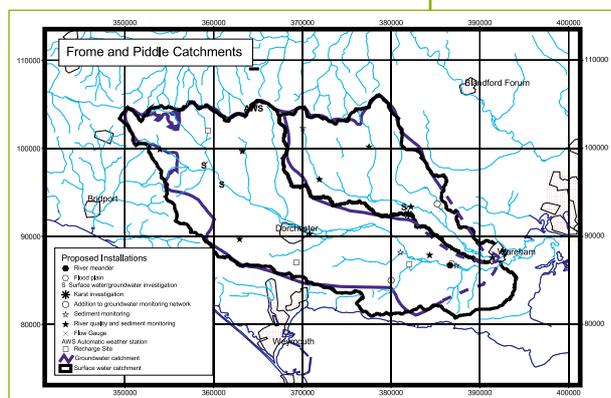
National groundwater survey

This core activity of the programme continued with the regional studies of the hydrogeology of the Chalk of Yorkshire, Lincolnshire, the North Downs, and the Wessex Basin, together with the initiation of a study of the hydrogeology of the Sherwood Sandstone in the Midlands. Regular meetings were held with Regional and National advisory panels in order to promote collaboration and ensure that the products are focused on the user. This project interrelates closely with other projects described here (such as LOCAR and BASELINE) as well as data management projects (WellMaster and DGSM), and projects being undertaken by the Environment Agency and water companies.

Lowland Catchment Research (LOCAR)

The NERC Lowland Catchment Research (LOCAR) Thematic Programme has been designed to gain improved understanding of the hydrological cycle at the catchment scale by addressing the following issues:

- What are the key hydrological processes controlling surface water-groundwater interactions and the movement of groundwater in lowland catchments?
- What are the key physical, chemical, and biological processes operating within the valley floor corridor that affect the surface water and groundwater?
- How do varying flow regimes control in-stream, riparian and wetland habitats?
- How does land-use management impact on lowland catchment hydrology, including both water quantity and quality, and on wetland ecology?



LOCAR: proposed new infrastructure to support the LOCAR Thematic Programme in the Frome and Piddle catchments of Dorset. Some of the material contained in this plot has been reproduced from an Ordnance Survey map with the permission of the Controller of Her Majesty's Stationary Office. © Crown copyright.

- How can the hydrological, hydrogeological, geomorphological, and ecological interactions resulting from natural or anthropogenic changes be predicted using integrated mathematical models?

LOCAR focuses on two pairs of catchments on the Chalk and one catchment on the Permo-Triassic sandstone. The BGS and CEH (Wallingford) are responsible for the technical and scientific aspects of the installation of infrastructure for the LOCAR Programme. This includes revision geological mapping in the three catchments and an extensive drilling programme of more than 70 boreholes totalling some 4000 metres in length, of which 2800 metres are planned to be cored. Detailed logging and sampling of the cores and boreholes will follow.

BASELINE UK

The baseline quality of aquifers in England and Wales is being studied as part of a joint project with the Environment Agency. The aim of the project is to form a basis for defining water-quality status and standards in the UK and to provide a quantitative basis for the definition of groundwater pollution. A total of 36 study areas and reference aquifers have been selected for detailed study and will be used to provide a scientific foundation to underpin UK and EU water-quality guideline policy. A Europe-wide BASELINE project is described on page 44.

Critical period groundwater yield study

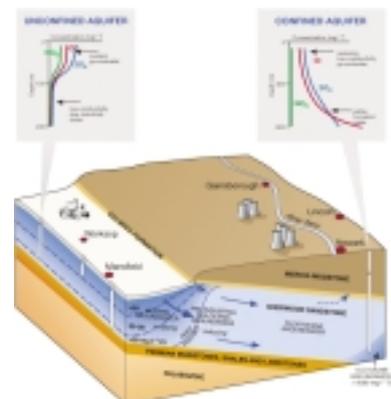
The ability to assess the yield available from surface and groundwater sources is an essential part of water resource and operational planning, and in particular it is important to be able to assess source yield under drought conditions. Prediction of source yield is made more difficult by uncertainties associated with future climate change scenarios. The BGS has been assisting W S Atkins in a project funded by UK Water Industry Research Ltd (UKWIR) and the Environment Agency, which has the aim of improving methodologies for predicting groundwater source yields from boreholes under future drought conditions. Groundwater source yield is dependent on a range of factors, including groundwater level, and the BGS has investigated the relationship between historical rainfall and groundwater level at a number of sites. Historical groundwater level records held by the BGS in the National Groundwater Archive at Wallingford have been used with Environment Agency rainfall records to produce calibrated groundwater hydrographs. When these are combined with predictions of future rainfall trends, estimates of future groundwater levels can be made, including return periods for annual groundwater level minima. Hydrograph calibrations have been performed for a range of aquifers, including the Chalk, the Permo-Triassic sandstones, and the Jurassic limestones, on boreholes with a wide geographical spread. Results indicate that annual minimum groundwater levels in the Chalk of south-eastern England are likely to be more susceptible to future changes in rainfall than the Triassic sandstone aquifers of the Midlands and north-west England. Although typical annual groundwater level minima are not expected to change significantly for the range of climate change scenarios investigated, changes in the seasonality of rainfall events and increased year-on-year variability in rainfall may lead to more frequent groundwater droughts.

Groundwater flooding at Water Street, Hampstead Norreys in the Pang catchment on the Berkshire Downs, February 2001.



BGS © NERC

BASELINE UK: three-dimensional distribution of water quality in the East Midlands Triassic sandstone of Nottinghamshire. Modern groundwater, with pollution indicators, migrating downgradient. High-quality natural fresh water occurs in this aquifer although some natural salinity starts to be found at depth.



BGS © NERC

Environment and Hazards

Earthquake & Forensic Seismology

Rapid access to data from the UK seismic network and magnetic observatories is used to provide a wide spectrum of users in government, industry and academia with information on earthquakes and magnetic storms. Research into advanced seismic methods for application in the oil industry helps to improve reservoir imaging and management.



National Earthquake Monitoring: map of the felt effects of the Warwick earthquake, 23 September 2000, magnitude 4.2 ML. The contours show the European Macroseismic Scale intensities.



National earthquake monitoring: servicing one of the seismometer stations on the Eskdalemuir seismic array which provides data for monitoring the Comprehensive Test Ban Treaty.

National Earthquake Monitoring

Seismic activity is monitored and interpreted, with rapid dissemination of information to the public, government bodies, non-governmental organisations, and other clients. The project is co-funded through a broad customer base including the Department of the Environment, Transport and the Regions, the Health and Safety Executive, the Welsh Assembly, and representatives of the nuclear, oil, and water industries. Data from the 146-station UK seismic network are provided to neighbouring countries through exchange agreements, and to international agencies for research and seismic hazard assessments. The data are also used within the nuclear test ban monitoring system to determine the seismic response of UK geology. September saw the largest earthquake in the UK in 2000. It was centred on Warwick, had a magnitude of 4.2 ML and was felt up to 150 kilometres away. The earthquake caused widespread alarm but no damage. In total, there were 11 earthquakes felt on land and one offshore in the Bruce field. Overseas, the highest profile earthquakes occurred in El Salvador and India with casualties estimated at 800 and 10 000, respectively. Media interest was high for these and the UK events; some 200 interviews were given including 22 for television and 41 for radio broadcasts. Strong university links were maintained, including research collaborations with Bristol, Leicester, Brunel, Leeds, and Cambridge universities.

Calibration of the UK for forensic seismology

Forensic seismology is the technique of monitoring nuclear test ban treaties through seismic detection and identification of underground explosions. The BGS operates the UK National Data Centre, under contract to the Atomic Weapons Establishment (AWE) interacting, on behalf of the UK, with the Comprehensive Test Ban Treaty Organisation (CTBTO) International Data Centre (IDC) in Vienna, which provides data from a global network of sensors, including seismometer stations, for test ban monitoring. IDC event bulletins are assessed, and events of particular interest examined, by BGS seismologists using IDC and BGS seismic data. The UK provides the IDC with data from a multi-station seismic array at Eskdalemuir, designed to detect small seismic signals, which is also operated by the BGS. The CTBTO requires calibration data, such as local seismic velocity information, to allow seismic events to be located accurately. The BGS has the responsibility to provide this data for the UK region, and is collaborating in this work with several British universities. The BGS also works with AWE Blacknest and the CTBTO on data analysis and the provision of software to improve signal resolution, and on data communications via satellite and the Internet.

National Geomagnetic Service

Improvements continued to be made to operations at the three UK geomagnetic observatories, with data communications via the Internet and ISDN lines allowing processing in Edinburgh on a ten-minute cycle. The Atlantic Ocean observatories, in the Falkland Islands, Ascension Island, and Sable Island, continued to work reliably and provide data for global geomagnetic field models. The BGS plays a leading role in INTERMAGNET, an international project to improve geomagnetic observatory standards and data communication, and acts as a World Data Centre for observatory and repeat station data. The Geomagnetism Information and Forecast Service (GIFS) giving online information via the Internet, has seen

& Geomagnetism

a steady growth in its use. Co-funding from a number of organisations with a direct interest in geomagnetism supports the project. The Ordnance Survey publishes magnetic information on maps derived from a regional model. The Ministry of Defence and a consortium of oil companies support global data collection and modelling efforts. Oil companies require near real-time information on short-term geomagnetic field changes caused by electric currents in the upper atmosphere to process survey data collected while drilling wells. Information on geomagnetic storms is important for the electricity industry, and the BGS has been working with Scottish Power to provide a geomagnetic prediction and monitoring service, with information supplied directly to the grid control room.

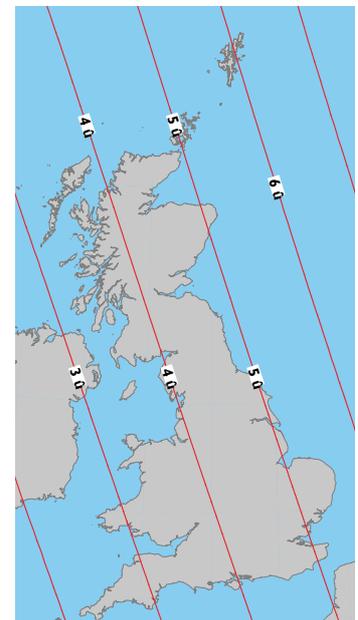
The Edinburgh Anisotropy Project

Research into how seismic waves travel through anisotropic and inhomogeneous rocks continued with the support of a consortium of oil operating and service companies which has co-funded the project for thirteen years. Fundamental advances were made, enabling improved reservoir imaging through the application of efficient algorithms to implement the new results. The ideas were validated by demonstrating the improvements in imaging achieved by re-processing datasets, supplied by the industry sponsors, for three offshore oilfields. Other research highlights included investigations into the possibility of using low-frequency seismic waves for sub-basaltic imaging, which is a problem hampering oil exploration in some new frontier areas, and attempts to determine rock type and the type of fluid contained within rock fractures from seismic data. Instrumentation, by the oil industry, of the ocean floor is improving the quality of seismic data and, increasingly, more repeat seismic surveys of fields are being carried out. By comparing seismic images of the reservoir at different times during the production process, fluid flow and structural changes in the reservoir can be monitored. This research into 'time-lapse seismicity' will help to plan future drilling to drain reservoirs efficiently.

Environmental monitoring

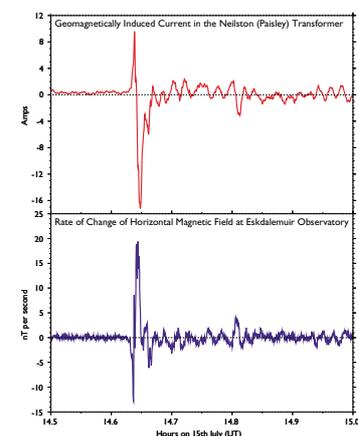
Sensors monitoring a range of environmental parameters were operated at five sites in Scotland throughout the year. The data recorded at these remote sites are continuously transmitted through UHF radio links to regional collecting nodes, which then relay the data to a central collection centre in BGS Edinburgh for analysis, dissemination to users, and archiving. Parameters measured include air and ground temperature, humidity, wind speed and direction, solar and nuclear radiation, and concentrations of pollutant gases (sulphur dioxide, ozone, and nitrogen oxides). Collaboration with the Meteorological Office has enabled the integration of a standard automatic weather station into the system. The infrastructure provided by the seismic network sites offers the possibility of monitoring a range of environmental variables in rural locations across the country at relatively low cost by co-locating environmental monitoring systems. The systems have been designed to be entirely compatible with the UK seismic network data logging and transmission technology. Ease of access to data is a requirement of the modern research community and to meet this requirement software allowing users direct access to data recorded at the remote field sites has been developed. This web-based package can be installed on any PC connected to the Internet and data from any sensor can be viewed graphically or stored digitally for future analysis.

National Geomagnetic Service: in July 2000 magnetic north was to the west of grid north by the amount shown.



S Macmillan, BGS © NERC

National Geomagnetic Service: Geomagnetically Induced Current (top) compared with Magnetic Field Variation (bottom) during the 15th July 2000 magnetic storm.



A W P Thomson, BGS © NERC

Environment and Hazards

Urban Geoscience & Geological Hazards

The aim of this programme is to provide information on, understanding of, and solutions to, problems with ground conditions and land quality, particularly in urban areas. These include the likely occurrence of geological hazards, ground instability and voids; identification and sterilisation of mineral and groundwater resources; geotechnical and engineering characteristics of rock and soil formations; past land use and the distribution of artificial ground; contamination and pollution; the legacy of mining; waste disposal; flooding; damage to SSSIs and sites of archaeological interest.



A H Cooper, BGS © NERC

Karst hazards GIS: subsidence crater caused by the dissolution of Permian gypsum at the village of Sutton Howgrave, North Yorkshire. Collapse started in December 2000, the photograph was taken on 14th February 2001 when the hole was five to six metres in diameter and 11 metres deep with water at a depth of eight metres.

The karst hazards Geographical Information System

Soluble (or karstic) rocks, which include salt, gypsum, chalk, and limestone, can dissolve to form caves and a special landscape (karst) prone to subsidence or difficult engineering properties. Knowing where these hazards are, and how they behave, is important for planning, construction, and insurance purposes. Furthermore, understanding the behaviour of karstic systems is important for modelling aquifer behaviour, vulnerability, and groundwater flow. It is also important for the assessment of dissolution rates (and related subsidence rates) in the very soluble rocks such as salt and gypsum. The karst hazards GIS allows the digital capture of map and database information about features such as subsidence hollows (dolines), springs, stream sinks, and building damage.

Geophysical–geotechnical property relationships

The BGS is carrying out long-term research into the characterisation and prediction of physical properties and behaviour of the rock mass and superficial deposits using innovative non-invasive geophysical methods. Relationships have been developed between geophysical properties and moisture content, one application to embankment stability being presented to the Railways 2000 conference. Similar laboratory and field studies have begun to assess the resistivity and shear-wave relationships of brickearth deposits in Kent as a function of moisture content (in collaboration with the Universities of Nottingham Trent and Birmingham). These reworked aeolian deposits consist of a complex ‘open-bonded’ arrangement of silt-sized quartz grains and clay minerals. This grain fabric is critical in controlling their engineering behaviour when loaded under changing moisture conditions. Intraparticle porosity, such as ‘dead-end pores’ within recent carbonate-rich sea-floor sediments have been predicted by combining resistivity and acoustic measurements with simulations of electric current flow in 3D pore spaces (in collaboration with US Navy scientists). 3D numerical modelling techniques have been developed to improve our estimation of geophysical properties from non-invasive surface measurements and are also being applied to enhance predictions of flow within faults and fracture zones using standard downhole logging data (co-funded by Enterprise Oil and undertaken in collaboration with Leicester University).

Engineering geology of the Lias Group

A BGS research report on the Mercia Mudstone has recently been published and follows the report on the Gault Clay. Data analysis and reporting on the Lambeth Group and Quaternary brickearth deposits — the latter being undertaken in collaboration with the Nottingham Trent University — are also due for completion in the near future. Acquisition of Lias geotechnical data from selected high-quality site investigation records across the country has been completed, and the borehole logs geologically annotated according to current stratigraphical nomenclature. Lias data from over 2000 site investigation boreholes (amounting to over 8000 ‘samples’, each with a suite of geotechnical parameters) now form part of the BGS’s geotechnical property database. The Lias project investigations and sampling programmes are being carried out in concert with other related BGS core programme research studies. These include the assessment of shrink–swell characteristics of UK clay/mudrock formations, and new work to investigate the effects of weathering processes on the material, geotechnical, and hydrogeological properties of principal lithologies in characteristic ‘weathering domains’ across the UK.

Detection of mine shafts

Identifying natural cavities and abandoned mine shafts is important in urban planning. Improved thermal infrared remote-sensing techniques can be applied to detect the surface-temperature anomalies associated with ground disturbed by cavities and mine shafts that have hitherto remained unmapped. Using a former mining area on Baildon Moor as a test case, the work has involved two key activities. Firstly, the identification of potentially unmapped shafts by comparing the location of temperature anomalies on a thermal image with mine shafts located on field survey maps and aerial photographs. Secondly, ground surveys to confirm the thermal anomalies coincident with mapped and unmapped mine shafts by geophysical investigation techniques. A coincidence of geophysical and thermal anomalies could be proved as an unmapped shaft by soil stripping. Many mapped mine shafts produced significant thermal anomalies and some significant geophysical anomalies. Thermal anomalies not associated with mapped mine shafts produced some small geophysical anomalies such as those coinciding with areas of standing water.

Urban geoscientific survey of the Swansea–Port Talbot area

The survey aims to present data relevant to the issue of contaminated land in a GIS format that can provide planners and technical specialists with improved insight into the location of potential contaminant sources and pathways at a city scale. The survey area has a legacy of heavy industries, notably in diverse metal manufacturing, which may be associated with contamination of soils and groundwater. The survey is identifying potential contaminant sources by assessing current and former land use and relating this to the nature and thickness of artificial deposits proved in site investigation records. The mineralogy of the artificial deposits is being assessed using a rapid field-based tool, the Portable Infrared Mineral Analyser. The presence and saturation of contaminants is revealed from geochemical data collected from the BGS G-BASE programme and site investigation reports. The study aims to determine characteristic ranges of heavy metals in different natural superficial deposits and for artificial deposits associated with diverse industries. The research is improving the understanding of the 3D geometry of the geology, which along with collation of hydrogeological and hydrological data, will permit a regional understanding of contaminant pathways. The project is investigating application of a hazard-ranking system to provide a semi-quantitative characterisation of these pathways.

The urban water regime in Manchester

New geo-environmental data have been gathered in Manchester, such as information on water levels, infiltration rates, surface sealing, and soil type to try to understand the controls on shallow groundwater variability within an urban environment. This is being combined with more traditional BGS data, such as surface geology and 3D models of superficial deposits. The demand for groundwater vulnerability assessments in urban and industrial areas will increase as Local Authorities begin to carry out their responsibilities under the Contaminated Land Act Part IIa regulations and the European Union water framework directive. The new water regime information brought together by the research in Manchester will be a valuable source of information, for example, in the prioritisation of development sites.

Engineering geology of the Lias Group: Blue Lias Formation, Lyme Regis, Dorset. Reconnaissance and sampling visits have been made to several key Lias locations in the UK.



Peter Hobbs: BGS © NERC

Urban water regime: in times of increased flooding, integrated information will assist in understanding urban water pathways. The picture shows flooding of a recent urban development in Nottinghamshire, November 2000.



Caroline Adkin: BGS © NERC

Environment and Hazards

Pollution & Waste Management &

This programme currently employs over 30 multidisciplinary geoscientists with a wide range of experience in geochemistry, risk assessment, hydrogeology, remote sensing, geophysics, mining, mathematical modelling, radiochemistry and geomicrobiology. It specialises in the investigation of pathways that control exposure to, and the migration of, pollution resulting from hazards such as land contamination, leachates, pollution plumes, and gases in the shallow subsurface and from deeper, engineered disposal facilities.

Radiometric surveys

A thorough review of environmental radioactivity projects has led to the definition of a new project that improves integration with related BGS work on radon protective measures, airborne surveys, and geological mapping. Ground follow-up of airborne radiometric surveys was undertaken with support from an M.Sc. student and a Commonwealth post-doctoral fellow. Relatively high levels of natural radioactivity have been found associated with colliery spoil heaps, fly-ash tips at coal-fired power stations, and the waste products of a disused iron foundry site. An initial ground appraisal of higher radioactivity levels associated with the Marlstone Rock Bed was also carried out as part of a small multidisciplinary project. Digital capture into a rugged palmtop computer of radioactivity measurements from a field-portable instrument and positional (GPS) data was evaluated. As a result, the acquisition software has been improved and should now cope with maximum data rates. The BGS automatic gamma-ray core logger was upgraded to allow logging of sediment cores up to three metres in length to provide a detailed analysis of radionuclides in the core with depth.

Environment and health

An outline work programme was produced, largely shaped by the priority research needs identified by other agencies. This will help to guide the BGS in the application of geochemistry for a better understanding of the impacts of environmental contaminants on human health in the UK. This year saw the production of a major monograph for the World Health Organisation on depleted uranium, reviewing its geochemical behaviour in the ground and its radiological and toxic properties. Another review was focused on arsenic and molybdenum. The BGS continues to belong to the Bioavailability Research Group Europe (BARGE) initiative, a European network organisation led by the National Institute for Public Health and Environmental Protection (RIVM) in the Netherlands. It brings together institutes and research groups to study the human bioavailability of priority contaminants, such as lead, cadmium, and arsenic in soil, through uptake via the gastroenteric tract. The first aim of BARGE is to compare and evaluate different systems and models developed to estimate bioavailability and contaminant exposure. A Geographical Information System (GIS) has helped to identify areas of Central Eastern Europe affected by excessive amounts of fluoride in drinking-water as part of this EC Inco-Copernicus project.

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Natural attenuation of chiral mecoprop

The phenoxyacid herbicide, mecoprop, is 'chiral' — it exists as two mirror image forms (enantiomers) which have identical chemical and physical properties, but which behave differently in biological systems. Studies have shown that the enantiomers biodegrade at different rates and, consequently, any change in the enantiomeric ratio is an indication of natural attenuation. In order to understand how mecoprop behaves in the Lincolnshire Limestone aquifer, the enan-

courtesy of Prof Vlaslav Povozroznik, Institute of Gerontology, Kiev, Ukraine.



Environment and health: the brown pitting and staining of teeth indicative of dental fluorosis caused by high dietary fluoride intake.

Extraction Industry Impacts

tiomers and their stable carbon isotope ratios have been studied along a flow path from a landfill which has received up to 40 tonnes of mecoprop. Within the methanogenic and sulphate-reducing zone in the waste, the mecoprop is still racemic — i.e. it contains equal concentrations of the two enantiomers, suggesting that no degradation has occurred. In the iron- and nitrate-reducing zones of the landfill plume, the concentration of (S)-mecoprop exceeds that of the (R)-mecoprop, but in aerobic conditions the ratio reverses. Associated changes in ^{13}C were slight and inconclusive. As a preliminary conclusion, it appears that changes in the enantiomeric ratio hold important information on the natural attenuation of mecoprop within zones of different redox conditions in the aquifer.

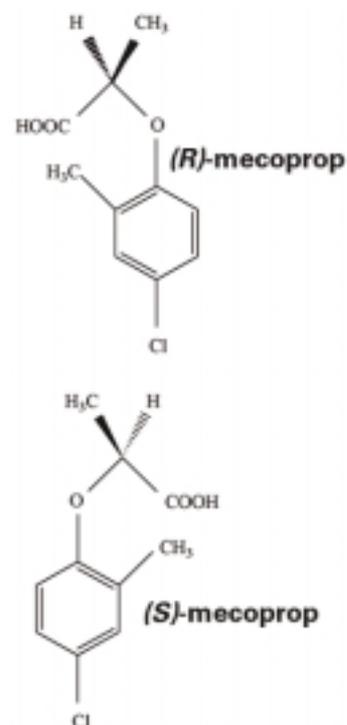
Estimation of PRA parameters and risk methodology

A review of some commonly used environmental and human health risk assessment schemes and models has been carried out. The resultant report considers three categories: qualitative and semi-quantitative hazard-ranking schemes; quantitative risk-assessment models; and groundwater flow and contaminant transport models. The emphasis was on examining the different data requirements of each model and the extent to which these can be met by datasets currently held by the BGS. Risk assessment models of the future will have greater integration of model functions — such as linking environmental and human health risk assessment packages — and have improved treatment of uncertainties through probabilistic methods. The Values for Environmental Risk Assessment by Multivariate Statistical Methods project (VERASTATS) has been started. This new venture has been designed to derive transport and sorption parameter values for different UK soils and rocks by applying multivariate statistical methods to basic index properties.

Transport and fate of heavy metals from mines

Three main areas of investigation have been pursued during the year, with the bulk of the work focused on south-west England and the abandoned tin mining areas. A study was carried out to construct a Geographical Information System (GIS) for a small area south-east of Redruth, Cornwall. The GIS contains information on mine locations attributed with mineralogy, geology, and mineralisation and in the future will contain a Digital Terrain Model (DTM) and remotely-sensed hyperspectral data. Mine shafts were also digitised from the 1:10 000 standards and an algorithm developed to plot mine shaft density per square kilometre. This feature might prove useful in future land-use planning. A detailed site study was carried out at Devon Great Consoles Mine. Copper was originally mined here, and subsequently arsenic. The latter was processed on site to produce arsenic oxide by roasting arsenopyrite. Over seventy soil samples were collected from waste rock piles, tailings, and the surrounding area. Arsenic values ranged from 350 to 44 000 milligrams per kilogram and are distributed log-normally with a mean of 7000 milligrams per kilogram. Work is in progress to assess the bioavailability of the soil arsenic. A small study was carried out in Upper Weardale in the Northern Pennines to scope the transport and fate of mining-derived cadmium. Samples of soil, tailings and waste rock, vegetation, and sheep excrement were collected to assess the retention of cadmium by sheep around a small, abandoned mine site.

Natural attenuation of chiral mecoprop: the two enantiomers of mecoprop.



Transport and fate of heavy metals from mines: derelict Brunton arsenic condenser at Devon Great Consoles mine. Elevated levels of arsenic were found in soil samples taken at the site.



Environment and Hazards

Coastal Geoscience & Global Change

The aim of this programme is to understand past and present patterns of erosion, transport, and storage of sediments (and associated materials) in order to predict and better manage future change.



A Jarrow, BGS © NERC

Futurecoast: the naturally eroding cliffs at Covehithe, Suffolk, one of the most rapidly retreating sections of coast in England.

Futurecoast

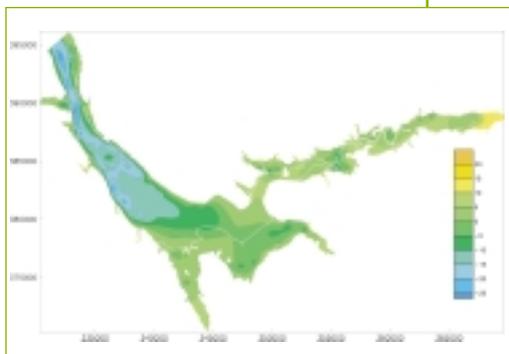
A particular weakness identified in many of the Shoreline Management Plans (SMPs) for England and Wales was the lack of understanding of long-term coastal change. To address this issue, MAFF commissioned a consortium led by Halcrow, and including the BGS and Risk and Policy Analysts, to undertake an outline study. The specific objectives are: to undertake a prediction or estimation of coastal evolution over the next 100 years; to assess the sensitivity of these predictions to a set of standard potential climate-change scenarios as produced by UKCIP; and to allow contemporary coastal processes and past, present, and future management decisions to be placed within a longer-term and wider-scale framework providing a vision for the coast and a scientific basis for sustainable strategic management. This study will provide an appreciation of long-term evolution of the coast, based upon a nationally consistent approach. It will consider the extent of change expected and likely variability in the predictions made. The overall purpose is to provide a sound scientific baseline and comprehensive framework from which to develop the second round of SMPs. This will be used to guide appropriate coastal defence management and development planning, ideally feeding into the preparation and revision of all such plans.

Coastal and estuarine evolution

As the UK's coastline is put under ever-greater pressure from the often conflicting demands of residential property, commerce, leisure, and conservation, there is an increasing requirement for more sensitive and cost-effective solutions to the issue of coastal change. Future sea-level rise and forecasts of climate change mean that there is a need for the environmental pressures and the coastal responses to these pressures to be better understood in order to aid the planning process. This project, to examine the Holocene evolution of the UK Coastal Zone, is being expanded over a variety of timescales from decades to millennia to improve our understanding of the long-term processes which drive coastal evolution, and to enhance the prediction of the future response of the coast to various scenarios of environmental change. Innovative and transportable methodologies and conceptual models of coastal evolution are being developed particularly in the fields of coastal erosion and sediment budgets, estuarine geomorphology, relative land-level changes, and coastal flood risk.

Carbon dynamics

While atmospheric concentrations of CO₂ and terrestrial carbon sinks (living biomass) draw most media attention in the debate on pollution and the greenhouse effect, sediments form the most important store for carbon by far. A new project 'Geological Controls on Carbon Dynamics in Oceanic and Terrestrial Systems' will undertake a scoping study to assess the relative global importance of the three main forms of carbon storage in sediments: organic carbon and kerogen, carbonates, and methane clathrates. The relative importance of marine shelf and deep-water environments as carbon sinks will be evaluated, and the potential impacts of climate change (sea-level and temperature changes) on the marine carbon stores will be assessed. An overview of the carbon cycle in which the carbon fluxes between sediments, the sea and atmosphere, and the living biomass will be explained in a popular BGS publication. The scoping study also aims to provide estimates of the size of



BGS © NERC

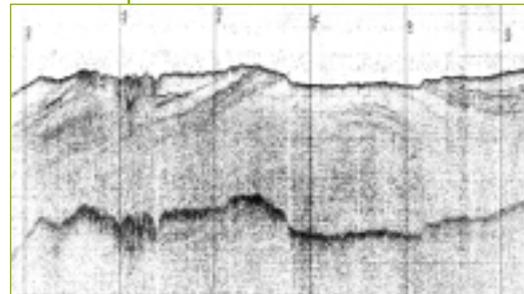
Coastal and estuarine evolution: a Digital Terrain Model of the base of the Holocene sediments in the Mersey Estuary.

carbon stores and fluxes which can be used to calibrate the models of the NERC Earth Science Modelling Initiative.

Inshore sea-bed characterisation

The nearshore zone, out to 20 kilometres offshore, is a dynamic environment in which the elements of wind, wave and tide combine to erode, transport, and deposit sediment. A considerable amount of geoscientific data available in this zone around England and Wales is being brought together in a common format. A report was produced on the Thames Estuary sector between Dungeness and the Deben Estuary, completing the coverage of this project from Flamborough Head to Portland Bill. The use of geological data in coastal and marine habitat mapping, a field of growing interest to government and conservationists, continues to be developed through collaboration with CEFAS Laboratories and a report was completed for DETR. A report was also completed for CEFAS on sampling and survey methods for a DETR project on monitoring sea-bed rehabilitation after aggregate dredging. GEOSYNTH, an EU INTERREG II project, extends the themes of the inshore sea-bed characterisation across the Dover Straits and this project continued in association with the Bureau de Recherches Géologiques et Minières.

Inshore sea-bed characterisation: south to north seismic section from the Shoreham area showing structures in Tertiary rocks (vertical fix lines 500 metres apart, depth between multiples about 35 metres).



BCS © NERC

Estuarine contamination

As the first phase of a systematic survey of contaminants in major UK estuaries, an extensive sampling programme has been undertaken in the Mersey Estuary, from the mouth upstream to the outskirts of Warrington. In the inner estuary, upstream of Garston, the sedimentary fill is largely exposed at low tide and a hovercraft has been used to gain access to the intertidal sand and mudbanks, where over 150 shallow sediment cores have been collected. Cores have also been taken on foot in the intertidal parts of the outer estuary, whilst the subtidal areas have been sampled using a Day grab from a survey vessel. Analysis for a range of organic and inorganic contaminants is under way. This will be supplemented by detailed mineralogical, sedimentological, and age-dating studies.

Cliff stability

This project contributes to cliffed coast stability zoning by detailed examination of the role of landslides in 'soft rock' cliff recession, and hence in coastal erosion generally, and will be based on modelling of geotechnical and oceanographic factors. Terrestrial morphological and submarine bathymetrical data will be combined to produce continuous profiles at six sites around England's east and south coasts. These cover a wide variety of lithology and types of active instability. The relation of the project data to established and new cliff recession models will be examined. A key aspect of the project is 'time lapse' 3D modelling of cliffs and beaches at key sites of active landslide movement using a long-range laser scanner. This determines the loci of thousands of points on the cliff face and beach which are combined to form an accurate 3D model of the cliff. Currently, coastal landslide activity is particularly high as a result of unprecedented rainfall.

Cliff stability: scanning of cliffs to access movement. Key sites of active landslide movement, e.g. in Dorset, Norfolk, and Yorkshire, are the subject of 'time lapse' 3D modelling using a long-range laser scanner.



P Hobbs, BCS © NERC

Information Services and Management

Information Management

This programme is responsible for the management of all data and information within the BGS. Its scope extends to all the digital databases, paper archives, and material collections, including the fossil collections. The aim is to manage the information in a coherent and integrated manner for the benefit of BGS scientists, industry, and the citizen.

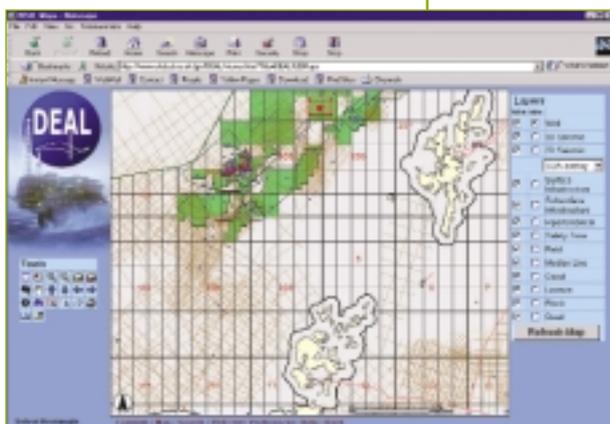
Information about key resources — groundwater

The BGS is the custodian of the national collection of groundwater data, and this significant data-set is receiving increased attention. The BGS holds paper archives and digital data about more than 100 000 water wells and boreholes, water levels, and the physical and chemical properties of UK aquifers. These data are being integrated with other data-sets as part of a strategy for improving access to groundwater information. Groundwater data are collected under several BGS programmes, other data are provided by third parties under provisions contained within UK Water Resource Legislation. To improve access to hydrogeological information, data from paper records are being entered progressively on to the WellMaster database, which supports a range of applications to provide data to environmental regulators and the water industry. 25% of the water borehole data held for England and Wales, and more than 60% of Scottish data have been digitised, and the BGS has entered into an agreement with the Environment Agency to accelerate data entry and provide Agency staff with access to WellMaster. Monthly hydrological summaries, on paper and on the Internet, are produced in partnership with the Centre for Ecology and Hydrology, providing a synoptic overview of the state of river flows and groundwater levels across the UK. These summaries generate significant media interest during extreme hydrological events — the serious flooding during the 2000/01 winter being one example.

Information about key resources — energy

The Digital Energy Atlas and Library (DEAL) is a web-based GIS system that promotes and facilitates access to data and information relevant to offshore exploration and production of hydrocarbons on the UK Continental Shelf. The DEAL web site is the result of a BGS commission from CDA, a wholly owned subsidiary company of the United Kingdom Offshore Operators Association, and stemmed from a joint oil industry and DTI initiative called PILOT.

There are three aspects to DEAL: iDEAL, uDEAL, and eDEAL. iDEAL provides access to a complete and reliable reference set of basic cultural spatial data, and will become the definitive web site for the UK Oil Industry and DTI for this information. The data-set includes well positions, licence data, details of offshore hazards and locations of pipelines. uDEAL provides a comprehensive catalogue of data products associated with GIS spatial layers, and represents a web-based marketplace for data users and vendors alike. Vendor catalogues are mapped to the DEAL data model, so that their products can be linked to specific spatial features. eDEAL will act as a portal to a network of distributed data repositories, so that data users can place orders and download the data. Identification of data products by GIS or by forms-based searches will provide DEAL subscribers with dynamic access to vendor databases accessible on the Internet.



BGS © NERC

Example view from the Digital Energy Atlas and Library.

Rock, mineral, and fossil collections

Control of all the individual BGS collections of rocks, minerals, fossils, and borehole core has been centralised to form the National Geoscience Materials Collection. Significant donations

during the year included the Seager Collection of rocks and related samples from the Lizard Peninsula, and the collection of Nirex drillcore, thin-sections, and documentation. Notable additions by BGS scientists included an exceptionally well-preserved Silurian conodont assemblage (the mouth-parts of an early Chordate) from the Moffat Shale Group of the Southern Uplands of Scotland. Development of the new palaeontological database, PalaeoSaurus, has begun, and data from two separate legacy databases will be imported. PalaeoSaurus has been extended to include fossil identifications, citations, and other key information. Stratigraphical information is linked to the BGS Lexicon of Named Rock Units, allowing more complex searches to be carried out. The importance of collection conservation has increasingly been promoted, and continuous environmental monitoring of storage areas has started. Work has commenced on formulating curatorial policies and procedures for managing the collections, and these will be developed in conjunction with an external collections advisory committee, recently appointed from several of the UK's major museums and institutions.

Understanding BGS digital data

The digital database system is a crucial component of the BGS information strategy. It stores not only geoscientific data but also digital indexes to non-digital records. A considerable amount and variety of information is already held within the database. To facilitate understanding of this wealth of information, the BGS has built a detailed digital inventory. The inventory itself also forms part of the digital database and, because it is used to describe other data, this additional information is known as 'metadata'. The qualified term 'technical metadata' is used to distinguish the information from other forms of metadata. Technical metadata provide highly-detailed descriptions of all database elements (such as tables, views, indexes) that are components of the BGS corporate digital data holdings. The technical metadata team has introduced the concept of the 'databank', which is an aggregation of various database objects (tables, views, indexes, triggers, procedures) that serve collectively to describe a homogeneous geological data-set. Currently, access to information about more than 70 databanks is provided through the BGS Intranet.

Using BGS digital data

The Intranet Data Access (IDA) system is a web-based tool, providing scientists with ready access to a wide variety of geoscience data over the BGS Intranet. This user-friendly interface to the existing corporate geoscience databases provides users with input, retrieval, and other data management facilities. The IDA replaces and integrates the former functionality of several legacy applications. Provision of an integrated and consistent Intranet interface to a number of data-sets has brought several benefits, including the facility to emphasise links between related data-sets, and thus improve data combination and exploitation. The availability of a large corporate data access system of this type also encourages conformance with corporate policies. The web-based application architecture reduces the maintenance previously required by the several legacy applications. The intuitive web interface minimises the training resources required to familiarise users with the system, and opens access to important BGS data-sets to any staff member with a desktop web browser, whether using a PC, a Macintosh workstation, or a UNIX machine.

Using a 'man-up' fork lift truck to retrieve a pallet of core boxes in the Keyworth core store.



Tim Cullen, BGS © NERC

Photomicrograph (cross-polars) of ophitic clinopyroxene in gabbro. North side of Glen Kinlock, Rum (S97001). From the National Geoscience Materials Collection.



Emrys Phillips, BGS © NERC

Information Services and Management

National Geoscience Information Service

The NGIS programme is responsible for the delivery (internally and externally) of BGS data, knowledge, and information. Activities managed and operated under this programme are the BGS Library, Enquiry Service, Sales, Intellectual Property Rights (IPR), Electronic Dissemination of Information (EDI), Public Understanding of Science (PUS), and the Digital Geological Map of Great Britain (DigMapGB).

The BGS Enquiry Service

The Enquiry Service handled 14 000 commercial enquiries during the year. Commercial income grew by 20% over the year in response to an improved and more widely available service. Over £430 000 of commercial income was earned, more than covering the costs involved. The Enquiry Service also dealt with over 20 000 enquiries from the public and academic communities. The infrastructure and efficiency of the Enquiry Service was improved with a new network of enquiry teams and contacts across the BGS. New communication and enquiry recording systems were put in place and a central tracking and recording database was completed during the year, to further improve monitoring of enquiries. Significant investment was made in raising the profile of the Enquiry Service within the geoscience community. New pages were created on the BGS web site, explaining where to find data, information and advice within the BGS. A UK-wide advertising campaign was begun in the Yellow Pages.

DigMapGB

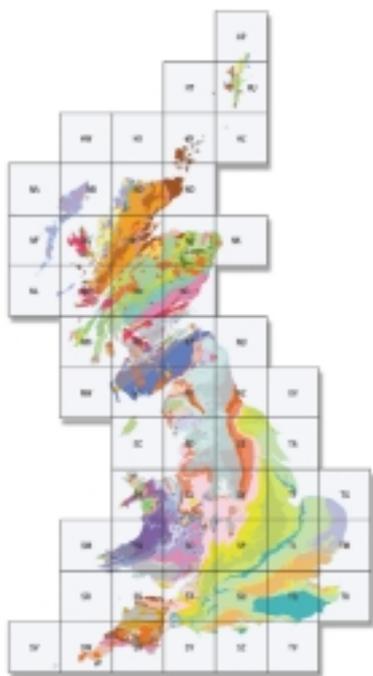
The purpose of this project is to prepare nationwide digital geological map data in vector GIS format at a range of scales. Of the available 1:50 000 scale map tiles, 95% were completed for England and Wales, and 36% for Scotland. DigMap50 is now providing the prime reference set of geological map data. All the map sheets have been reviewed and the nomenclature revised so that each geological unit has an approved up-to-date lithostratigraphical name. DigMap50 tiles are not simply digital copies of the published map face; many errors and omissions have been corrected and some new linework imported. Five new tiles in East Anglia have been especially compiled from old 1-inch-to-the-mile data. An external agency was used for the digitisation of about 20% of the 1:50 000 maps. There is an increasing demand for 1:10 000 scale data (DigMap10), especially in urban areas for contaminated land issues, but also in rural areas, as in the recent foot-and-mouth disease outbreak. There was also enhancement of the DigMap250 database, with addition of some offshore 1:250 000 scale Solid, Quaternary, and Sea Bed Sediment data, prepared to meet customer demand.

Sales

This has been a year of planning and development for sales in BGS. The outbreak of foot-and-mouth disease which devastated tourism in the UK during 2001 made any increase in sales of the BGS publications — aimed at geologists, walkers, and tourists — extremely difficult. However, the Tourists' Rock, Fossil and Mineral Map of Great Britain published in June 2000 is easily the best-selling BGS publication to date and continues to do well. Major plans are under way to re-launch publications and widen our markets — not just for printed publications but also for the range of services such as customised reports and digital data sales. These plans include strategies to raise the profile of the BGS and increase general awareness of our activities and publications by securing as wide a coverage as possible for reviews of BGS publications and increasing the numbers of suitable industry-based web sites with links to the BGS main web site.

Library

Progress has been made with the implementation of GEOLIB, the web-based catalogue to the Library's holdings. The database is being populated with a range of material, both new and old,



BGS © NERC

DigMapGB: Solid geology data coverage at 1:250 000 scale, showing the standard 100 by 100 kilometre grid tiles.

in a variety of formats. Over 125 000 records are already included. Preparatory work on indexing articles from the core UK geological serials is under way. New archival record standards are being investigated with a view to including the archives holdings list in GEOLIB using the formats laid down in EAD and ISAD standards. Courses have been arranged to train BGS users in the GEOLIB system as part of the BGS Training Programme. Digital content of the Library resource has advanced significantly during the year with desktop access becoming available to a number of serial publications.

Intellectual asset management

Priority has been placed on enforcing the BGS's rights under current Intellectual Property (IP) legislation and associated EU directives. The Intellectual Property Rights (IPR) section offers general guidance on IP matters and continues to advise staff and external parties on the terms and conditions relating to the use of BGS materials. The number of such requests continues to rise. Convincing staff that their ideas and materials are a valuable tradable asset that merits protection is important and awareness-raising activities include: ad hoc advice, information sheets, copyright clinics, workshops, and presentations. It is equally important to reinforce to external parties the need to apply for permission before using BGS's materials. The IPR Section had a modest expansion in its staff complement and these extra resources helped to achieve an increase of over 50% in income generated from data licences and copyright permission fees. Enquiries about digital data increased significantly resulting in the issue of many more digital data licences. On average over 80 copyright and other IPR related documents are being processed each month. Requests for permission to use images from the BGS's National Archive of Geological Photographs (now viewable on the BGS web site) continue to be received from national and international publishing houses, educational users, charities, universities, researchers, professional associations, training establishments, private individuals, promotional companies, television, and other media. The IPR Manager represents BGS on the NERC Best Practice Network and commissioned work has been undertaken advising international commercial scientific businesses about IPR.

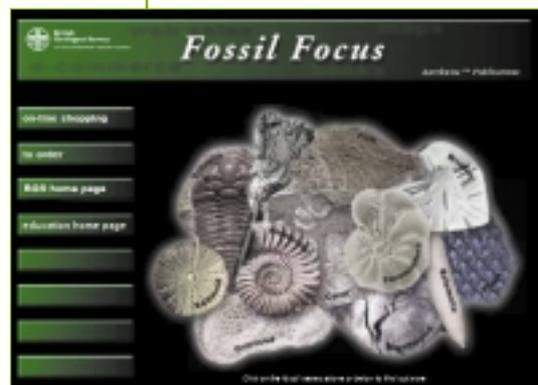
Electronic Dissemination of Information (EDI) project

The main BGS web site has been radically overhauled to reflect changes within the organisation and to provide a modern, professional design. To reduce maintenance of the site, many sections are now dynamically generated. The relaunched site comprises several new sections, including GeoData, Reference, Education, and GeoPortal areas. The site is in a continual state of growth, increasing the information on BGS holdings available to external visitors. A new BGS report management system has been implemented to manage the Survey's extensive report series. Over the coming year, more reports will become available to view and download from the main web site. In April 2000, the Survey launched a commercial web service enabling visitors to purchase BGS products online. The BGS Internet Shop is the first online commercial venture by any geological survey in the world. Sales from the commercial site have been steady and it is hoped to expand the site in the future to offer additional types of information, principally access to BGS digital information.

Public Understanding of Science

The BGS promotes the earth sciences generally and publicises its work to as wide an audience as possible. Activities aimed at a public audience included a series of evening classes on the theme Geology and the Environment. This was the tenth season of lectures held in collaboration with the University of Nottingham and is an accredited course leading towards a certificate of higher education. An introductory evening class in geology was held on behalf of the Workers' Educational Association. The BGS also participated in national and regional events such as National Science Week, the Earth Alert Festival of Geology, and Scottish Geology Week. Presentations on the work and history of the Survey and guided tours of the BGS sites are regularly given to community groups. Schools liaison activities include the provision of information on geoscientific careers, work experience placements, and Nuffield Bursary studentships.

EDI: a page from the new Education section of the relaunched BGS web site. The web site helps to raise public awareness of the earth sciences by providing free access to geoscientific information.



Information Services and Management

Publications Production

The Publication Production programme produces by modern digital cartographic, GIS and desktop-publishing methods the maps, books, reports and other publications which result from the Core Strategic and Commissioned Programmes. Outputs are delivered in both digital and hard copy format. Publication Production is a major contributor to the BGS digital data holdings, particularly DigMap. It also operates the BGS photographic service.

Cartographic Services

Cartographic Services has continued to publish maps at a variety of scales over the past year including the following:

- 22 new 1:50 000 scale maps printed or released as print-on-demand with a further nine started during the year.
- One new 250 000 scale map printed.
- Three new 1:1 000 000 scale Gravity Anomaly Maps released as print-on-demand with a further two started during the year.
- A poster-style map showing the building stones used around the UK has been completed; and will be printed and available during the summer of 2001.

More digital information is being made available at a variety of scales:

- Digital information at 1:50 000 scale has been rapidly extended with 300 tiles out of 360 for England and Wales now complete and a further 61 out of 186 Scottish tiles available (18 of which contain Solid geological information only).
 - Progress with capture of data at 1:10 000 resolution has also increased with 11 new tiles becoming available during the year.
 - The 1:25 000 scale BGS Mineral Assessment Map Series has been vectorized and is now available for use in GIS format.

There has also been cartographic support to overseas projects, with eight geological maps and 28 geochemical maps under production for Morocco, and a further six geological maps for Zambia.

Reprographic and Print Services

Reprographic and Print Services meet the reprographic needs of map and book production, photography, remote sensing and other sections of the BGS. Services include high-resolution scanning, film plotting, and colour proofing. The section also manages the print facility and provides print-ready data and artwork for all types of BGS publications. Significant advances were made in digital reprography with introduction of a wide format scan-to-print system (replacing the dyeline copying facility), and outsourcing the printing that had previously been carried out on an in-house litho-print machine. These advances provided major health and safety benefits to the operation.

Photographic Services

Photographic Services provides a range of services including studio and location work for scientific reports, web pages, and presentations. During the year the De la Beche conference centre was extensively refitted with modern audio-visual facilities. The NERC aerial photography archive was transported to the BGS Keyworth office for management within a dedicated facility. Three photographers were awarded Licentiate status to the British Institute of Professional Photographers.



BGS © NERC

Tourist map with examples of Holiday Geology Guides and new Sheet Explanations published in 2000/01.

Book Production Services

Book Production Services continued to produce a range of formal reports and popular publications throughout the year, including the following:

- Four memoirs representing a comprehensive description of the geology of areas or districts.
- Three Sheet Descriptions and three Sheet Explanations as accompaniments to the map sheets.

In addition several commissioned research and special publication titles were produced:

- Five litho-printed Technical Reports.
- One Regional Geochemistry Atlas.
- Four magazines/journals.
- Four annual publications.
- Four Holiday Geology/Tourist Guides as part of the Popular Publication series.

PDF versions of many of the titles listed above were produced as Internet downloads or as an accompaniment to the hard copy book. Book Production has also been involved in producing the templates for Research Reports which are now available on the BGS Intranet.



Regional geochemistry of Wales and part of west-central England: stream water and Memoirs for the Kirkcudbright, Birmingham, and Lowestoft areas, published during 2000/01.

Photographic Services operate modern, professionally-equipped studios to provide high-quality photographic images. A broad range of subject matter is encompassed from meticulous records of scientific material, such as type fossils, for academic publications, to creative and abstract images for magazine covers.



Caroline Adlin, BGS © NERC

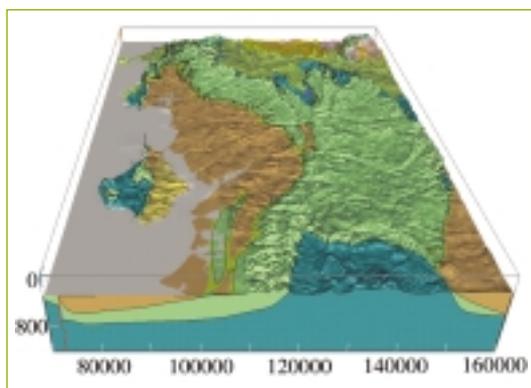
Aerial photograph of Ailsa Craig, composed of a distinctive microgranite and source of the stones used in the game of curling. Photographic Services maintains the National Archive of Geological Photographs, which contains over 100 000 images dating back to 1891.



Andrew Christie, BGS © NERC

Information Services and Management

DGSM and GeoHazarD projects



Gary Kirby, BGS © NERC

The Digital Geoscience Spatial Model: block models (above and below) representing the Wessex Basin in three dimensions. The model above shows a three-dimensional view, looking west, of the geology. Created using EarthVision®.

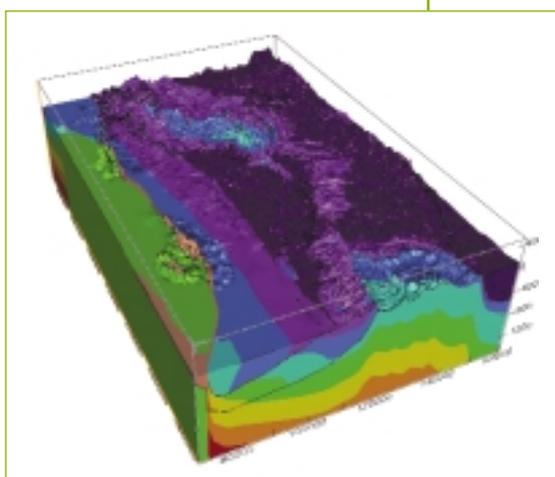
Digital Geoscience Spatial Model (DGSM)

The Digital Geoscience Spatial Model (DGSM) project has been established to develop a system for collating and capturing information and for ensuring that it is available over the World Wide Web. The year 2000/01 was the first of a five-year project, funded by the NERC Science and Technology Board. The funding is matched by ongoing modelling projects within the BGS, the output from which will be co-ordinated to ensure compliance with the emerging DGSM standards.

The understanding of earth science is greatly enhanced by the ability to visualise earth models in three-dimensions. Computers can bring these models on to people's desktops by providing detailed pictures in real-time.

A range of information is associated with such models, describing and qualifying them: this information will include descriptions of the rocks comprising the models, their geotechnical and hydrogeological properties, and information on the way in which the model was constructed and its reliability. The DGSM project is developing a system — a three/four-dimensional framework — to store, analyse, and provide this information. Structured and consistent data will allow the BGS's customers to identify and access the information that they require. Procedures used in modelling are being evaluated and described.

A 'Geoscience Large Object Store' is being established for storing model files. This consists of a database for a wide range of types of model, together with index information that conforms to corporate standards. Because the data contained within it will be application-specific, a parallel database is being designed to deal with spatial data in a form that is shareable with other software packages. The applicability and benefits of a range of three-dimensional modelling software are being assessed and methods for applying 'mark-up' language codes to digital text files that will enable users to select text on particular themes are being tested. Applications are being developed that will allow users to access the complex of information in as simple and intuitive a manner as is possible. Software is also under development to allow borehole geological data and completed models to be visualised over the Internet.



Chris Evans, BGS © NERC

The Digital Geoscience Spatial Model: a block model of the seismic velocity of the Wessex Basin in three dimensions for the same area as the geological model (top). Created using EarthVision®.

In order to ensure that the structures and procedures the BGS are developing are realistic, pilot studies are being carried out to build models for a range of geological environments. These include south-east England, with an initial focus on the Chalk; the Midland Valley of Scotland, with its emphasis on the coal-bearing formations; the Cheshire Basin, which is a deep Permo-Triassic structure with potential for hydrocarbons, minerals, and groundwater; the offshore Atlantic Margin, representing the frontier area of hydrocarbons exploration; and the Humber Estuary, with its active coastal processes and Quaternary succession.

GeoHazard

The public's understanding of the effect of ground conditions on the safety of their property, and the implication for the value of their property, is growing. At the same time, local councils are under increasing pressure to provide environmental information. These factors have led to an increase in public and commercial need for information about geological hazards.

The most pressing need is the identification of areas with a potential for ground movement or contamination. The presence of such unrecognised hazards may lead to financial loss by developers, householders, or local government. Once the hazard is recognised, these costs could include increased insurance premiums, the devaluation of house prices, and engineering works to stabilise land or property. However, if the hazards are unrecognised, the cost of stopping and repairing a ground failure could be much greater than its prevention and, in a worst case, could include injury or death.

The Geological Hazard Data (GeoHazard) project will provide data that can aid the identification of potential geohazards to the human environment and improve the BGS's responses to geohazard enquiries. It will accelerate the production of some strategically important geological hazard data layers for Great Britain.

The project objectives are:

- To create a number of Great Britain-wide digital geohazard data-sets.
- To make these data more easily available to the public and commercial customers.
- To prioritise the data according to their usefulness for land assessments in regard to geohazards.

The intermediate and end-product data-sets include: drift thickness, man-made ground, historical Ordnance Survey maps, hydrogeological characterisation of geology, radon, mass movement, natural subsidence, mining-related hazards and scanned copies of all 800 000 BGS borehole logs and reports.



GeoHazard: data layers will include natural and man-made geohazards such as landslides, contaminated land from industrial processes and landfill, natural and mining-related subsidence, and potential radon emissions.



Geoscience Resources and Facilities

Geoscience Resources & Facilities

The role of the Geoscience Resources and Facilities Directorate (GRFD) within the new BGS management structure is to ensure that adequate human and physical resources are available to the Science Directorates to enable them to deliver their scientific programme, and to develop scientific capability. Scientific staff are managed and deployed between four Heads of Discipline covering the areas of Geology, Geotechnics, and Palaeontology; Geophysics and Marine Geoscience; Geochemistry, Mineralogy, and Hydrogeology; and Information Systems. A separate Head of Discipline is responsible for administration and finance staff.

The work of GRFD has resulted in increased flexibility in deploying staff and building appropriate teams to meet the challenges of the new scientific programme. A new database system was developed to monitor bids for staff time and to track changes to allocations. As a result, there was significantly less staff 'down-time' than in previous years. Gaps in the skills base were addressed by 'new-blood' recruitment of 27 staff during the summer of 2000; the buoyant external job market, especially in relation to potential recruits with IT and geophysical skills, means that this exercise will have to be repeated annually. The new arrangements allow for improved career development for staff, and specific procedures have been installed for induction training and mentoring during the initial stages of a person's career with the BGS.

Training and Career Management

Heads of Discipline work closely with Training and Career Management to identify the training and development needs of staff, and to develop appropriate training courses in response to the changing scientific and business requirements of the BGS. Preparations are under way for a reassessment, in July 2002, of our Investors in People status in line with the recently revised Standard. A series of fortnightly lectures was launched, with speakers alternating between BGS staff and distinguished earth scientists from the academic and commercial sectors.

Capital equipment and infrastructure

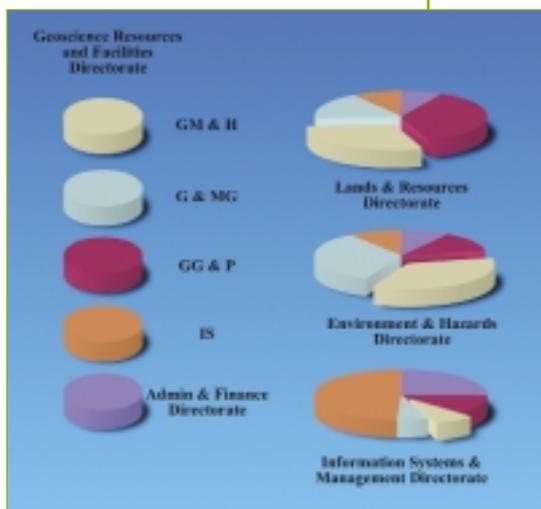
A new five-year rolling programme for capital equipment purchase was implemented and a review of use of office and laboratory accommodation within the Keyworth site was initiated. Centralised management of capital equipment and IS infrastructure (hardware and software) has made best use of resources by avoiding duplication of equipment, developing a maintenance strategy, and establishing corporate standards and systems. Installation of a video link between the main BGS offices resulted in improved communication and a decrease in travel costs.

Development of capability

The GRFD Development of Capability programme was redesigned to carry out scientific research that underpinned the Core Strategic and Commissioned Programmes of the BGS.

Geology, Geotechnics, and Palaeontology

This component of the programme has fostered links and collaboration with the Quaternary Research Association (characterisation and stratigraphy of Quaternary deposits), the Geological Society (peer review of BGS Stratigraphical Framework Reports), and the Natural History Museum (collaboration on web-linked fossil databases). The BGS initiative in Quaternary science was supported through the Quaternary Network which advised on characterisation, mapping methodologies, and Quaternary stratigraphy in collaboration with industry and the academic community. Research in stratigraphy was enhanced through the StratBase project, which underpins the generation, organisation, and dissemination of multidisciplinary stratigraphical information via the World Wide



Chris Wardle, BGS © NERC

Staff deployment, by discipline, across the BGS scientific programmes.

Web, in collaboration with the Stratigraphy Commission of the Geological Society of London. Capability in palaeontology was underpinned through the Determinative Taxonomy Online project which is developing an online taxonomic database of BGS fossil material based on a trial using Cenomanian ammonites and Permian palynomorphs.

Geophysics and Marine Geoscience

Deep-water sampling capabilities have been upgraded, and the BGS oriented rock drill developed to operate at depths of up to 4500 metres. Both the capability and reliability of the five metre rock drill/vibrocoring have been enhanced. Electrical tomographic methods for detection and characterisation of non-aqueous phase liquid pollutants have been developed through NERC URGENT and DTI LINK co-funding. A pilot study to develop new methods for integrating diverse data relating to the physical properties of subsurface rocks has been adopted by the Digital Geoscience Spatial Model project.

Geochemistry, Mineralogy, and Hydrogeology

Emphasis was placed on enhancing capability in environmental mineralogy and geochemistry to support major initiatives within the Environment and Hazards Directorate. The range of trace-level radionuclides that can be analysed has been expanded to include strontium-90 and technetium-99 — both of which are important with regard to licences and release levels in the Irish Sea. A chlorofluorocarbon analysis line has been constructed for 'dating' post-1940s groundwaters, and new methods have been developed for speciating chromium(III) and chromium(IV) and also for recognising microbial indicators of faecal contamination in groundwater. A monitoring network of deposition gauges has been established in Swansea City in partnership with its Environmental Health department, and mineralogical, chemical, and isotopic data on particulates are being integrated with air quality information. Expertise within the BGS on fault and fracture characterisation has been consolidated into a new project to underpin new initiatives in the hydrocarbons, water management, waste disposal, and CO₂ storage sectors.

Information Systems

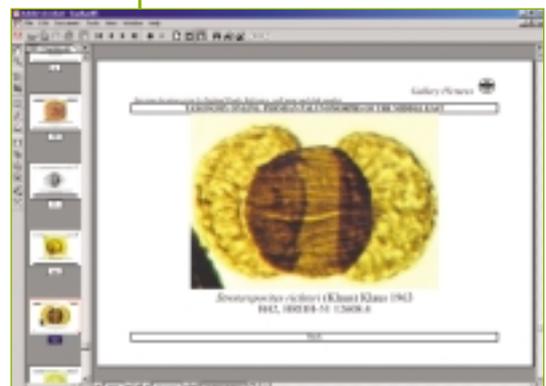
This component of the programme continued to enhance and develop software solutions to support geoscientific research. The first UK Landsat Thematic Mapper mosaic was prepared by the remote sensing project and released as part of the Geoscience Data Index on the BGS web site. Digital photogrammetric techniques were enhanced to cope with more complex structural terrains, facilitating rapid mapping of a larger proportion of the UK onshore mapping programme. A study was carried out jointly with the University of Edinburgh on a rule-based knowledge system for classifying and determining consistent structural domains. Geostatistical simulation and modelling using ISATIS was applied to several datasets on a regional and local scale, allowing probabilistical assessment of field characterisation. User requirement, specification, and preliminary field trials were completed in readiness for field data capture in the onshore mapping programme. More efficient and robust links were developed between GIS and 3D modelling systems, allowing the Digital Geoscience Spatial Model to take advantage of more efficient workflows from field capture of data to final model and map outputs.

Geophysics and Marine Geoscience: the BGS oriented rock drill was recently deployed in its improved form, and retrieved samples of the sea floor near the mid-Atlantic ridge, operating successfully in water depths up to 4520 metres.



BGS © NERC

Geology, Geotechnics, and Palaeontology: online illustration of the Permian pollen *Strotersporites richteri* from the Taxonomy Online database.



BGS © NERC

Geoscience Resources and Facilities

NERC Isotope Geosciences Laboratory

Funded directly from the NERC Science Budget, NIGL's remit is to conduct fundamental and applied research and Ph.D. student training involving isotope measurements for the community of NERC institute and university-supported scientists in the UK. A wide range of projects was addressed in the year including heavy metal, nitrogen, and sulphur pollution in soils and waters, palaeoclimate studies to define variations of environmental conditions in the recent past, U–Pb geochronology for precise dating of geological units and to determine the rates of geological processes, and the development of state-of-the-art methods in isotope analysis.

Sulphur and strontium isotopes in waters from the Worcester Basin help trace the origin of dissolved sulphate

High sulphate concentrations in stream and groundwaters are of environmental and geotechnical concern because of the detrimental effect on concrete structures, particularly motorways. Calcium aluminate phases within Portland cement are converted to calcium sulphur aluminate (ettringite). This process in turn leads to a decrease in the mechanical strength of the concrete. The foundations of the M5 motorway in the Worcester Basin have suffered serious local damage and identification of the cause is of major economic importance. Fertilisers were suspected as a major anthropogenic source. In a joint study, the NIGL and the BGS used strontium and sulphur isotopes to investigate the distribution and origin of sulphate in waters from the Worcester Basin. The results show that the anomalous concentrations may be explained by the potential geological sources in the study area (evaporites from the Mercia Mudstone Group and oxidising sulphides from the Lias Group) without the need for additional anthropogenic sources of sulphate such as fertilisers.

U–Th–Pb geochronology by LA-PIMMS

Building on the NIGL's strong history of U–Pb dating, we have further enhanced the capability using the new laser ablation plasma ionisation multicollector mass spectrometers (LA-PIMMS). Analytical methods were significantly improved by the use of a Tl–U monitor solution during ablation of minerals and standards, and by the incorporation of a common Pb correction. U–Th–Pb dating of either grain mounts or minerals contained in thin section can now be performed on a 30 by 35 micron scale achieving $^{206}\text{Pb}/^{238}\text{U}$ precisions of $\pm 2\%$ for ages as young as 15–20 million years. This capability was applied to the Nanga Parbat Himalaya in Pakistan as part of a NERC-funded grant to study the origin of accessory minerals in metamorphic rocks. The new data show that the Pliocene uplift of Nanga Parbat involved a greenschist facies metamorphism rather than amphibolite facies as had previously been assumed. The amphibolite facies metamorphism contained in the rocks has been proved to be Proterozoic in age, a conclusion that requires significant revision to tectonic models for the Nanga Parbat Himalaya.

Palaeoclimate reconstruction using $\delta^{18}\text{O}_{\text{diatom}}$ from alpine lakes on Mount Kenya

Palaeoclimate records from tropical regions are essential to understanding past changes in the Earth's climate system, equator–pole linkages and the sensitivity of tropical regions to future climate change. In collaboration with the Universities of Lancaster and Swansea, a 14 000 year-long $\delta^{18}\text{O}_{\text{diatom}}$ record has been compiled from two adjacent tarns located on the north-east flank of Mount Kenya. The $\delta^{18}\text{O}$ data correlate with the amount of precipitation rather than with air temperature. The data suggest that anomalously heavy snowfall on the peaks of Mount Kenya associated with high sea-surface temperatures over the tropical South Atlantic and Indian Oceans, as well as El Niño–Southern Oscillation events, may account in part for the neoglacial ice advances dated at greater than 5700, and 3200–2300 and 1300–1200 years ago. Lake-level curves from the East African–South Asian monsoon region support our



courtesy Philip Barker, University of Lancaster

Palaeoclimate reconstruction: Hut tarn on the summit of Mount Kenya.

climatic interpretation of the $\delta^{18}\text{O}_{\text{diatom}}$ data. Environmental changes on Mount Kenya are therefore symptomatic of the same climatic-forcing mechanisms that affected low-altitude tropical areas.

Environmental changes recorded by wheat

Annual samples of wheat grown and collected at the Rothamsted agricultural station since the mid 19th century display a circa 2‰ decrease in $\delta^{13}\text{C}$ values during the past 153 years. However, the pattern of decrease does not match the trend found for the decreasing $\delta^{13}\text{C}$ values of atmospheric CO_2 preserved in the Greenland GRIP ice core. In addition, the carbon isotope discrimination (Δ) computed from the difference between plant and atmospheric $\delta^{13}\text{C}$ values, shows only a poor correlation with major climate variables. The long-term trend of Δ appears to have two distinct phases: from 1845 to the mid-1960s, when Δ for grain was relatively constant; and from the mid-1960s to the present, when the Δ values increased by 1.4‰. We believe that the large change in Δ values is due to a combination of the exponential increase in atmospheric CO_2 concentration (25% during that period) and the limitation in the supply of nutrients (particularly nitrogen). This conclusion calls for caution in simplistic palaeoenvironmental interpretation of $\delta^{13}\text{C}$ values in plant material when the atmospheric CO_2 concentration and/or the availability of nutrients cannot be assessed independently.

Extremely rapid exhumation of Bohemian granulites from the Czech Republic

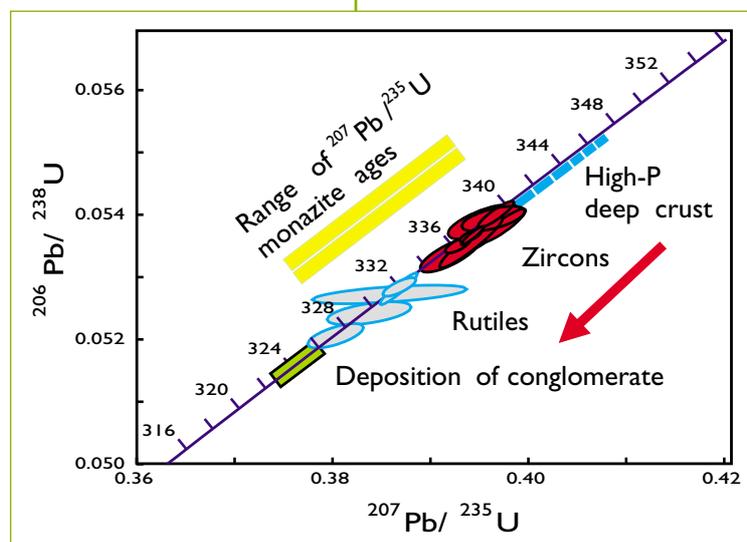
The NIGL completed the final year of a three-year EU-funded project on the Palaeozoic Amalgamation of Central Europe (PACE). In one project with the Czech Geological Survey, cobbles of granulite within a Viséan (circa 325 million years old) conglomerate that overlies the Bohemian massif in central Europe were studied. These are similar to other *in situ* granulites metamorphosed to peak conditions of greater than 800°C and 25 kilometres depth, and suggest rapid erosion. Zircon, monazite, and rutile from several cobbles were precisely dated using the uranium–lead (U–Pb) method. The data indicate that the time duration from peak metamorphism to deposition of these samples in the conglomerate was only a few million years at most, at about 330 million years ago. The denudation rates exceed several kilometres per million years, which requires extensional faulting and tectonic denudation. The resultant denudational rates of up to five kilometres per million years are as rapid as have been documented anywhere in the world, and require an unusual tectonic setting to be invoked at the end of the Variscan orogeny.

Environmental changes recorded by wheat: the archive of agricultural samples at IACR Rothamsted, started 150 years ago, is a unique source of material for long-term soil, plant, and general environmental studies. The photograph shows the changing methods of storage of soil (a–1860, b–1890) and grain (c–1920, d–1990).



courtesy of IACR Rothamsted

Extremely rapid exhumation: U–Pb ages indicate rapid exhumation of Variscan granulites found in a Viséan conglomerate, overlying the Bohemian massif, Central Europe.



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International and Corporate Development

BGS International®

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

Ecuador

A five-year residential Geological Information and Mapping Programme which began in April 1995 was completed. This project was funded by the DFID (ODA), in conjunction with the World Bank for operational costs, and carried out on behalf of the Ministry of Energy and Mines, Ecuador. The remit was to produce a modern, accurate and consistent geoscience database for an area of 35 000 square kilometres covering the entire Western Cordillera of Ecuador. This was primarily achieved through the production of five 1:200 000 scale geological maps and reports, fully compatible multi-element (36) geochemical data-sets/maps, and a GIS-based Minerals Information System. The GIS included information about the geology, geochemistry, geophysics, geochronology, palaeontology, and base and precious metal mines/deposits. This comprises a significant contribution to the understanding of the geology, tectonics, accretionary history, and metallogenic evolution of the Ecuadorian segment of the northern Andes. Research papers have been presented at numerous conferences and published externally. The availability of project data has raised the profile of DINAGE, the counterpart organisation, and attracted a significant level of interest from international mining companies such as Placer Dome, Billiton, Anglo-Gold, IamGold, and Newmont, who have increased their exploration investment in Ecuador. The database also provides a strategic resource for, among other things, resource planning, environmental control and impact assessment, and natural geohazard assessment and disaster awareness (landslides, volcanoes, and seismic risk). Development of an institutional capacity to continue the work programme was an important component of the project. This was addressed through the deployment of local staff in all aspects of the data collection and interpretation programme. On-the-job training and technology transfer through practical courses were also provided, as were formal courses, lectures, and overseas training in the UK.

Montserrat, West Indies

The BGS continued to be commissioned by the Government of Montserrat, DFID, and the Foreign and Commonwealth Office (FCO) to carry out scientific monitoring of the activity at the Soufrière Hills Volcano. This is done through monitoring seismic activity, ground deformation measurements using Global Positioning Systems, gas flux composition, and standard volcanological techniques, including petrography and litho-geochemistry, mapping of deposits, volume calculations, structural analysis, and remote sensing. This information is used to advise the Government of Montserrat and the FCO of the potential risk from the volcano to the population of Montserrat, its infrastructure, and economy.

Zambia

The BGS completed a three-year project for the Zambia Geological Survey Department as part of the world bank-funded ERIPTA project aimed at assisting the Ministry of Mines and Mineral Development of Zambia. There were three main components to the project:

- Regional mapping and geochemical exploration of about 15 000 square kilometres in north-west Zambia.
- Preparation of a modern database and overview of the mineral resources of Zambia.



BGS © NERC

Montserrat: the Soufrière Hills Volcano, September 2000.

- Preparation of modern 250 000 structural geology maps of eastern Zambia showing mineral resources.

Additionally the Zambian Geological Survey Department were provided with new vehicles and equipment, and training for staff. The science component comprised:

- Investigating the Meso- and Neoproterozoic development of Zambia's continental crust.
- Integrating Zambia's Precambrian geology into global reconstructions of Precambrian crustal plates, such as the formation of the Rodinia supercontinent.
- Investigating local and regional controls on base metal and gemstone mineralisation.
- Providing a background stream sediment geochemical data-set for an unspoilt area that can be used to monitor future pollution of surface waters throughout Zambia and especially in its copper belt.

The project resulted in significant improvements in our knowledge of Mesoproterozoic geology, not just in central Africa but in terms of global reconstructions of the major Rodinia supercontinent. A scientific paper based on the work of the project in north-west Zambia has been completed and accepted by an international journal. The geochemical survey in north-west Zambia was the first modern multi-element exploration survey in Zambia and the results will form the basis for detailed exploration in the project area over discovered metal anomalies. The results will also be used as standards for exploration elsewhere in central Africa and to monitor pollution of surface waters throughout Zambia and the rest of central Africa.

Morocco

A project to investigate the regional geology and geochemistry, commissioned by the Moroccan Ministry of Mines and Energy, was completed. The geochemistry project involved the collection of 15 000 stream sediment samples from an area of 15 000 square kilometres and analysis of samples to produce 28 single-element map sheets for five topographic map sheet areas. This was to initiate the geochemical mapping component of the Moroccan 'Plan National de Cartographie Géologique' which has the main objective of increasing investment in the country through mineral exploration. The project work included:

- Determination of the optimum sampling strategy.
- Relating geochemical distribution to the known geology and mineralisation.
- Statistical analysis and interpretation of a large database to identify areas for exploration targets.
- Design of maps to display the results.

A related geological mapping project involved the production of eight geological maps at 1:50 000 scale for three areas in the Anti-Atlas Mountains of Morocco, which are prospective for base and precious metals. A principal aim of the project is to enhance the attractiveness of Morocco to the national and international mining sector. The project employed conventional field surveys in conjunction with remote sensing techniques (aerial photographs, LANDSAT TM and SPOT imagery) and mineralogical, petrological, geochronological, and geochemical analyses of field samples. Geological maps were produced in hard copy and digital format, each map being accompanied by a booklet describing the geology and mineral resources. Digital databases incorporating all types of data will be developed for each map sheet. Moroccan coun-

Ecuador: a large gold nugget discovered in Ecuador.



John Aspreen, BGS © NERC

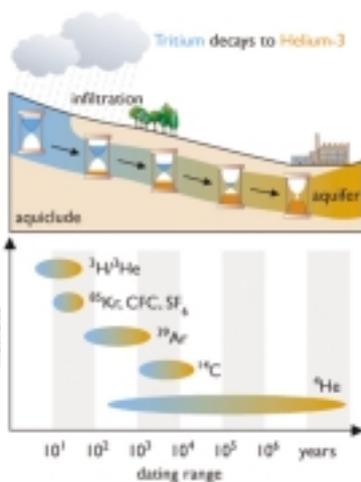
Zambia: emeralds recovered from open pits in the Copperbelt District are a major source of foreign exchange for Zambia. All of the emerald mines are included in comprehensive databases of all of Zambia's mineral occurrences prepared for the World Bank-funded ERIPTA project led by the BGS.



Roger Key, BGS © NERC

International and Corporate Development

BGS International[®]



BGS © NERC

BASELINE EU: the age of water can be determined by measuring relative amounts of parent and daughter isotopes. Different methods, based on isotope and tracer techniques, are used in BASELINE to date waters of different ages.

terpart staff were trained on-the-job and through specialist short-term courses both in the UK and Morocco. The project resulted in major advances in the understanding of the geology, mineralogy, geochemistry, geochronology, and evolution of the Precambrian and Lower Palaeozoic sequences and superficial deposits in the Anti-Atlas region. A complete revision of the Precambrian crustal evolution in the region was made, together with a refined geochronology for the evolution of the Neoproterozoic rocks in Morocco. The type (Gondwanan) Cambrian succession, including basin evolution, sedimentology, and trilobite biostratigraphy have been revised. New insights were gained into the mineralisation of the basement and cover sequences, especially lead–zinc–silver and baryte mineralisation of the north-east Anti-Atlas range.

BASELINE EU

A Europe-wide project assessing the baseline groundwater quality of European aquifers is being undertaken in collaboration with partners from nine countries. Co-funded by the EU, it aims to integrate scientific issues at the European level and to provide a forum for discussion with policy makers and end users. Detailed studies of selected reference aquifers including water quality, timescales of groundwater movement determined using state-of-the-art techniques and trend analysis will be used as a basis for underpinning the EU Water Framework Directive.

Assessing the risk to groundwater from on-site sanitation (ARGOSS)

More than one billion people in the developing world still lack access to safe water supplies and more than 2.4 billion are without adequate sanitation. In the continuing effort to address this situation, water and sanitation are increasingly being provided together and, often due to limited financial resources, as low-cost, shallow groundwater supplies and on-site sanitation. Disposing of excreta to the same ground from which water is abstracted increases the potential for groundwater supplies to be contaminated. Protecting supplies from contamination relies on adequate separation from on-site sanitation. However, existing guidance has tended to be too prescriptive, laying down fixed distances which do not take account of hydrogeological conditions or user requirements. These guidelines are often too conservative for densely populated areas, or allow sanitation too close to groundwater supplies in the more vulnerable environments. Funded by DFID, the BGS along with collaborators in the UK, Bangladesh and Uganda have developed improved guidance in the form of a framework for decision making based on the evaluation of the risks. The guidelines developed are based on easily available data that do not require hydrogeological expertise. They are expected to be useful to all who have a role in the planning of water and sanitation projects.

Low permeability rocks in sub-Saharan Africa

Throughout sub-Saharan Africa, often-scarce groundwater forms the main source of clean and safe domestic water supply for many rural communities, especially during the annual dry season. In many areas the nature of groundwater occurrence and its development potential is little understood. The siting and installation of successful wells and boreholes within the underlying low permeability strata is often difficult. These 'low permeability' areas are being investigated by the BGS



J Davies, BGS © NERC

Low permeability rocks in sub-Saharan Africa: bail test at Mwangundu village borehole Nzega district, northern Tabora Region, Tanzania.

as part of a three-year project funded by the DFID. Simple techniques using readily available equipment are being devised to enable water project staff to realise how groundwater occurs and assess these resources so that they may better inform user communities in these difficult areas. These techniques are being piloted with the assistance of WaterAid and their associated local NGO groups in two areas: the Tabora area of north central Tanzania and the Afram Plains area of central Ghana. In the latter area the hydrogeological potential of the Voltaian sedimentary rocks underlying the Afram Plains is being undertaken in association with DANIDA. At the end of the project, a manual of techniques will be produced for use by WaterAid and other interested NGOs. Detailed reports and maps will also be produced of the two study areas.

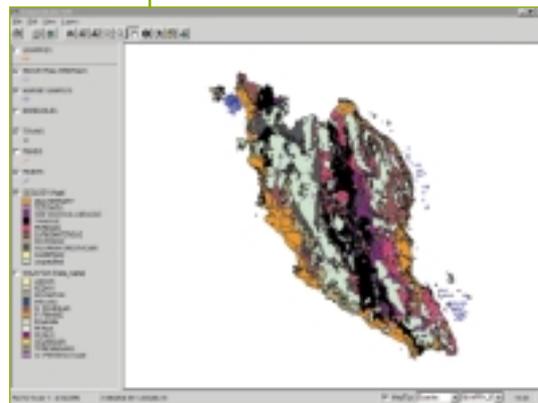
Maximising geoscience data value

This was the last year of this project funded by DFID under their Knowledge and Research (KAR) programme. The aim of the project was to assist Geological Survey Organisations (GSOs) in developing countries to increase the value of their data by using modern information management techniques. The project developed modules covering data management procedures, metadata, data quality, data modelling, database implementation, database population, GIS, and the use of the World Wide Web. The GSOs of developing countries cover a wide range of expertise in information management — from those which are still wholly paper-based and wanting assistance in organising their data, to those with extensive digital databases wanting advice on web dissemination. The project modules were structured to cover this range and the BGS collaborated with the GSOs of Botswana, Malawi, and Malaysia to ensure awareness of the real user requirements. To achieve widespread dissemination and application, a web site was developed. A distance learning based training module was also developed for the web site. This provided introductory and intermediate level training in each module topic.

Assisting small-scale mining in the developing world

The DFID KAR project 'Recovering the lost gold of the developing world' is carried out in partnership with Intermediate Technology Group (ITDG) and has the objective of improving the livelihoods of small-scale gold miners by increasing the recovery of gold and encouraging better environmental practices. In the rainforest of Guyana, where water is plentiful, miners use large sluice boxes and process large volumes of gravel. The perceived problem was substantial losses of very fine-grained gold. Testing of ores and tailings showed that there was actually very little fine gold present and that loss of coarser gold was the problem. In collaboration with a Canadian project, more efficient gold-trapping systems have been introduced and it has been demonstrated that recoveries are improved by over 25%. There is widespread adoption of this more efficient technology. In Zimbabwe, by contrast, artisanal miners use very simple panning and sluicing methods to process small volumes of ore. The poverty and lack of resources restrict the scope for improvements. Advice and training on better practices has been given and a small, simple, but more efficient sluice, with a better gold-trapping system has been designed, fabricated and tested. This is demonstrably more efficient and final efforts to decrease the cost are in progress.

Maximising geoscience data value: the user interface of the demonstration GIS showing geology and sample data for Malaysia.



BGS © NERC

Assisting small-scale mining in the developing world: BGS geologist and technician from the Guyana Geology and Mines Commission advising miners on modifications to a sluice box.



courtesy of Guyana Geology and Mines Commission

Programme Managers

Programme Managers

For more information on the BGS programme, contact the relevant Programme Manager.



BGS © NERC

The Wallingford site.



BGS © NERC

The Keyworth site.

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Health and Safety

Health and Safety highlights

New NERC H&S procedures and guidance

The NERC Safety Management Group (SMG) has issued new Health and Safety guidance and procedures in the light of the new NERC Safety Management Systems. These have been introduced across the BGS and have been well received by staff. They include:

- Health and Safety Project Management Procedures.
- Risk Assessment Procedures.
- Visual Display Unit Risk Assessments and Procedures.
- Manual Handling Risk Assessments and Procedures.

Laboratory safety

A review is under way of all Health and Safety aspects in the BGS laboratories. 'Generic' Risk Assessments and Procedures are also being developed. One of the aims of this project is to improve working conditions and research facilities to meet current and forthcoming legislation. Work is also proceeding to improve the safety of all work machinery on BGS sites to ensure full compliance with the 'Provision and Use of Work Equipment Regulations 1998'.

Office safety

A significant effort has been put into improving workstations and reducing the occurrence of Work Related Upper Limb Disorders (WRULDs) and Musculoskeletal Disorders (MSDs). This has involved the use of our occupational health teams and ergonomic specialists. A project is in hand to prevent MSDs caused by the use of vertical map presses by NERC staff and visitors. Full details of these modifications will form part of our report to the European Agency for Safety and Health at Work. This will, in turn, form part of their report for the next 'European Week for Safety and Health at Work 2002', contributing to their campaign to share good practice within the European states aimed at preventing injuries in the workplace.

Manual handling

A review of all aspects of manual handling across the BGS is ongoing. This follows basic training for staff engaged in manual handling activities and is intended to prevent WRULDs and MSDs. The use of additional mechanical aids is being investigated, e.g. electrically-powered stair-climbing trucks for delivery staff and for IT support staff required to move VDUs and printers across sites, and vacuum lifting devices for the Core Store at Keyworth and Loanhead.

Contractor and vehicle safety

Work is nearly complete on the installation of Fall-Arrest systems for contractors and maintenance staff working on roofs and at heights on the Keyworth site. We are shortly to introduce an induction course for all our main contractors to reinforce the Health and Safety message and standards. Projects are in hand to review the operation of the BGS vehicle fleet, the replacement of older vehicles with those more suitable for modern driving conditions, and staff training for all drivers in basic and advanced driving skills, including Land-Rover on-road and off-road driving, use of trailers, and other 4x4 vehicles used.

BGS staff receiving fire awareness training, one of a number of courses available under the Health and Safety training programme.



Tim Cullen, BGS © NERC

Lathes in the BGS workshops have been fitted with interlocks to prevent machinery being operated without the safety screen in place.



Paul Todd, BGS © NERC

Administration and Finance Directorate

Vital statistics

Personnel

The introduction of the BGS matrix management system in 2000/01 resulted in a change to Personnel's role with the requirement for close interaction with the new Geoscience Resources

and Facilities Directorate (GRFD). This included providing GRFD managers with human resource information relating to career development. Personnel staff were closely involved with the organisation and operation of the regular GRFD meetings and played an important role in supporting the newly introduced system for planning staff deployment under matrix management. The BGS restructuring exercise saw an increase in recruitment to positions identified as essential to the Survey, fulfilling its corporate needs.

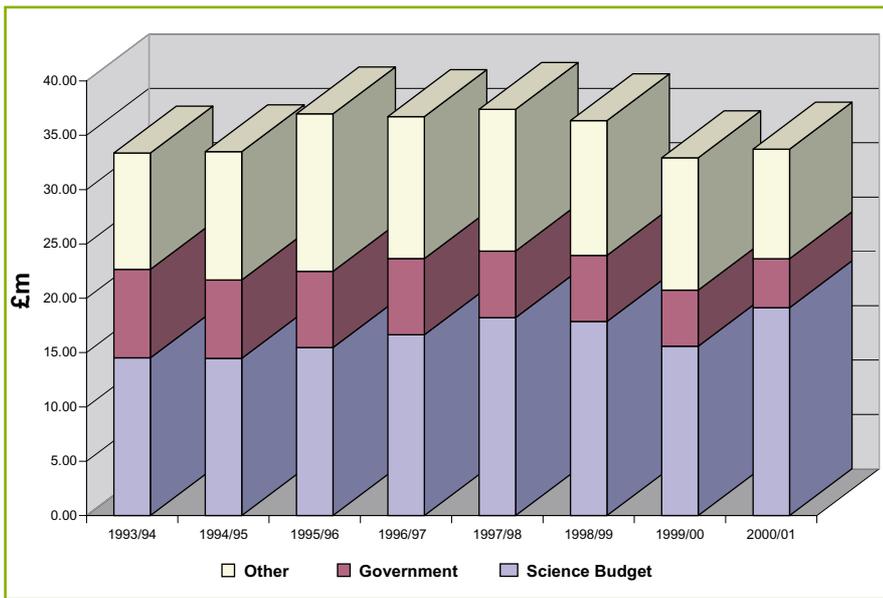
Recruitment policy saw a move away from fixed-term to open-ended appointments. The table (*left*) provides details of the BGS complement as at 1 April 2001. A total of 74 staff have been appointed in the science and IT/IS areas as part of the drive to inject new skills and competencies into the organisation during 2000/01. The recruitment programme also considered longer-term needs as the Survey prepares for

an accelerated level of age retirements as the decade progresses. Personnel staff oversaw the full introduction of new recruitment and training packages, with work commencing on a centralised CV database.

	Science	Non-Science	Total	FTA	O/E	Total
Full Time	462	242	704	90	614	704
Part Time	20	53	73	9	64	73
Total	482	295	777	99	678	777
Male — F/Time	362	127	489	54	435	489
Male — P/Time	5	1	6	1	5	6
Female — F/Time	100	115	215	36	179	215
Female — P/Time	15	52	67	8	59	67
Total	482	295	777	99	678	777

Facilities Management

Two major projects undertaken this year have been the extension of the National Geoscience Records Centre (NGRC) building to accommodate new acquisitions from the Coal Authority and UK Nirex, and an initial study looking at energy efficiency/environmental issues at BGS sites. The project to extend and fit out the NGRC is valued at £1.07M and is on schedule to be completed by the end of summer 2001. The project is being carried out to a very tight timetable and despite some weather-related delays should be completed within ten days of the original completion date. The work will increase the floor area in the core storage hall by 780 square metres, or 40%, and the records storage area by approximately the same floor area, an increase of 50%. These extensions will allow the Survey to house the collections already mentioned and provide much needed spare capacity to receive additional material in the future. An awareness about environmental issues coupled with rising fuel and power costs, together with the imposition of the Climate Change Levy have led to a major initiative aimed at saving energy at the Survey's main sites. Initial investigations have indicated that a Combined Heat and Power scheme would be viable at Keyworth and it is the intention to work up a fully costed scheme for the site during 2001/2. Such a scheme would have the advantage of both reducing total emissions and lowering the recurrent costs for energy. Other than these two projects, there has been ongoing work to maintain and upgrade the building fabric and services at all sites. Highlights of this programme have been the window replacements and re-covering of flat roofs at Keyworth, and the heating and controls upgrade at Murchison House.



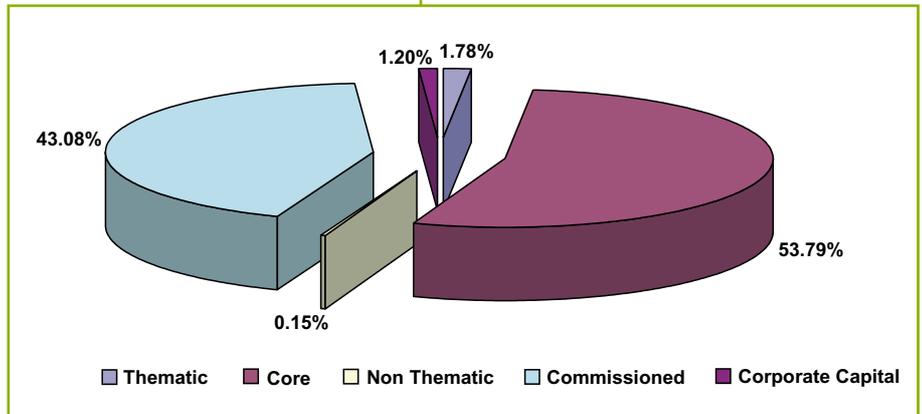
Sources of BGS income 1993/94–2000/2001 (at 2000/2001 prices).

The Financial Year 2000/01

CORE STRATEGIC ACTIVITY	
Lands and Resources Directorate	£6,456,499
Environment and Hazards Directorate	£3,751,605
Information Services and Management Directorate	£6,568,490
Development of Scientific Capability	£1,179,556
Additional core activities	£184,669
Total Core	£18,140,820
Responsive Thematic	£14,528,658
Seedcorn & Non-thematic	£51,998
Corporate capital	£403,940
Grand total	£33,725,588

External funding for research

External funding meets the costs of commissioned and co-funded research carried out by the BGS. Known as the Commissioned, or Responsive Programme, it comprises strategic commissions, partnerships, and contracts with a wide range of clients, which include government departments, agencies, local authorities, the European Union, international aid agencies, and development banks, as well as industry, commerce, and the public. The Commissioned Programme enhances the BGS Core Strategic Programme through funding, ideas, data, and review. It facilitates a more vigorous multidisciplinary scientific programme than could otherwise be provided, including the development of expertise and the maintenance of critical mass within each programme area. The Commissioned Programme enhances the relevance of the BGS's capability to meet the requirements of government, industry, and the wider community.



BGS expenditure — 2000/01.

The BGS Board as at 1 January 2001



BGS © NERC

Back L to R: David Holmes, Geoff Robinson, Tony Harris, Ian Jackson, Colin Read, Owen Bavinton, Jeff Smith.
Front L to R: Roger Scrutton, Marian Carter, David Falvey, John Mortimer, Jane Plant, Frank Curry and Chris Browitt.

Remit

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

Board Members

Mr J Mortimer	Chairman
Dr D A Falvey	Executive Director, BGS
Dr O A Bavinton	Senior Vice President — Exploration, Anglo American plc
Dr M J Carter	Managing Director of M J Carter Associates
Professor A L Harris	Dean of Science Faculty, University of Liverpool
Mr C M Read	NERC Finance & Information Systems Director
Dr Geoff Robinson	Retired, former Director General of the Ordnance Survey
Dr R A Scrutton FRSE	Reader in Marine and Applied Geophysics and Head of the Department of Geology and Geophysics, University of Edinburgh
Dr B R Marker	(Observer) Department of Environment, Transport and the Regions
Mr Jeff Smith	Managing Partner, Wardell Armstrong
Mr F G Curry	BGS Executive Committee Member
Dr Chris Browitt FRSE	BGS Executive Committee Member
Mr David Holmes	BGS Executive Committee Member
Mr Ian Jackson	BGS Executive Committee Member
Dr Mick Lee	BGS Executive Committee Member
Professor Jane Plant CBE	BGS Executive Committee Member

Secretariat

Mr D K Talbot of the BGS

Membership

Board members are appointed by the NERC Chief Executive and approved by NERC Council. The membership includes between six and ten non-executive members and the members of the BGS Executive Committee. The non-executive members are appointed by reason of their qualifications and experience and represent a broad cross-section of the BGS's user community. They include senior representatives of industry, government agencies, and the academic community. Members may be appointed for up to four years in the first instance and may be reappointed for a further period of up to four years.

Obituaries

Steven Robertson (1960–2000)

Steve Robertson was a dedicated field geologist with a sharp eye for detail and an enquiring mind. Born in 1960 and brought up in Devon he attended Exeter University obtaining a B.Sc. in 1981 and carried on to complete a Ph.D. in 1985 with Professor Ken Coe on the subject of Late Archean crustal evolution in Ivusartoq region, south-west Greenland. This research involved the integration of field observations with petrographical, geochemical and isotopic analyses and established a long-standing passion for the 'twisted stones' of complex metamorphic terrains.

Steve joined the BGS in 1985 as a member of the then Tectonic Evolution Research Group but a year later moved to the Highlands and Islands Unit. Over the next 14 years until his untimely death he worked in the Grampian Highlands with the East Grampian and Monadhliath projects. During his career he gained an in-depth understanding of the issues and problems that surround the unravelling of the lithostratigraphy and structure of the Lower Dalradian and the Caledonian orogeny as evidenced by his publications on the timing of Barrovian metamorphism, the 'Older Granites' and the Geal Charm – Ossian Steep Belt. One of his proudest achievements was to complete and oversee the compilation of the last 1:50 000 primary survey map sheet in the UK landmass (Sheet 63E, Dalwhinnie). Latterly, he had also taken on the duties of District Geologist for the Northern Highlands and was active in initiating both academic and commercial projects in the area. Steve also authored the Metamorphic Rock Classification Scheme, a very pragmatic and efficient piece of work.

He was a highly perceptive and free thinker in scientific debate and a key influence in group discussions with stimulating models which were always supported by sound field and petrological observations. His grasp of the local intricacies and regional implications impressed colleagues and academic researchers alike and he was highly respected and involved in the ongoing controversies of Highland geology. Recently he revitalised his contacts with the Greenland Survey and exported some of his Scottish talents to the Caledonides of East Greenland.

Alice Wain (1972–2000)

Alice Wain was a highly qualified, hard working and dedicated scientist with an enviable academic record. Born in 1972 and brought up in Twickenham she attended the University of Oxford obtaining a top class Honours BA in 1994 and carried on to complete a D.Phil. in 1998 with Professor John Dewey and Dr David Waters. Her chosen topic, ultra high-pressure metamorphism in the Western Gneiss Region of Norway established her abilities as a meticulous, focused researcher with a passion for the science of geology and in particular for unravelling the intricacies of complex metamorphic terrains.

Alice joined the BGS in 1998 as a member of the then Scotland and Northern England Group. Her talents were put to immediate use in the Southern and Central Highlands where she tackled the full range of metamorphic facies conditions from sub-greenschist to upper amphibolite. Until her tragic death, she had made an excellent start, rising to the challenges and impressing colleagues with her sound judgement and ability to cut to the core of the issues and controversies that surround much of Highland geology.

On 3rd May 2000 four staff of the Scotland and Northern England Group and an academic collaborator were involved in a road accident which tragically resulted in the deaths of two highly respected and skilled geologists Drs Steven Robertson and Alice Wain.

Steven Robertson (1960–2000).



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Alice Wain (1972–2000).



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