Annual Report

1999–2000

British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

NAVIGATION

HOW TO NAVIGATE THIS DOCUMENT

- The main elements of the report are bookmarked enabling direct links to be followed to the principal section headings and sub headings.
- In addition, the report contains links:
  - from each page number back to this page.

Foreword

Eric Hassall CBE, D.Sc., C.Eng., F.I.Min.E., FRICS, FGS
Chairman of the BGS Board

I am pleased to contribute this foreword to the 1999/2000 Annual Report of the British Geological Survey.

This has been a successful year for the BGS. Starting with a forecast of a substantial deficit, the Survey has finished the year with a positive balance. Equally importantly, it has put in place new systems and a new structure which provide sound financial and organisational bases from which to launch its scientific programmes for the next and subsequent years.

During the year the Survey has enhanced its experience in consultation; engaging its staff and its users in its planned activities. The new organisational structure followed a staff-led consultation exercise. The new strategy, *Foundations for a Sustainable Future,* launched in the House of Commons by Mr Chris Mullin MP, was developed from country-wide consultation with users.

This Strategy quite properly reasserts the importance of maintaining excellence, quality, impartiality and objectivity, and the continuation of basic research, enhancing scientific knowledge to address the needs of society.

The year has seen an excellent programme of commissioned research, nationally and internationally. I am pleased to see that the new Strategy encourages all staff to become commercially entrepreneurial and plans to sustain and enhance this performance in coming years, channelled through a new Marketing and Business Development Executive.

The Survey is in a global society and continues to maintain and extend its external links. It has established formal arrangements with several national and international organisations, private companies, public bodies and universities, which add value to its science, its products and services.

The British Geological Survey Board, which now includes the Executive Director and all members of the Executive, is committed to the highest standards of corporate governance. It ensures that the Survey contributes actively towards the Mission of the Natural Environment Research Council and operates in accordance with Government policies and guidelines on benchmarking, on openness and transparency in its science, administration, management and stewardship of public funds.

I am aware of the Government's quinquennial review of Research Councils in which, no doubt, the present arrangements between the Natural Environment Research Council and the Survey, its subsidiary body, will be reviewed. As with previous reviews, I am not yet convinced that it would be easy to find better arrangements which, in the public interest, would add value to both bodies. Regardless of the outcome of the Review I am pleased to report that the British Geological Survey is in a powerful position to advance geoscience knowledge and provide relevant up-to-date information, services and advice to the highest standards in forms which users need and to compete in an ever-expanding global market.

This position has been reached through the dedication and hard work of all involved. I cannot overemphasise the importance of the roles played by all the staff, the then executive committee of Assistant Directors and the Director in achieving this highly satisfactory position. The Board has played a major role in the management, strategic planning and programme development.

I most sincerely thank all those who have given their support to me and to the Survey in this and previous years and wish the Executive Director and British Geological Survey all success in the future.

Bibliographical reference

BRITISH GEOLOGICAL SURVEY, 2000.
Annual Report of the British Geological Survey 1999–2000.
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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 utilise 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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The BGS is a component body of the:

NATURAL ENVIRONMENT RESEARCH COUNCIL

The UK Natural Environment Research Council (NERC) funds and carries out impartial research in the sciences of the environment. It also trains the next generation of independent environmental scientists — more than 3000 postgraduate students have been funded by the NERC over the past five years. About half its budget supports research and training in universities, and half is invested in research in its Research Centres (see left).

The NERC is the research council that does earth system science: it deals with planet Earth as a complex, interacting system. The NERC's work covers the full range of atmospheric, earth, terrestrial and aquatic sciences, from the depth of the oceans to the upper atmosphere.

It has three strategic objectives: to enhance the excellence of the science base for the environment, to focus NERC science on priority issues, and to put NERC science to work.

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Director's introduction

I am delighted to be able to introduce the BGS Annual Report for 1999/2000, a year dominated by planning for the implementation of the new BGS Strategy and adjusting to the financial reality of reduced external income.

The new year began on a very difficult note. All our financial projections indicated that the BGS might face a deficit by the end of March 2000. This had been brought on by a number of factors, including the coincident ending of a number of key commissioned research projects, and a modest reduction in our Science Budget allocation. As a result, severe spending and recruitment controls were introduced, which lead to an end-of-year balanced budget.

The Strategic Planning Group, set up in 1998, continued the final stages of consultation and redrafting at the start of 1999. The new BGS Strategy received the provisional approval of the BGS Board in March 1999. Gradually, the final Strategy document took shape, and its implications gained more widespread acceptance. The key issues that came out of the strategic planning exercise were a tighter focus on the needs of the client base and the delivery of a programme that addresses major resource, hazard and environmental issues directly. Implementation task forces were established to position the BGS to deliver the aims of the new Strategy.

Through the work of the task forces, a new programme and organisational structure emerged. The new structure is based on a matrix with each member of staff occupying one of six disciplines in the Geoscience Resources and Facilities Directorate. Staff work on projects across the organisation in a revised programme built around three directorates addressing Environment and Hazards, Land and Resources and Information. After a great deal of effort on the part of the BGS programme and organisational task forces, the new structure was accepted by BGS senior staff at a workshop in September 1999 before being approved by the BGS Board at its October meeting. The new Strategy was officially launched at a function in Parliament House on 2nd November 1999.

One sad episode punctuated 1999/2000. For the first time in its long history, the BGS was forced to declare a state of redundancy. Under a voluntary redundancy programme that was initiated in 1997, a large number of volunteers had come forward through 1998 and early 1999. But in the end some nine scientists, who had been identified as not having the skills required under the new Strategy nor the potential for retraining, had to be made compulsorily redundant. It was a traumatic experience for all, and I hope that through careful planning under the new structure, it never has to happen again.

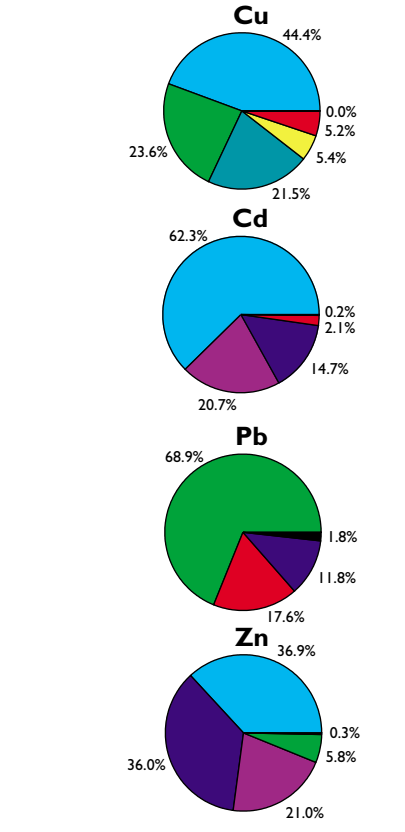
Following on from the Board's approval, intensive preparations were made for the roll-out of the new programme and structure on April 3rd 2000. As the new BGS develops over the coming years, I wish to emphasise and positively promote the concept of 'distributed leadership' — everyone knowing what needs to be done, doing it, and accepting the responsibility and rewards that follow. The forthcoming year promises to be both challenging and exciting for everyone at the BGS.

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

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

Research and development

Hazards and Health



Distribution of heavy metals between different physico-chemical substrates identified in heavily contaminated soil samples from Silver Bow Creek, Butte, Montana.

Environment and health: Bioavailability

Risk assessments are currently based on the total concentration of toxic substances present in contaminated land as presented in the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) guidelines. Many soils in the UK contain natural levels of metals which are higher than those set out in these guidelines, however, high concentrations of heavy metals may not present a hazard as their chemical form is unlikely to be available for animal or plant uptake. There is therefore a need to define a different parameter to judge the toxicity of a soil sample. Bioavailability is the fraction of a contaminant present in a soil available for absorption by a biological organism via a specific exposure route. The BGS has now set up a physiologically-based extraction test in which the contamination in a soil which is available for uptake can be determined. The test utilises simulated stomach conditions (a synthetic stomach solution at 37°C). These have been successfully applied to a number of potentially contaminated soils with arsenic concentrations above the ICRCL limit of 10 milligrams per kilogram and have shown in some instances that less than 1% of arsenic in the soil is bioavailable.

Shallow gas hazards

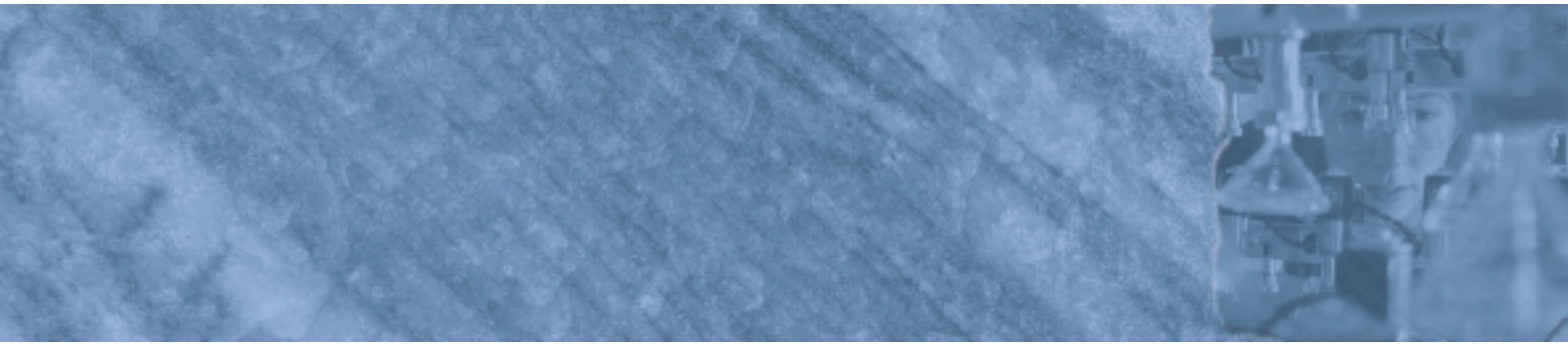
Shallow gas is one of several potential hazards to frontier development operations in deep waters north-west of Britain. On behalf of the Western Frontiers Association, the BGS has taken a lead in partnership with Hydrosearch Associates Ltd on the appraisal of the risks posed to safe operations by shallow gas. A regional analysis of the diagnostic features indicating the presence of modern shallow gas or other fluid transport and accumulation has been tied to the stratigraphy of Cainozoic sediments from the sea bed to approximately 1000 metres below sea bed. Geographical cover included the 17th Round Licence Tranches extending from the Donegal Fan northwards to the northern North Sea and westwards to between Rockall Bank and Lousy Bank in the NE Atlantic. Safety analyses included links to hazards identified with sea bed broaching, bottom simulating reflectors, and submarine landslide.

Properties of bentonite

Sponsored by the Swedish company Svensk Karbranslehantering AB (SKB), the BGS has continued to study processes occurring in a hard rock repository for nuclear waste, including resaturation and hydration of the clay barrier and the migration of gas liberated from the waste container. Diagnostic experiments are performed using a state-of-the-art gas permeameter. This apparatus has been enhanced to record axial and radial stress at multiple locations around the circumference of the specimen, providing a crude form of stress tomography. Changes in pore-water pressure and boundary stress are recorded as gas or water pressure is slowly increased at a filter located at the centre point of the specimen. The results of these experiments are used in the development of process models for repository safety analysis.

Detection of abandoned mine shafts and mine waste

The UK's legacy of mining poses serious risks to both health and safety and may also blight property values, planning and economic regeneration. New structures face the risk of collapse from subsidence and people may be at risk from mine contaminants such as heavy metals, acid waters, and



toxic gases. The BGS has been commissioned by the joint URGENT /Waste and Pollution Management Research Programme to develop a towed resistivity imaging system using non-contacting capacitive electrodes with a real-time kinematic global positioning system, to accurately locate old mine workings in the built environment. Capacitive electrodes permit continuous data acquisition on artificial surfaces (e.g. pavement and tarmac) as well as natural ground. The development of a prototype system is nearing completion. Advanced data processing and 3D tomographic imaging schemes are also being developed to improve target recognition and location. The project aims to improve the detectability of abandoned mine workings and minimise the cost of intrusive sampling in highly heterogeneous ground conditions. The project is supported by Ph.D. studentships at the Institute of Engineering Surveying and Space Geodesy and the School of Chemical, Environmental and Mining Engineering, University of Nottingham. Industrial partners include The Coal Authority, Commission for New Towns and Geometrics (UK) Ltd.

Transport of halogenated solvents in the matrix of the Permo-Triassic sandstone aquifer

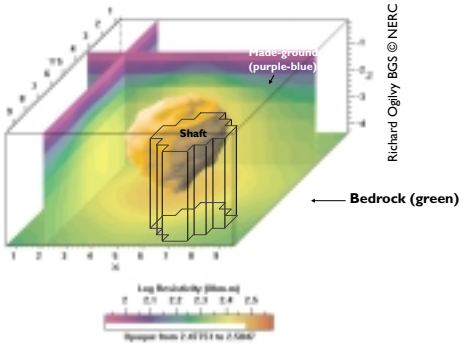
Halogenated solvents are a common contaminant in UK aquifers. They are dense non-aqueous phase liquids (DNAPLs) that, if spilled, may rapidly penetrate to great depths in aquifers. Slow dissolution from subsurface pools of solvents means that they may act as long term sources of groundwater pollution. Historic contamination of groundwater by halogenated solvents is particularly common in the Permo-Triassic sandstones of central and north-west England, and there is a need to understand the movement and subsurface distribution of halogenated solvents in this aquifer so that optimal monitoring and remediation strategies can be developed. The BGS is working in collaboration with a team from University College London to provide fundamental information to improve predictions on the depth of penetration and distribution of both liquid and dissolved phase halogenated solvents. Solvent transport characteristics are sensitive to lithological characteristics of the sandstone matrix and the work includes laboratory studies of solvent pore entry pressures and residual saturation, and measurements of solvent diffusion coefficients. Novel laboratory procedures have also been developed to study solvent dissolution and dispersion. This work is being supported by the EPSRC/NERC as part of the Waste and Pollution Management Thematic Programme.

Mathematical hydrogeology

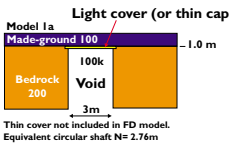
The project maintains and develops expertise in the numerical modelling groundwater flow and the movement of pollutants. Support is provided to various projects in order to achieve their groundwater modelling objectives. An example of this was the investigation of effect of seasonality on well catchments using particle tracking. The main activity was the development of radial flow modelling software to support major aquifer studies. A two-dimensional radial flow model was constructed, validated and a prototype user interface was developed. In addition, a novel method of assessing pollutant transport was further developed, the Multiple Analytical Pathway, or MAP, model. This can be used with existing groundwater flow models which use particle tracking techniques to determine groundwater movement. It has been applied to assess two examples of nitrate pollution in the Chalk aquifer; one in Yorkshire and another in the South of England.

The CORIM capacitively-coupled resistivity imaging system, developed to locate old mine workings, in use at a controlled test site.

Richard Ogilvy, BGS © NERC



Richard Ogilvy BGS © NERC



A result from a theoretical model study to predict the response of mine shafts from BGS prototype system. The opaque 3D volume (colour coded orange) reflects the air-filled shaft.

Groundwater Research

Research and development

"... freshwater of high quality is found at depth beneath the present coast in several countries. This originates from periods with different climatic conditions and lower sea levels than the present day ..."

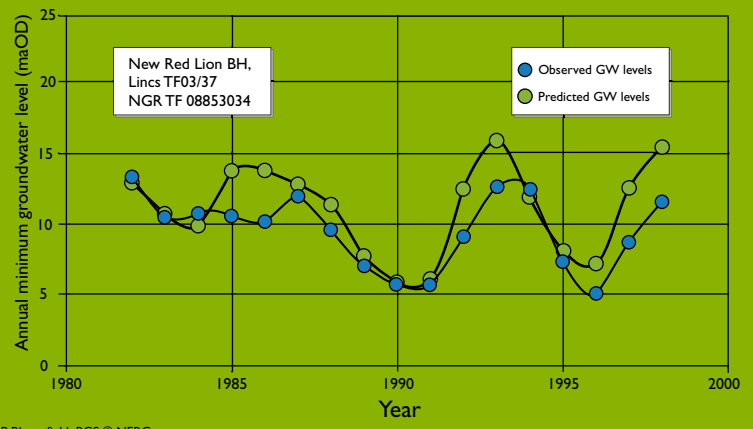
PALAEAUX

This EU-funded project has brought together up-to-date geochemical, isotopic and hydrogeological information on coastal groundwaters across Europe in a transect involving nine European countries from the Baltic to the Canary Islands. These data have been interpreted in relation to past climatic and environmental conditions as well as extending and challenging concepts about the evolution of groundwater near the present day coastlines over the past 100 000 years. Freshwater of high quality is found at depth beneath the present coast in several countries. This originates from periods with different climatic conditions and lower sea levels than the present day. The implications of the scientific results for management of aquifers in European regions are considered.

Europe 10 000 years ago, highlighting the areas investigated in the European collaborative study PALAEAUX.

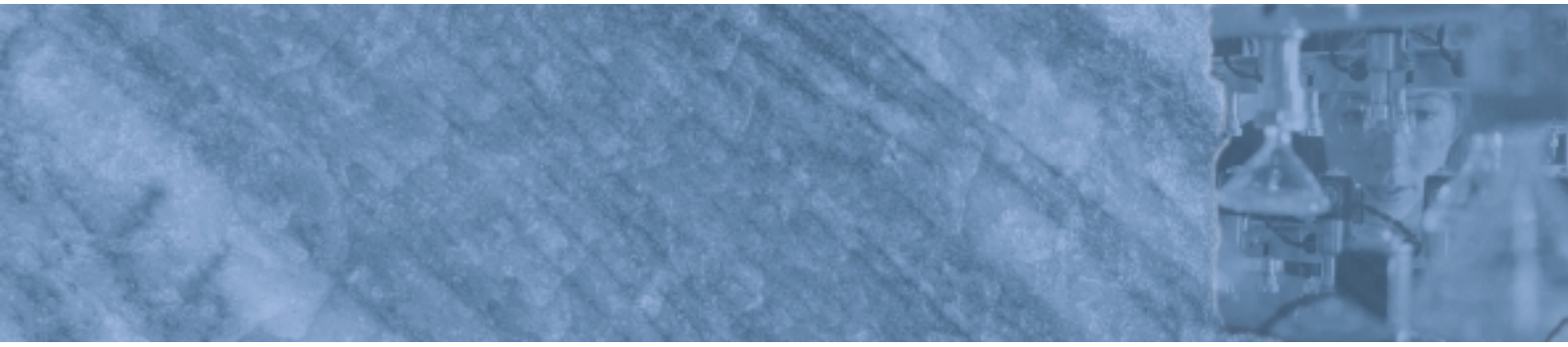
The impact of climate change on groundwater resources

A flexible modelling methodology is being developed to assess the impact of climate change on groundwater resources. Particular emphasis is placed on predicting low groundwater levels under drought conditions. The model will be applicable to a range of aquifer types and adaptable to a range of hydrological and hydrogeological scenarios. It will be used to evaluate impacts of the current range of accepted Global Change Model scenarios on selected regions of the three major aquifers (the Chalk, Permo-Triassic Sandstones and Lincolnshire Limestone). The modelling methodology will also be adaptable enough to be used where there is only limited data or with data of variable quality. It will highlight areas where additional research is required, and will provide guidance on data requirements related to climate change and on the future monitoring of groundwater resources under conditions of climatic uncertainty. This project is being undertaken in collaboration with CEH (Wallingford).



J P Bloomfield, BGS © NERC

Example of modelled minimum annual groundwater levels based on historical rainfall and groundwater level data for a site on the Lincolnshire Limestone.



Groundwater as palaeoindicator (GASPAL)

Under favourable conditions subsurface waters (unsaturated zone as well as saturated zone environments) may record antecedent climatic and environmental change in their chemical and isotopic signatures. This project, funded under the EC ENRICH initiative, is creating a database and links on information relating to groundwaters relevant to global change in several African Sahelian countries (Senegal, Niger, Nigeria, Chad). The work is being carried out in collaboration with partners in the UK, France, Italy, and Germany. Much of the existing data for the African Sahel region has been obtained as part of bilateral north-south projects and the present initiative therefore gives the opportunity to collate and to intercompare data on groundwater from many individual projects to arrive at a standard for the region as a whole. As well as the database activities, there will be workshops, scientific exchanges, and publicity material and external publications.

Edinburgh Anisotropy Project (EAP)

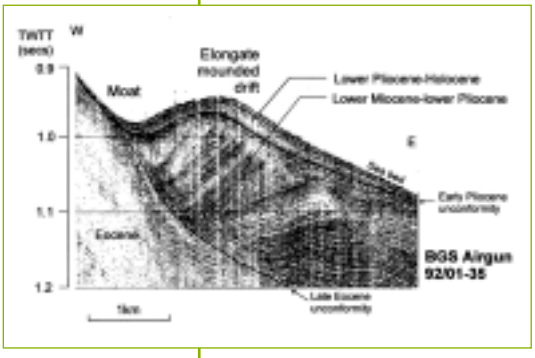
The EAP conducted research into advanced seismic methods with sponsorship from a consortium of operating, service and software companies. The focus of the year's work was to renew the sponsorship of the EAP, which is organised in three-year phases. A new research programme for the fifth phase (2000–2003) was launched, and twelve companies agreed to continue supporting the EAP. The programme contains five initiatives: converted-wave analysis; AVD (attributes versus direction) technology for fracture detection; sub-basaltic imaging; time-lapse seismic; and microseismic monitoring. This programme is built on the success of the Phase IV (1997–2000) programme. Technology development includes using multicomponent seismic data to image through complex areas (such as basalt, gas clouds etc.) and to characterise fractured rocks (i.e. fracture density, orientation and contents). The main theoretical advances this year include the demonstration of links between fluid flow and seismic anisotropy, and its association with multicomponent time-lapse seismic data.

Tectonostratigraphical framework for the Rockall Trough

A unified late Palaeogene-Neogene seismic-sequence stratigraphy has been developed for the first time for the entire Rockall Trough. The stratigraphy has been established in partnership with the Netherlands Institute for Sea Research and the University of Aarhus (Denmark) as part of the EU-funded ENAM II project. Three regionally-significant megasequence boundaries have been mapped throughout the deep-water basin, the development of which reflects major changes in the shaping of the continental margin off north-west Britain and Ireland. The construction of a tectonostratigraphical framework has established a potential linkage between tectonics and changes in the oceanographic circulation pattern, shelf-margin progradation and late Neogene climatic deterioration. This work was presented at an international meeting in April 1999 in Dublin — *The Petroleum Exploration of Ireland's Offshore Basins* — and will be published in a Geological Society Special Publication.

Seismic Methods

Stratigraphical architecture of a sediment drift from the western Rockall Trough reflects the sedimentary response to changes in the oceanographical circulation pattern, which are most probably linked to north-east Atlantic plate-tectonic events.



M S Stokes, BGS © NERC

Systematic surveying & data collection

Geological Mapping of Britain

Tom Bain, BGS © NERC

Geological mapping, Forth and Lothians: collapse feature in unconsolidated landfill infilling former sand and gravel pit overlying shallow mineworkings in the Burdiehouse Limestone.

Fergus McTaggart, BGS © NERC

Geological mapping, Ayr and Lanark: The spectacular Falls of Clyde formed by resistant posts of sandstone of the Siluro-Devonian Swanshaw Formation.

Geological Mapping of Britain

The 15-year programme of geological mapping carried out within the Multidisciplinary Regional Surveys sub-programme was started in 1990/91. The cumulative output over the nine years is 192 resurveyed or revised geological maps at the 1:50 000 scale, 71 memoirs, nine sheet explanations, two sheet descriptions, three new editions of regional guides and three subsurface memoirs. During the current year 5309 square kilometres were resurveyed or revised; 167 maps at the 1:10 000 scale were released to the public and 51 technical reports written.

Continuous Revision Programme

This programme addresses the needs of the user community for up-to-date geoscience information, particularly in areas of high demand and urban development, both within and outside the 15-year programme. It is of considerable long-term strategic importance to develop suitable methods of ongoing data collection and information databasing for map revision. In Scotland, 80 cored rotary site investigation and water boreholes comprising 2000 metres of core were examined. Examination of temporary exposures, primarily from engineering excavations, continued in conjunction with the databasing of information from non-coal mine plans, mine entries and quarries. This is being processed for use within a GIS in various possible applications including a mining referral system. In England, revised maps were made available for areas in South Yorkshire.

Quaternary Network

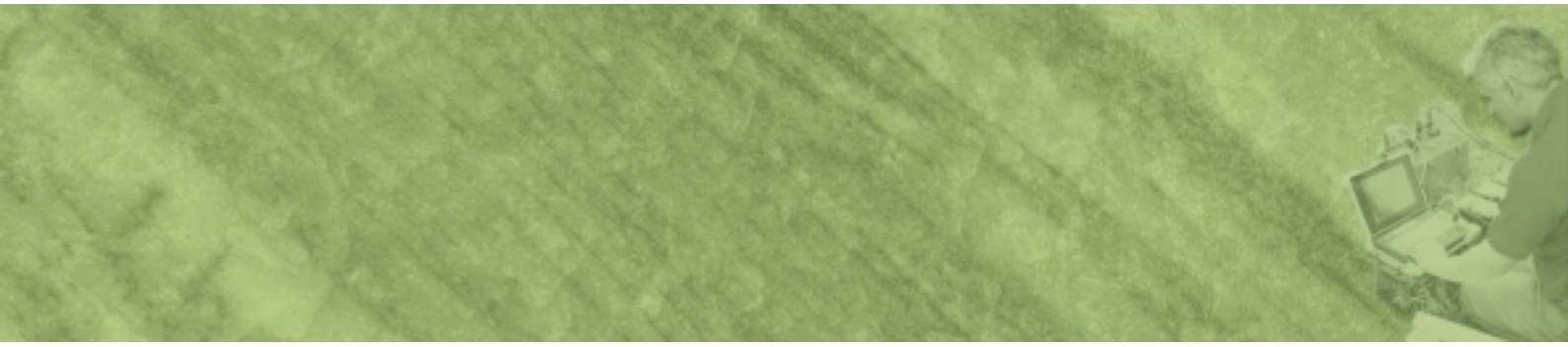
The report *Quaternary Geology: towards meeting user requirements,* published in September 1999, was circulated widely to external users. Knowledge of Quaternary geology is vital to the understanding of modern processes and for predicting climatic and sea level changes. Much of Britain is blanketed by Quaternary deposits which form the foundations for buildings and highways and provide natural sources of aggregate. Lithological and geotechnical properties, rockhead, weathering processes, resources, land stability and landfill are just some of the issues examined by the report. An accompanying questionnaire sought to influence BGS research objectives and this provided very positive feedback.

Lower Rheidol Valley geological model

In collaboration with the Environment Agency (Wales), a geological model of the Quaternary fill of the buried channel of the lower Rheidol Valley in west Wales has been produced. This is being used to assist hydrogeological studies of the gravels in the channel, which form a local aquifer, supplementing the local water supply.

Ground level change in the Thames Estuary area

A pilot study, funded by the NERC and the Environment Agency, for monitoring changes in ground level has been completed in association with Nottingham University. Over a 2.25-year period, height data were obtained for a network of stations using high precision GPS. Changes in regional ground level do not exceed a few millimetres per year, but there is some evidence for tectonic activity in the east of the estuary, where the north side is rising relative to the south.



3D basin analysis

This project has the ultimate goal of developing a 3D model of the geology and structure of the UK landmass and offshore area. This is achieved by integration of seismic reflection, stratigraphical, well log, petrophysical and outcrop data, and leads to the production of subsurface structure contour maps and a thorough understanding of the geological evolution of the area. The main component of this project currently comprises an investigation of the subsurface geology of the Cheshire-Staffordshire area with an emphasis on the pre-Permian succession. Interpretation is now complete and drafting of the subsurface memoir well under way. An associated publication, an atlas of structures in Southern Britain is also nearing completion. A database of stratigraphy encountered in boreholes is being populated: stratigraphical details for 6580 boreholes have now been entered.

Engineering behaviour of British rocks and soils

The advisory panel has continued to help the project meet the needs of the user community by commenting on the project programme. It has critically reviewed the project outputs in general and the *Engineering Geology of the Mercia Mudstone* report in particular. This report will go to press shortly. The study on the engineering geology of the Lambeth Group has confirmed its complexity and the importance of an appreciation of its engineering properties in construction. The collection of geotechnical data for Liassic clays has started and the work is guided by a report on the latest lithostratigraphical interpretation. Work on the engineering geology of Brickearth in collaboration with the Nottingham Trent University is well advanced. Development work on a new method of characterising the shrink-swell behaviour of mudrocks is continuing to show promise. A scoping study to assess the London Clay as a topic for more detailed study was completed. Geological contributions have been made to a Nottingham University LINK project using remote sensing to study seasonal ground movements in the London Clay.

Geochemical Baseline Survey of the Environment (G-BASE)

G-BASE continued the compilation of high resolution geochemical data for a variety of economic and environmental applications. The programme, which commenced in the 1970s, is due to complete the geochemical mapping of the UK by 2012. Sampling of the East Midlands region, which commenced in 1997, continued with the collection of stream sediment and heavy mineral concentrate samples at 1771 sites, stream water samples at 1442 sites, and soil samples at 2117 sites over an area of 4250 square kilometres. More detailed soil sampling was undertaken in the urban centre of Leicester, where an additional 657 samples were collected over an area of 165 square kilometres. Progress continued with the compilation of the stream water atlas of Wales, Welsh Borders and part of the West Midlands, and work commenced on the preparation of a parallel stream sediment geochemical atlas of the same area.

Natural Environment Radioactivity Survey (NERS)

Maps of radon potential and gamma-ray dose based on solid and drift geology for the Lake District area at 1: 250 000 scale were completed in draft form. A draft radon potential map of the

Geological mapping, Lancashire: a large landslip at Cornholme, West Yorkshire within Millstone Grit strata. Landslip studies in this area were carried out in conjunction with Kirklees and Calderdale district councils.

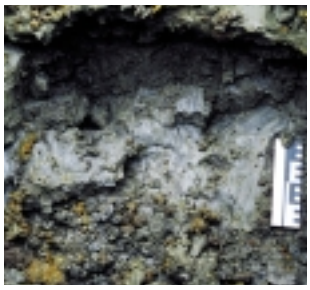
Peter Hobbs, BGS © NERC

Minerals and Geochemistry

Geological mapping, Yorkshire: Rough Rock overlying Rough Rock Flags of Namurian age at the Elland Roadcut, Halifax.

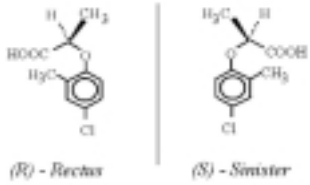
Robert Addison, BGS © NERC

Systematic surveying & data collection



Alan Brandon, BGS © NERC

Geological mapping, East Midlands: a slightly oblique view of a trial pit in solifluction material in the Vale of Belvoir, Leicestershire. An inclined basal shear plane separates the sheared clay layer from the brecciated clay bed rock beneath.



BGS © NERC

Right- and left-handed forms of the common herbicide Mecoprop (2-(4-chloro-2-methyl phenoxy)-propionic acid) are degraded differently during processes of natural attenuation. The study of how such enantiomers behave in the natural environment is of growing concern because of their increasing environmental abundance.

Geophysics

East Midlands was also prepared. Development continued on a Geographical Information System (GIS) based on Lake District data. This will allow a much more flexible approach to presenting data on natural radioactivity. Mineralogical studies of potential radon source rocks in the Liverpool Bay and Lake District areas were completed and investigations started on the Northampton Sand Formation in the East Midlands.

Minerals GIS Online (MINGOL)

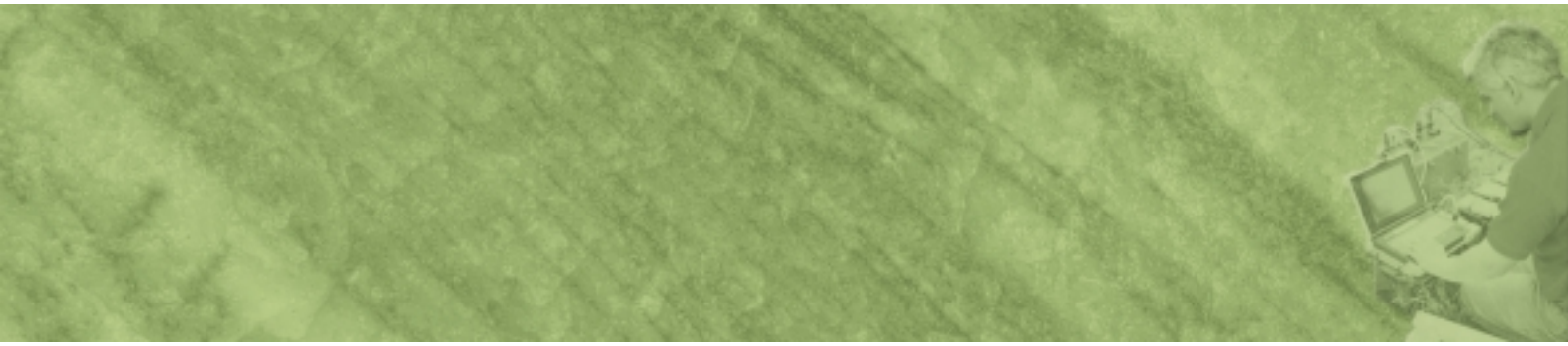
Data from an additional four county Mineral Resource Planning maps (Bedfordshire, Cornwall, Derbyshire and West Sussex) commissioned by the Department of the Environment, Transport and Regions (DETR) were incorporated into MINGOL together with a compilation of all the counties in the West Midlands Economic Planning Region (EPR). This is the first EPR to be completed; others will follow in due course. This work assists in underpinning this major commissioned programme. The Coal Authority-commissioned Coal Map is also now available in GIS form. This will be used to develop a CD-ROM product in the coming year. The BRITPITS mines and quarries database tables have been extensively revised with continual editing of the data to verify and update the records. An additional four major and some minor commodity chapters have been completed for Mineral Resources of Britain. Data capture for the Mineral Occurrence Database continued, especially in south-west England; this will support several Core Strategic and Commissioned Programmes.

Stereo-specific transformation of contaminants during migration

In conjunction with the Environment Agency and the Queens University Belfast, the BGS is undertaking research into the stereo specific degradation of enantiomeric forms of Mecoprop (R and S forms of 2-(4-chloro-2-methyl phenoxy)-propionic acid) a common herbicide at the Helpston Landfills in Lincolnshire. Measurements of the ratio of the two stereo isomers of Mecoprop undertaken by BGS staff in the laboratories of the Queens University Belfast indicate: (a) changes in the S:R ratio of mecoprop suggesting that it is biologically labile; (b) increase of the S:R ratio in the anaerobic aquifer suggesting inversion of R to S; (c) the S:R ratio gradually reduces as (S) is degraded in preference to (R) further downstream in the aerobic zone.

Collaborative trial airborne environmental surveys

In June 1999 trial airborne environmental surveys were flown over five test sites in the East Midlands. This project was a collaboration between the BGS and the Geological Survey of Finland (GTK), co-sponsored by the DETR and the Environment Agency. For some years GTK have successfully used their dual frequency wing-tip electromagnetic (EM) system to map and monitor potential pollution hazards associated with defective landfill sites in Finland. The main objective of the present trials was to test the effectiveness of the airborne EM technique in a similar application in the generally less favourable UK environment. The results are encouraging and numerous conductivity anomalies were detected. Some of these, apparently associated with landfill sites and colliery spoil heaps, may relate to subsurface pollution but it is stressed that they remain to be tested by detailed ground follow-up surveys. Gamma spectrometry and magnetic data were also collected during the surveys.



Hydrogeology

Uranium and thorium complexation and speciation in groundwater

The BGS has completed its EC- and Environment Agency-funded *Humics* project investigating the effects of humic substances on the migration behaviour of uranium and thorium in groundwaters. The results from a suite of kinetic experiments on the interactions between the aqueous metals and a purified fulvic acid were presented at a Workshop in the Institut für Nukleare Entsorgungstechnik, Forschungszentrum Karlsruhe GmbH, near Karlsruhe. These new data were used successfully by other project partners for improved groundwater modelling of uranium and thorium moving away from a proposed deep radioactive waste repository.

Geophysical borehole logging

Fifty-seven boreholes have been logged during the year ranging from 9.6 to 423 metres in depth and located throughout England, Scotland, Wales, and Northern Ireland. The logging has characterised diverse formations and identified groundwater inflows in support of Public Water Supply schemes, Aquifer Storage and Recovery (ASR) investigations, Fracture Flow Project studies (including deviated holes), studies of contaminant movement in the unsaturated zone overlying sandstones, studies of surface water and groundwater interaction in an upland Lower Palaeozoic catchment, as well as supporting exploration for the growing private sector mineral water industry. Acquisition of new logs has reduced from the record number of boreholes logged in the previous year as emphasis has switched to detailed interpretation of log data for fewer major projects. The largest effort has been in support of the National Groundwater Survey of the Chalk aquifer of the South Downs and Wessex Basin, and providing log interpretation of lithostratigraphy and water inflow of a Chalk aquifer for a major water company. A trial of the new technique of videoscanning proved exceptionally effective in displaying the lithology of existing boreholes.

Minor aquifers of England and Wales

The aim of this three-year collaborative project between the BGS and the Environment Agency project has been to collect, collate, and present information concerning the physical hydraulic properties of the minor aquifers in England and Wales. These properties include hydraulic conductivity, porosity, transmissivity, and storage coefficient. In addition, specific capacity (yield per unit drawdown) values are included for many of the formations described, together with yields for those formations where aquifer properties data are sparse. Within the report, each chapter takes the form of a detailed review of the physical properties of a group of minor aquifers, subdivided as appropriate on stratigraphical or geographical grounds. The purpose of the review is to present the magnitudes and variability of the data in the context of current understanding of the aquifer systems involved and the controls on the data. To that end the review includes geological, geographical and physical hydrogeological aspects of the aquifers. Useful summaries of data from the database are included on the accompanying CD-ROM. A further purpose of the report is provide a comprehensive set of references by which the reader can obtain more detailed information about particular areas of interest in an aquifer. The report complements the major aquifers review which was published in 1997.

Geophysical borehole logging — the BGS logger and BGS coring rig at Selbourne, Hampshire.

David Buckley, BGS © NERC

Geophysical logging of a borehole at the site of the new Scottish parliament building, Edinburgh.

David Buckley, BGS © NERC

Systematic surveying & data collection

Map of the UK showing the major aquifers and National Groundwater Survey study areas.

National Groundwater Survey

The Hydrogeology Report Series was launched with the publication of *The Chalk aquifer of the South Downs* and *Hydrogeochemical processes determining water quality in upland Britain.* This series will grow with the publication of further regional aquifer study reports. Under the guidance of national and regional advisory panels, progress continues to be made in the compilation of reports on the regional studies of the Chalk aquifer in Wessex, Yorkshire, Lincolnshire, and the North Downs. These reports are programmed for publication in 2000/01. Collaboration with the Environment Agency has been particularly successful in the Bourne Catchment study, the results contributing to the Wessex Chalk aquifer study. The BGS's input to the study included geological mapping, geophysical logging, and hydrochemical investigations and a review of aquifer properties data.

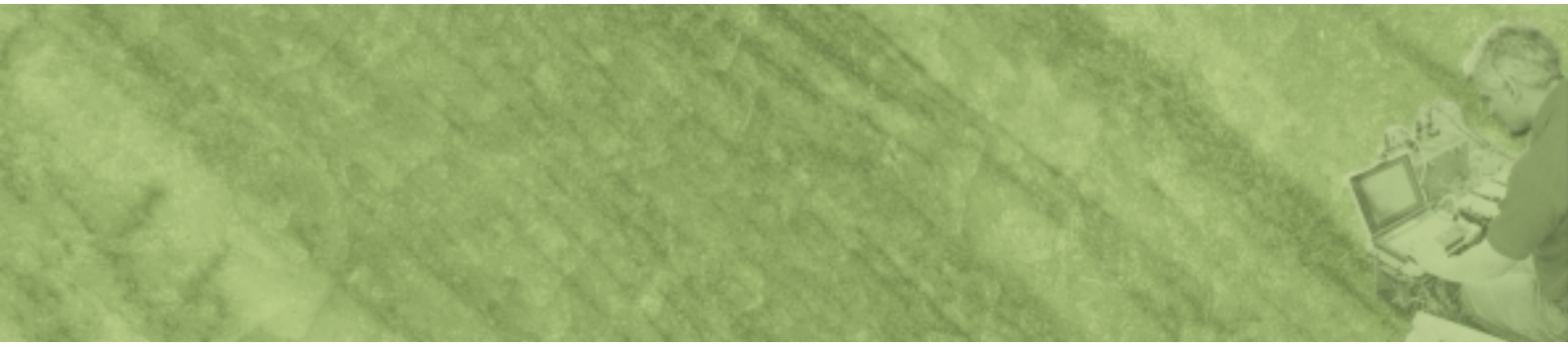
Lowland Catchment Research (LOCAR)

A new NERC Thematic Programme — the Lowland Catchment Research programme — is a unique initiative designed to gain improved understanding of the hydrological cycle at the meso-catchment scale. It will enhance understanding of the processes occurring within lowland permeable catchments through a programme of integrated monitoring and research initiatives. This in turn will enable optimisation of future strategic monitoring programmes. LOCAR will focus on two pairs of catchments on the Chalk (England's prime aquifer in terms of public water supply) and one catchment on Permo-Triassic sandstone (England's second most important aquifer) and will address 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 which affect the surface water and groundwater?
- how do the 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?
- how can the hydrological, hydrogeological, geomorphological and ecological interactions resulting from natural or anthropogenic changes be predicted using integrated mathematical models?

The BGS and CEH (Wallingford) have carried out a review of existing hydrological, hydrogeological and ecological data for the three catchments. This indicated a great variability of data availability, both in type and space, and it is recognised that significant investment will be required to provide a minimum standard of baseline data to enable researchers to improve our understanding of the catchment processes occurring. Costed proposals of the catchment infrastructure required to support the future research programme have been developed.

"... significant investment will be required to provide a minimum standard of baseline data to enable researchers to improve our understanding of catchment processes ..."



Coastal and estuarine evolution

As part of a project examining the evolution of the UK coastal zone over a variety of timescales from decades to millenniums, a seismic reflection profiling survey was carried out in the Mersey Estuary in October 1999. Data from this survey was used in conjunction with a purpose-built borehole database to improve the definition of the antecedent topography of the estuary and to produce a model of the history of Holocene sedimentation. This will allow a better understanding of the long-term processes which drive coastal evolution and deliver geoscientific knowledge and data to enhance the prediction of the future response of the coast to various scenarios of environmental change. Seven papers arising from the project have been published in the Geological Society Special Publication *Holocene Land-Ocean Interaction and Environmental Change around the North Sea.* Further papers from the project were presented at the Coastal Sediments '99 and Marine Sandwave Dynamics meetings in New York and Lille.

Inshore sea bed characterisation

Thematic maps of the nearshore zone created in previous years have now been translated into MapInfo format as a means of providing a further platform for the dissemination of results. Collaboration with CEFAS Laboratories concentrated on developing the use of BGS-derived sea bed facies and sediment data in conjunction with CEFAS benthic data to provide a basis for constructing habitat maps of the sea bed. DETR provided some co-funding to examine sea bed habitat classifications and undertake a literature review. During the year the project was extended to cover the whole of the Dover Strait in collaboration with the Bureau de Recherches Géologiques et Minières. Funding for this two-year collaborative venture has been provided through the EU INTERREG II Community Initiative.

Sea bed maps

The Central Rockall Basin solid geology map has been compiled jointly with the Petroleum Affairs Division (PAD) of Ireland. This map is being produced at a scale of 1:500 000, and integrates existing 1:250 000 scale solid geology maps on the eastern flank of the basin with data acquired as part of the BGS/oil company Rockall consortium, as well as available commercial data supplied by the PAD.

Igneous province studies

The development of a GIS of igneous structures on the north-east Atlantic margin has been initiated. The project aims include the provision of attributed map layers and associated report information regarding the Paleogene igneous structures, such as the distribution, age, and characteristics of central complexes, lava successions, sill complexes, and dykes. Linework coverages compiled for this project were supplied to the Passive Margins Modelling Project as initial constraints to modelling on the basis of published work. Research work associated with the project resulted in the presentation of two papers at the Geological Society conference on *The North Atlantic Igneous Province: Magmatic Controls on Sedimentation.* One of the presentations illustrated the seismic character of sill complexes on parts of the north-east Atlantic margin and the other recognised the presence of a major north-east-trending feeder dyke associated with the Faeroe Channel Knoll and other igneous centres.

Marine and Coastal Geology

Richard Waters, BGS © NERC

Quarries at Kenfig Pool

In collaboration with the National Assembly for Wales, studies into the effects of the proposed deepening and dewatering of the Cornelly Carboniferous Limestone quarries on Kenfig Pool, near Penarth, have been carried out. This work included geological modelling for both the hydrogeology and hydrogeochemistry of the aquifer, where karstic features are widespread. The photo above shows a karstic cavity in Carboniferous Limestone at Cornelly quarries on Kenfig Pool.

Systematic surveying & data collection

Records and Databases

North Sea oil province studies

A general account has been prepared which synthesises recent published work on the Mesozoic structural and stratigraphic evolution and petroleum geology of the central and northern North Sea Basin. Three 1:1M scale maps accompany this report and draw upon a stratigraphical database compiled from numerous released exploration wells to indicate the extent and thickness of Middle Jurassic, Upper Jurassic, and Lower Cretaceous successions.

BGS-geoIDS

The BGS-geoIDS project (BGS Geoscience Integrated Database System) was conceived as a way to redress the widely recognised fragmentation and inaccessibility of corporate data and so prevent further loss of existing digital data. The main aim of the BGS-geoIDS project is to establish an integrated data repository, which will contain digital geoscience data in its many forms. A secondary aim of the project is to provide the necessary tools to access the data in the most cost-effective way available to the BGS. The project is currently in its third and final year of the 1998–2001 project plan with the main emphasis on the implementation of corporate standards and applications.

Borehole database

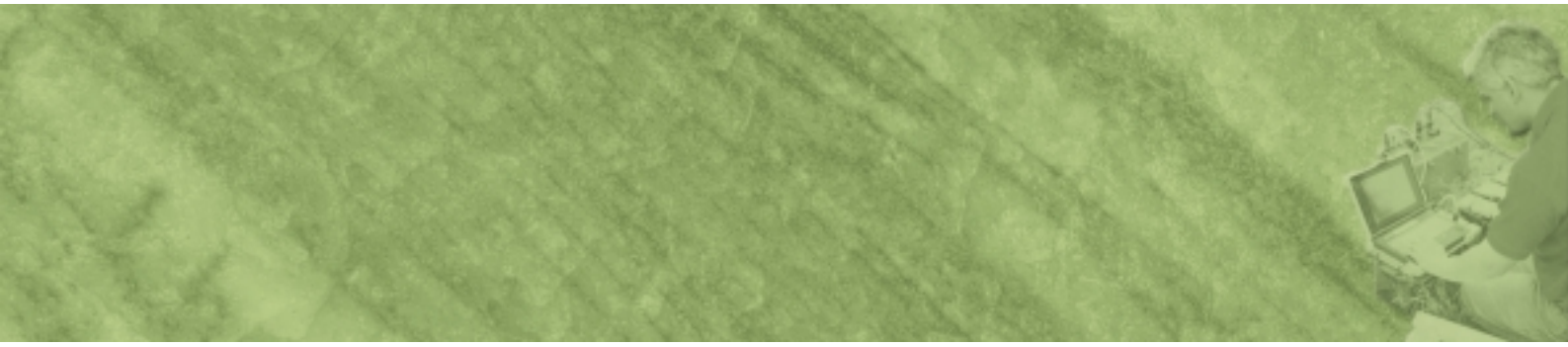
The National Geological Records Centre (NGRC) received over 48 000 new records donated by over 100 external organisations. Some 65 000 records were registered and databased; bringing the total number of entries on the Single Onshore Borehole Index (SOBI) to 888 854. Work continued on improving the quality of the database and 51 662 entries were updated. The backlog of unprocessed data has been significantly reduced to less than 50 000 boreholes and all data are now processed within twelve months of receipt. Two pilot scanning projects successfully converted 8770 images from records held on microfilm and 8595 from new analogue reports. A Data Management plan and a *User Guide and Procedures Manual* were published. The new SOBI User Group had a considerable influence on the integration of related data and the development of the database.

Collections administration

Through the year a number of donations were received from commercial operators, mainly comprising material from UK onshore hydrocarbon boreholes. As for previous donations of this type, agreements were reached with the operators covering the ownership, storage, and access to the material. The final tranche of onshore hydrocarbon boreholes was transferred from the DTI Core Store at Gilmerton to the BGS Keyworth Core Store. The total acquisitions amounted to: 67 136 m of cuttings, representing 44 boreholes; 8897 m of drillcore, representing 183 boreholes; and 2302 registered borehole specimens from 63 boreholes. As part of the work to create a borehole materials database a programme of bar-coding was initiated for the borehole material held in coreboxes on pallets. Each box is individually barcoded and eventually, by reading the barcode, the borehole, depths, and lithostratigraphy of the material contained will be identified. Nearly 20 000 out of the 106 000 coreboxes held have been processed.

Tim Cullen, BGS © NERC

Asteroceras obtusum (Sowerby), Jurassic (obtusum zone), Lyme Regis, from the BGS's comprehensive research collection of British fossils.



Discovery Metadata

The BGS has recently been compiling Discovery Metadata to populate the BGS metadata system. Metadata is 'data about data' in its simplest form and allows us to query for 'databanks' (these are defined as logically grouped data tables based upon a geoscience specialism or product). The metadata hold a description of the databank, its usage, contact information, details on update frequency, and logical keywords that relate to the databank. An end-user searches the BGS metadata through a web-enabled interface either by typing in their choice of geoscience keywords or a direct databank word search on the 'title' and/or 'description'. Our metadata have recently been released on the BGS Internet site and the National Geospatial Data Framework (NGDF) gateway for both our internal and external customers to be able to access the BGS data holdings quickly and effectively.

Geochemistry database

This project brings together the management of all databases in the geochemistry, mineralogy, and economic geology disciplines of the new BGS matrix structure. The BGS geochemistry database now holds in excess of six million determinations and systematic coverage of drainage geochemistry extends to all of Scotland, Wales, and northern England. Sample collection has been completed in the English Midlands and has commenced in East Anglia. The BGS has extensive holdings of rock specimens and thin sections that are indexed by means of the BritRocks database. Current extension of this database to track specimens held by the BGS will form the basis for improved curation and availability to enquirers. The database of mines and quarries in the UK is now a corporate ORACLE database and it has proved to be an essential cornerstone of several projects on mineral resource planning for the DETR. The Mineral Occurrence Database holds data on UK mineral deposits and has applications in identifying hazards from former workings and prospecting for new deposits. A new database is being created to hold the absorption spectra produced by the Portable Infrared Minerals Analyser (PIMA), which are an important reference tool for studies of hydrothermal alteration, clay minerals and in remote sensing.

Groundwater data management

The BGS is the custodian of several groundwater data-sets of national importance, including 100 000 water borehole records and data on aquifer properties, water level, chemistry and geophysics. These data-sets are key to research and development activities focused on understanding and managing groundwater in the UK. The data-sets consist of a combination of paper records and digital data. Paper records are being transferred to a digital database, WellMaster, in a systematic programme designed to improve access to data for users, both within the NERC and externally. The digital database is linked to other BGS digital data holdings, and access through the BGS Intranet and World Wide Web is being developed. BGS staff, in conjunction with interested commercial users who have supported data entry in local areas, set priorities for database population. Other data management activities included the dissemination of hydrological data, in partnership with the Centre for Ecology and Hydrology (Wallingford), with monthly publication of summaries of hydrological and hydrogeological conditions across the UK. Much of this information is now published on the Internet.

Geological mapping, West Midlands: Caughley Pit near Broseley, Shropshire producing opencast coal, fireclay and brick clay.

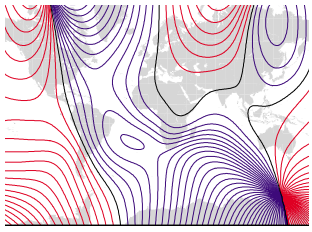
David Bridge, BGS © NERC

The Crocodile Spring at Compton Abdale in the Cotswold Hills. The water issues from the Great Oolite Limestone and flows into the River Coln, a tributary of the Thames. The spring has never been known to fail.

BGS © NERC

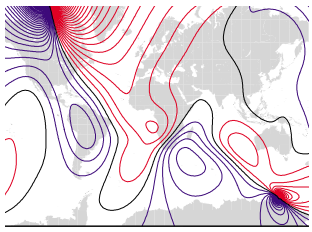
Long term monitoring

Seismic and Magnetic monitoring



Susan Macmillan, BGS © NERC

Declination at midnight, 1st January 2000 from the World Magnetic Model. Contour interval is 5 degrees, red is east i.e. magnetic north is to the east of true north, blue is west and black is zero.



Susan Macmillan, BGS © NERC

Predicted annual rate of change of declination for 2000–2005. Contour interval is 3 arc-minutes per year, red is change to the east, blue is change to the west and black is zero change.

Magnetic modelling

The World Magnetic Model, designed for air and sea navigation, is revised every five years. Production of the year 2000 revision of the model, the standard magnetic model used in Ministry of Defence navigation and attitude and heading referencing systems, was the joint responsibility of the BGS and the United States Geological Survey. It incorporates data from satellite magnetic surveys and ground-based observations.

The production of the 1999 revision of the BGS Global Geomagnetic Model was supported by an oil industry consortium and the UK Health and Safety Executive and incorporates the latest data from organisations around the world. This model is used by the oil industry as a source for magnetic reference data in Measurement While Drilling (MWD) methods.

A model of the geomagnetic field in the region of the UK is derived annually, incorporating all newly available data from the UK repeat stations and observatories. This model is used to provide up-to-date magnetic north data on Ordnance Survey map products for the benefit of compass users. In 1999 measurements were made at 11 of the 51 sites in the UK magnetic repeat station network.

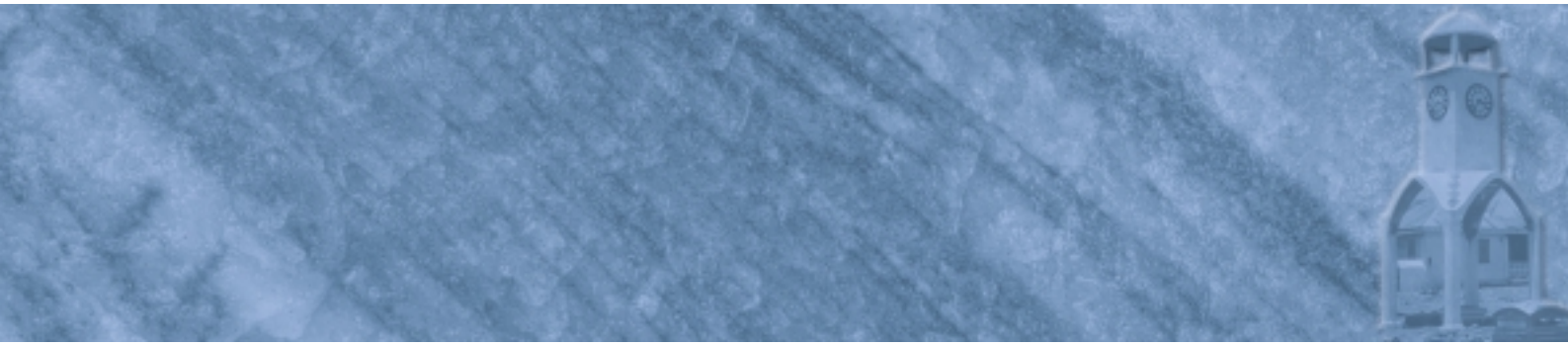
Seismic monitoring and information service

A broadly-based group of customers led by the DETR and including the nuclear, water, and oil industries, together with a number of public bodies, has supported the UK seismic monitoring and information service for eleven years. Seismic activity is monitored throughout the UK using a network of 146 seismic stations with information about significant earthquakes disseminated rapidly to customers. The data are compiled into monthly and annual bulletins and reports, and are used to populate the database for seismic hazard assessment. There was a high media interest during the year with over 600 interviews conducted, including 27 for television and 94 for radio. Of the 141 British earthquakes located 29 were felt, with some causing alarm locally. Of the overseas events, the earthquakes in Turkey and Taiwan dominated the headlines with 18 000 and 2400 fatalities, respectively.

Geophysical monitoring

The UK magnetic observatories at Lerwick, Eskdalemuir and Hartland continued to operate successfully with rapid data retrieval to Edinburgh using telephone and Internet links and data products published on the Geomagnetism Information and Forecasting Service (GIFS), accessible via the World Wide Web. GIFS provides a seven-day, 24-hour service to academia, government and commerce. The BGS magnetic stations on Ascension Island and in the Falkland Islands were maintained and, through the INTERMAGNET programme, data from a global set of magnetic observatories were exchanged in near real time with agencies in the USA, Canada, Japan and France.

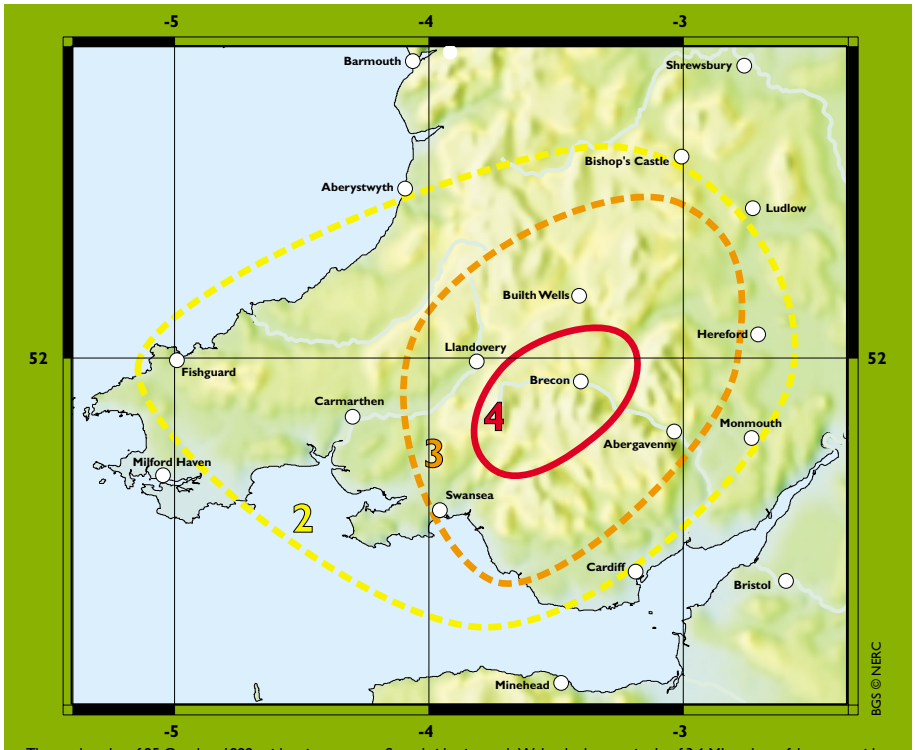
Improvements were made to the instrumentation and data collection hardware and software installed at sites in the 146-station UK seismic network, with particular efforts made to ensure Y2K compliance. The network was extended to the Faroe Islands with the support of the GEM oil company group and the Faroes Geological Department. The recording of strong ground motions from nearby earthquakes was improved and this will provide data relevant to safety considerations for the nuclear industry. Every six hours, recordings of seismic events were retrieved to



Edinburgh automatically, under computer control, and analysed promptly to determine time, location and magnitude. Rapid exchange of seismic data on significant earthquakes in Europe was promoted through cooperation with several European institutions. The National Seismological Archive, a repository for bulletins, seismograms and other papers from seismological observatories in the UK that have now closed, and other material of seismological interest, continued to be maintained and to be an important source of information to seismologists worldwide on data from past earthquakes.

Multicomponent seismology

Research on seismic wave theory was carried out to investigate the effects of fluid-filled fractures on wave propagation. Synthetic modelling has demonstrated links between fluid flow properties and seismic anisotropy. Significant advances were made in the analysis and interpretation of multicomponent sea bed seismic data in the presence of anisotropy. These include modelling and imaging algorithms for converted waves in anisotropic and inhomogeneous media, and the building of common velocity models for migrating both compressional and converted shear waves.



The earthquake of 25 October 1999, with epicentre near Sennybridge in south Wales, had a magnitude of 3.6 ML and was felt over a wide area. This map shows lines of equal intensity (isoseismals) using the European Macroseismic Scale. The data were provided by more than 270 members of the public who returned questionnaires published in local and national press. The values can be interpreted as: 4 = felt by many, windows and doors rattle; 3 = felt by few; 2 = felt by very few.

Earthquake damage in the Gölchuk region of Turkey from the Kocaeli earthquake of 17 August 1999 00:01 UTC, magnitude 7.5 Ms, which killed 17 000 people. BGS staff were involved in the post-earthquake damage survey.

Russ Evans, BGS © NERC

"... the production of the 1999 revision of the BGS Global Geomagnetic Model was supported by an oil industry consortium and the UK Health and Safety Executive and incorporates the latest data from organisations around the world ..."

Working for our customers

International Development and Assistance

Recovering the lost gold of the developing world

This project is aimed at improving the livelihood of small-scale/artisanal gold miners and their families by enhancing the recovery from their often inefficient mining operations. A scoping study of both technical and sociological aspects showed there was great room for improvement and that field demonstrations and training were likely to be the most effective means to help the miners. Field workshops have been held in Guyana and Zimbabwe introducing best practice techniques and demonstrating better recovery. Measurements by a Canadian collaborator in Guyana showed that, at one of the better operations, recovery improved from around 60% to 80% hence even larger improvements might be expected when less efficient miners adopt best practice.

Clive Mitchell, BGS © NERC

Ore testing using a mini-sluice in Zimbabwe as part of a project to enhance recovery from small-scale gold mining operations.

Volcon

The utilisation of volcanic rocks as raw materials for construction is the focus of the present Volcanics for Construction (VOLCON) DFID-funded KaR project. The main volcanic raw materials used include lavas, pumice and scoria, perlite, zeolite-rich rocks, ashes and tuffs. These materials are used in construction as sources of aggregate, lightweight aggregate, pozzolana for cement and concrete, and expanded perlite which is used as loose-fill granules and in plaster-board. The philosophy adopted by the project is to try where possible to evaluate the potential of volcanic raw materials *in situ* rather than try to sample the rocks systematically and dispatch vast volumes of material for laboratory inspection. With this in mind we have evaluated several chemical tests which permit the field identification of zeolite minerals. We are also using the recently developed Portable Infrared Minerals Analyser (PIMA) in order to identify zeolite-bearing rocks, and hydrated volcanic glasses which are prospective perlites.

Fluoride reduction in groundwater of Central Europe

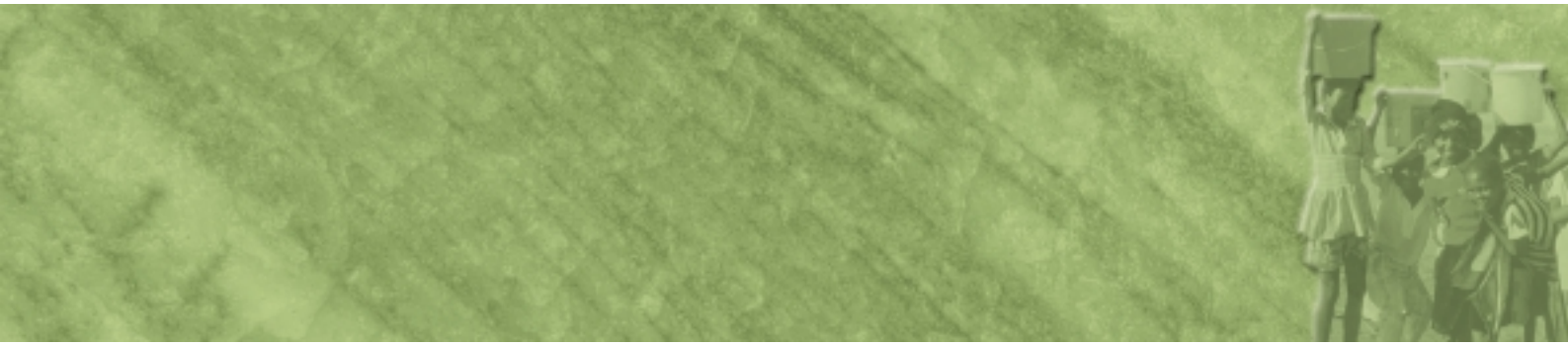
High fluoride concentrations (greater than 1.5 milligrams per litre) in drinking water can cause dental and skeletal fluorosis in humans. This three-year project, co-funded via the EU Inco-Copernicus programme, aims to develop a low-cost water treatment system to remove fluoride from drinking water. The system will be tested and installed at a number of sites in Central Europe where high fluoride in water is a known problem. The BGS component of the project is to develop GIS-based fluorosis vulnerability maps for Moldova, Ukraine, Hungary, and Slovakia to indicate areas where remediation treatments may be required. The detailed framework of the project GIS has been agreed and initial geoscience data incorporated into the prototype GIS. Generic methods of combining different types of data to produce risk assessment maps have also been tested. The bulk of the data from geochemistry and health studies under way in Ukraine and Moldova will be made available to the GIS during 2000, allowing the full development of the GIS and risk assessment maps.

Peter Dunkley, BGS © NERC

A field test method for the identification of zeolites being trialled in Ecuador. Such tests may be a valuable tool in evaluating the potential of volcanic raw materials.

FAMEST

FAMEST is a project, co-funded by the EU, to study the fundamental aspects of metal speciation and transport in metal-contaminated soils and aquifers. It uses the latest laboratory and modelling techniques to understand the fate of metals in metal-contaminated sites in the UK, France, the Netherlands, and Switzerland. The contaminated sites include two sites near lead-zinc smelters, a



farm site contaminated by zinc- and cadmium-laden sewage sludge applications more than 20 years ago, and an experimental plot where copper was added, and the soil pH adjusted, to give a wide range of pHs. The aim of the project is to develop simple and reliable methods that can be used to predict the concentration of metals in soil solutions and how these will change with time as the metals are gradually leached by natural processes. A new method has been developed for measuring directly the very low free metal ion activities of soil solutions. These often depend on the concentration of natural dissolved humic materials present. A generic database for proton and metal ion interactions with such humic materials has also been prepared. This can be combined with geochemical speciation and transport models to estimate the movement of metals through the soil to the underlying aquifer. Other, simpler, transport models have also been applied which are more appropriate when less is known about the detailed soil properties.

Evaluation of hazards from mine wastes

Pyrite oxidation and the associated acid leaching of toxic metals from mine wastes can be a substantial problem at many active and abandoned mine sites, as the resulting migration of contaminants into surface drainage courses and groundwater may present a serious hazard to local water consumers. In most developing countries, the resources available for the remediation of these hazards are limited and there is a need for techniques which allow the relative risks at different sites to be assessed, so that resources can be effectively targeted. With this aim in mind, a decision-support software package, MINDEC, is being designed with funding from the DFID under the KaR programme, to assist with the cost-effective risk assessment of mine waste sites, on the basis of the limited data-sets which may be available as model input. A preliminary version of the software has been completed during 1999/2000 and field data were collected from a variety of mine sites in Chile and Zimbabwe in order to validate the model.

Acidic leachate with high concentrations of heavy metals draining from mine tailings, Chile.

BGS © NERC

Mercury pollution of rice fields

The lack of appropriate technology and proper health and safety procedures in the informal gold mining sector in Mindanao, Philippines has led to severe environmental degradation and mercury pollution of river systems and adjacent agricultural sites. UNIDO contracted the BGS to conduct a study of the extent of mercury and related chemical pollution of two river systems and their neighbouring rice fields and banana plantations. Most of the pollution emanates from the Diwalwal mining centre where gold is extracted from ore by cyanidation and amalgamation using mercury. Silt-laden mercury-contaminated mineral processing waste waters have been used over the past decade to irrigate rice paddy fields of the Naboc Communal Irrigation Systems which provide food for about 600 farmers and their families. Multiple influxes of irrigation water have deposited silt containing up to 90 milligrams per kilogram mercury that has been ploughed into the soil profile. The maximum permissible concentration of mercury in UK agricultural soils (one milligram per kilogram) is exceeded in most of the rice paddy soils. Studies by CEH, Monks Wood indicated that little mercury was adsorbed into the rice grain. Adsorption of mercury onto secondary iron hydroxides and organic matter together with the formation of mercury sulphide in the anoxic layers of the soil profile may render mercury relatively unavailable to plants.

Mercury contaminated, silt-laden irrigation water in a canal and an adjacent rice paddy field, Mindanao, Philippines.

Don Appleton, BGS © NERC

Working for our customers

Jeffrey Davies, BGS © NERC

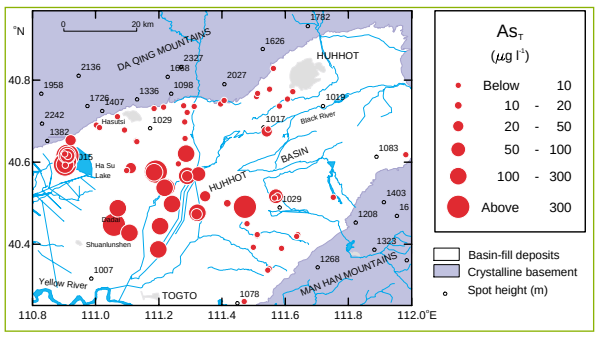
Four women are required to operate this low-yielding deep-set India MkII handpump at a World Vision installed borehole at Nyambakyere, Afram Plains, Volta Region, Ghana. The borehole is installed in Cambrian age Voltaian quartzitic sandstones.

Groundwater from low permeability rocks in Africa

Low permeability sedimentary and crystalline basement rocks underlie much of sub-Saharan Africa. Groundwater is the preferred source of water for rural communities located upon such strata. The DFID are funding the BGS to provide understanding of the groundwater occurrence, resource limitations, and development methods within such geologically difficult areas. Reconnaissance groundwater resource studies have been undertaken, in collaboration with WaterAid and their local NGO associates, in four project areas in Ethiopia, Ghana, Tanzania and Zambia. Further, more detailed, studies will be made of the areas in Ghana and Tanzania during the second year of the project. The aims of the project are to develop methods, suitable for NGOs and local government staff, for providing an initial assessment of the groundwater resource development potential of a limited area at minimal cost.

Environmental arsenic exposure

The BGS has recently completed a three-year DFID-funded (KaR) project investigating the occurrence and causes of arsenic contamination in groundwaters and identifying suitable mitigation measures. Arsenic problems in groundwaters typically occur under a restricted set of hydrogeological and geochemical conditions: under strongly reducing conditions; under oxidising conditions where groundwater pHs are high (greater than 8), such as in semi-arid regions; in areas of sulphide mining; and in geothermal areas. During the project, field studies were carried out in the Quaternary aquifers of La Pampa Province of central Argentina, Chapai Nawabganj District of western Bangladesh, and the Huhhot Basin of Inner Mongolia, all of which have serious and extensive groundwater arsenic problems. Studies highlighted different processes of arsenic mobilisation. In Inner Mongolia and Bangladesh, arsenic release occurs under strongly reducing conditions and is thought to be derived from iron oxides by desorption and dissolution. In La Pampa, the aquifers are oxidising and release from oxide minerals occurs by desorption under high-pH conditions. In both Inner Mongolia and Argentina, serious problems with fluoride contamination and high salinity also occur. Mitigation measures are very varied according to the aquifer situation, climatic conditions and other socio-economic factors. Options include detailed screening of wells to identify good-quality water sources, treatment of high-arsenic groundwaters, use of treated surface water where it exists, use of deep tubewells (Bangladesh, Argentina), and rainwater harvesting (Bangladesh, Argentina). The project has helped to identify the key factors involved in arsenic mobilisation in aquifers and to determine indicators likely to be diagnostic of arsenic vulnerability in other areas.

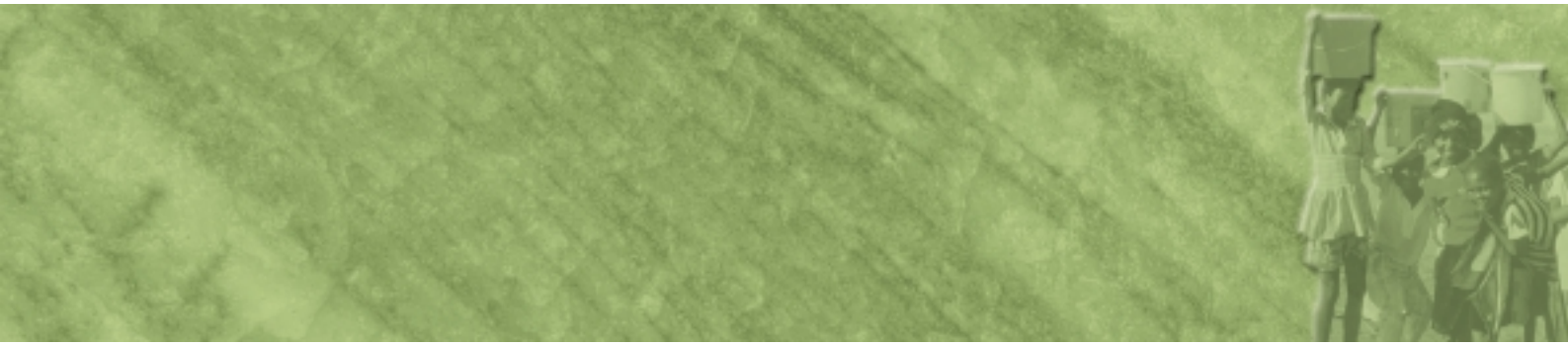


Pauline Smedley, BGS © NERC

Distribution of total arsenic (As_T) in groundwaters from the Huhhot Basin of Inner Mongolia. High concentrations (up to 1.5 mg/L) are found in the low-lying parts of the aquifer, where the groundwaters are strongly reducing.

The Falklands offshore hydrocarbons project

Petroleum work commissioned by the Falkland Islands Government has continued throughout the year on three fronts. Firstly, an in-depth analysis has been conducted into the results of the six exploration wells drilled for hydrocarbons in the North Falkland Basin



during 1998. This post-mortem review has established that a viable petroleum system exists in the region. The recovery of live oil, which flowed to surface during drilling, proves that there is potential in the area for commercial discoveries to be made. Results of the well analyses suggest that future wells should target play concepts developed around the basin margins, or those located stratigraphically below the main source rock interval. Work has also continued mapping other regions of the offshore area, principally with a view to defining future drilling sites in areas beyond that explored in 1998. Another strand of this work has been the delineation of potentially prospective areas that could be offered by the Falkland Islands Government for future oil licensing. Technical and administrative work has also continued in the area to the south-west of the Islands, in the so-called Special Co-operation Area, with the intention of establishing exploration there under the coordinated legislative regimes of both the Falkland Islands and Argentina. Recent geological interpretations have highlighted the potential for attractive exploration targets being developed in the region, and ways are being sought of offering licences to the international oil companies.

Mineral resource information

The preparation and review of Mineral Local Plans requires comprehensive information on the nature, extent and importance of mineral resources. This is essential for identifying areas of future mineral working and the longer-term objective of safeguarding important mineral resources against sterilisation by unnecessary development. To assist this process the BGS is carrying out research on behalf of the DETR and producing digital maps for incorporation into a GIS showing the extent of mineral resources and relating these to any environmental constraints that may effect their extraction. Maps ands reports were published for Warwickshire and the West Midlands, and Worcestershire and Herefordshire, and a further four counties are in preparation. At a more detailed scale, work on the mineral resources of the Wareham Basin continued. The Basin is highly valued for its landscape and nature conservation importance, particularly heathland. It also contains nationally important ball clay resources as well as sand and gravel resources of regional importance. A synthesis of the mineral resources and environmental constraints within the Basin has been produced and incorporated into a GIS which allows rapid integration and analysis of the data.

Brick clay planning issues

Fired clay bricks and related products, such as roof tiles and pipes, are essential for the construction and maintenance of the built environment. The UK brick industry is a significant contributor to the national economy, but a number of changes in the past 25 years have altered the relationship between this industry and the clay resources on which it depends. These changes have created difficulties for industry in accessing raw materials in some areas and undesirable environmental impacts in others. The BGS has been commissioned by the DETR is to identify and analyse the land-use planning issues which are contributing to these problems, and to recommend solutions. This involves developing an understanding of the economic, technical, environmental, and cultural factors which are driving change in the brick industry, and in assessing the planning response.

A typical Bangladesh handpump in the village of Mandari, Lakshmipur, south-eastern Bangladesh.

David Kinniburgh, BGS © NERC

Resources — Minerals

Fired clay bricks and related products are essential for the construction and maintenance of the built environment.

Tim Cullen, BGS © NERC

Working for our customers

Resources — Oil and Gas

Chris Turbitt/James Carrigan, BGS © NERC

The magnetic observatory under construction at the Environment Canada meteorological station on Sable Island. Due to the remote nature of the location, prefabricated huts were shipped to the island and set in place by helicopter.

Topography based on Ordnance Survey mapping © Crown Copyright. Ordnance Survey Licence number GD272191/2000.

Geological radon potential map of part of the five kilometre grid square (485265) encompassing the western sector of Wellingborough, Northamptonshire. The map illustrates the distribution of areas for which basic (blue) and full (pink) radon potential measures are indicated.

Improving accuracy in directional drilling

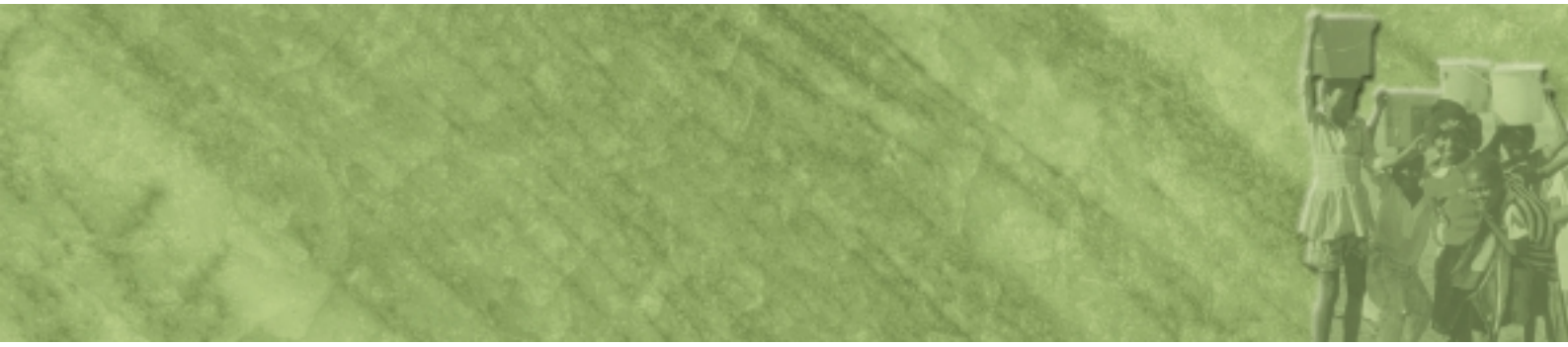
The method of improving the accuracy of the geomagnetic field as a direction reference when surveying directional well-bores, known as Interpolation In-Field Referencing (IIFR) is now widely used in the oil industry around the British Isles. During the year, 30 wells in 13 oilfields in the North Sea were drilled using a combination of data from the three BGS magnetic observatories to correct for magnetic storm variations. Corrections for the local magnetic field due to magnetic sources in the Earth's crust are made using either land-based measurements or aeromagnetic survey data. The technique has been developed and marketed under an Alliance Agreement with Sperry-Sun Drilling Services, who commissioned the building of a magnetic observatory on Sable Island, nearly 200 kilometres offshore Nova Scotia. This installation was made specifically to support directional drilling during the development of the offshore gasfields in the region. The magnetic observatory runs automatically with a satellite phone link to transmit the data to the BGS Edinburgh office for processing. Measurements can be made available to the drilling surveyors hourly if required. An aeromagnetic survey of the area was flown to allow corrections for crustal magnetic variations in the region to be made. In the first year of operation seven wells in four fields operated by two different clients benefited from the data supplied by the BGS.

Isle of Man geological projects

An extensive two-year collaborative research programme has been initiated regarding the Isle of Man and its offshore-designated area. The work programme has been agreed with the Isle of Man Government, and is generously funded by Elf Exploration and their partners Amerada Hess and Enterprise Oil. This programme will deliver direct educational, environmental and economic benefits to the Isle of Man Government, to industry, universities and the wider community. Elf Exploration and other companies have also provided large amounts of recently acquired data and information to the work programme, which includes extensive collaboration with university researchers, Manx National Heritage, and government departments on the Isle of Man. The three main deliverables that will result from the work are a new geological map of the island, a regional guide to the geology of the Isle of Man and its offshore-designated area, and a popular publication on geological aspects of general interest.

Rockall consortium

The BGS manages, and is a partner in, a consortium with 14 oil companies. In 1999 the BGS completed a successful shallow borehole drilling programme on behalf of the consortium. Seven boreholes were completed between June and July using the drillship *MV Bucentaur,* including the first ever boreholes drilled on Hatton Bank (800 kilometres west of the Scottish mainland and due south of Iceland). Two of the boreholes were drilled in Faeroese waters. Over 340 metres of continuous coring was undertaken with the sub-Quaternary recovery being excellent. The maximum water depth in which the ship operated was 1183 metres and the deepest borehole penetrated 166.5 metres below the sea bed. The results of the drilling, including all the analytical data, were compiled into a report which remains confidential to consortium members for a number of years. Subsequently, ownership of the core, and the results, reverts to the BGS and will be incorporated into published BGS map products. At the end of the year, plans were being made to build on the success of the drilling by conducting a



5000 kilometres geophysics cruise across parts of Rockall Bank and Hatton Bank in order to identify further possible drilling locations. Early in 2000 rationalisation in the oil industry caused a reduction in the number of oil companies in the consortium to eleven. Since the BGS instigated the consortium at the start of 1992, nearly 11 000 kilometres of seismic data have been acquired most with co-incident gravity, magnetic and bathymetry data, fourteen shallow boreholes have been drilled and over 250 gravity, rockdrill, or vibrocores have been collected. Numerous geological desk studies have also been undertaken. This work has been carried out in a frontier part of the UK offshore designated area where deep water and uncertain weather conditions cause difficult surveying conditions. Despite this the BGS and the Rockall Consortium have achieved a number of geological 'firsts' which will eventually become public domain information.

Radon Protective Measures GIS

The BGS has developed a Radon Protective Measures Geographical Information System (RPM-GIS) that provides reports for developers and householders indicating the requirement for radon protective measures in new dwellings and extensions. Reports are derived from a geologically-based interpretation of radon measurements in dwellings. The GIS is based on the principle that the variation in radon levels between different parts of the country is mainly controlled by the underlying geology. The RPM-GIS is being upgraded from 1:250 000 to 1:50 000 scale as new digital maps become available through the BGS DigMap programme.

Beachy Head stability

Slope stability and geophysical field surveys of Beachy Head have been carried out for Trinity House Lighthouse Service following the major rock slide of the 125 metres chalk cliff in January 1999. Debris from this, estimated at 260 000 tonnes, reached to within 40 metres of the light-house. The slide severed electricity cables running from a concrete bunker on the clifftop to the lighthouse. The BGS monitored an unstable block which remained attached to the cliff for several weeks after the main collapse and which caused delays in engineering work.

Geomagnetically induced currents and electricity transmission

Rapid field variations during magnetic storms can induce currents in power grids leading to operational problems and, in severe circumstances, to power cuts. Following on from a study for the National Grid Company carried out in 1998, Scottish Power commissioned the BGS to provide a geomagnetic monitoring and prediction service to assist in managing the risk to the power transmission grid posed by geomagnetically induced currents (GICs). Data from the three UK magnetic observatories are used to provide information to Scottish Power on the level of magnetic activity each hour. Software and procedures have been developed to provide reliable data communication. Additionally, a three-day forecast of the geomagnetic conditions is provided each working day, based on a combination of UK observatory data and space environment data from a wide variety of sources. Scottish Power have installed equipment to measure GICs at three sites, and are sharing these data with the BGS for further study to understand the response of the grid to geomagnetic storms.

Geology and Geohazards

Schmidt hammer testing chalk blocks within a fresh rock fall at Beachy Head for Trinity House Lighthouse Service.

Peter Hobbs BGS © NERC

Risk of Subsidence due to Evaporite Solution (ROSES) project

Natural breakdown cone of debris funnelling into the Mylinki Gypsum cave in the western Ukraine. The cone is developing beneath an area of subsidence at the surface.

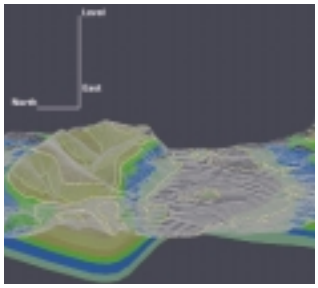
Tony Cooper, BGS © NERC

Working for our customers

BGS © NERC

Map indicating the density of landfill in England and Wales prior to 1974. The colours reflect the number of sites per 100 square kilometres.

Environmental Geoscience



Nick Robins BGS © NERC

A Vulcan® screen shot of the Lewes area looking eastwards. The alluvium of the River Ouse can be seen where it broadens out in the eroded core of the Lewes anticline. The Caburn syncline is to the north.

Land quality in the United Kingdom

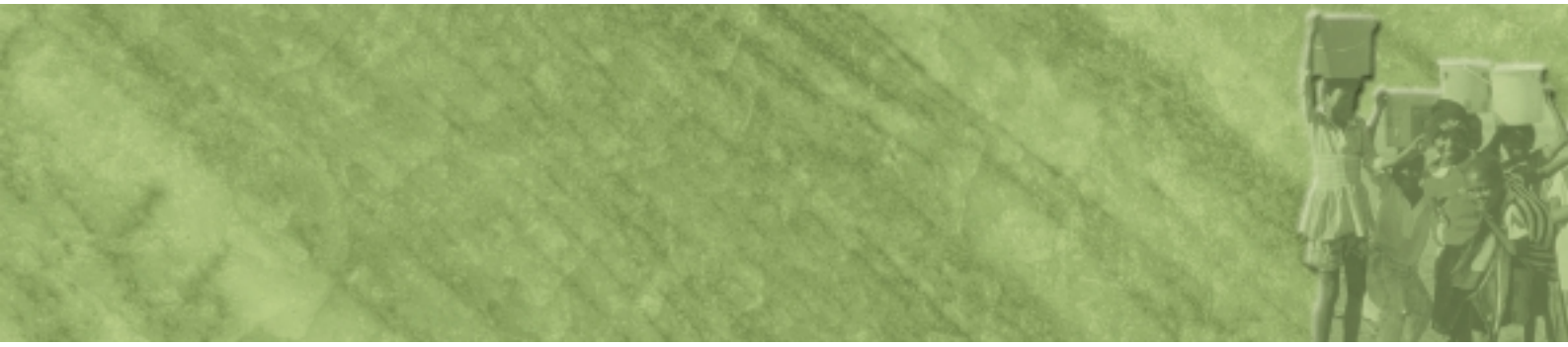
On behalf of the Environment Agency, the BGS undertook a review of information relating to land quality in the UK which produced four separate reports covering England, Wales, Scotland, and Northern Ireland. The sources of information reviewed included soil survey and environmental monitoring data, research studies, and land-use classifications. The study focused on those data-sets which were considered representative of land quality at regional and national scales, rather than local or site-specific scales. The study showed that traces of potentially toxic and carcinogenic substances, such as polychlorinated biphenyls, polynuclear aromatic hydrocarbons, dioxins, furans, and various inorganic compounds, have been widely reported in soils across the UK. The concentrations have also been found to be greater in urban areas and surrounding point sources than in rural locations. For many heavy metals and inorganic substances, elevated concentrations may be associated with naturally mineralised environments in both urban and rural locations. Knowledge gaps in land-quality information were highlighted, while a number of factors were shown to be limiting the exploitation of existing data. These factors include poor intercomparability of survey data and a lack of integrated digital data-sets for use in geographical information systems.

Visualisation and 3D modelling of the South Downs aquifer

A computer 3D geological and structural model of the Brighton and Worthing areas of the South Downs has been created. This work includes new geological mapping and reinterpretation of available seismic data for the area. The model forms the core of a joint project with Southern Water Group Water Resources Team which will lead to a new conceptualisation of the groundwater flow patterns in the South Downs. The 3D model uses the Vulcan® software which has highlighted areas of anomalous dips and discontinuous bedding planes associated with deeper tectonic features. The flowpath conceptualisation addresses a number of issues specific to Chalk hydrogeology. These include: whether the highest permeability zones in the Chalk are actually in the saturated zone of the aquifer; whether or not a borehole intersects a yielding fracture system; whether there is lateral continuity and hydraulic connection between the fractures; and the role of dissolution of karst features both today and in periods of lower (and higher) sea level over the past 20 000 years.

Aquifer storage and recovery

The water industry in the UK is actively investigating the potential of storing treated water underground in aquifers as part of their water resources strategies. ASR-UK is a Foresight LINK/UKWIR funded project to investigate the technique in the context of British aquifers. In the first year of this 30-month project, modelling has been developed to simulate the physical aspects of injected water movement and mixing with native groundwater. Additionally, the geochemical aspects of water/water and water/rock interaction have been modelled and attempts to link the two models have been made. Model validation will use results from current field trials being undertaken by water companies. A web site has been established on which interim reports are published.



Environmental GIS and digital environmental data

As a product of a BGS–Environment Agency project completed in March, the Agency has published a joint report entitled *Some guidance on the use of digital environmental data*. This report details how to set up a land quality geographical information system (GIS). This was partly based on experience gained by the BGS in three local authority test areas: the London Borough of Newham, Leicester City and the East Riding of Yorkshire. The demonstration GIS for Newham was adapted to show how contaminated sites can be prioritised for further investigation under the new Part IIA contaminated land regime of the Environmental Protection Act.

RESCAN resistivity tomography

As part of a wider study to assess the impact of unconfined landfills on groundwater quality, a 3D RESCAN survey was undertaken for the Environment Agency at the closed Thriplow Landfill, Cambridgeshire. The survey helped to define the subsurface 3D geometry of the deposited waste, to map the hydrostratigraphy, and to identify possible leachate pathways in the underlying Chalk. The study confirmed that the waste had been deposited in discrete gravel pits. The low resistivity values immediately below the waste pits at depths greater than ten metres suggest that leachate has infiltrated the Chalk bedrock.

Monitoring the Test Ban Treaty

The BGS operates the UK National Data Centre for monitoring the Comprehensive Test Ban Treaty (CTBT) by seismic identification of underground explosions. Data produced by a global network of seismometers is acquired via an International Data Centre (IDC) in Vienna, and recorded events are processed and analysed by BGS seismologists. The UK provides the IDC with data from a multi-station seismic array at Eskdalemuir, which is also operated by the BGS. Such arrays are particularly useful for the detection and analysis of small seismic signals. The BGS collaborates with AWE Blacknest and the CTBT Organisation (CTBTO) in Vienna in developing and applying specialised seismic analysis software. A workshop organised by the BGS and the CTBTO produced recommendations for the improvement of the CTBT monitoring effort, which the global monitoring community have endorsed for speedy implementation.

Metals entering the Irish Sea

A method of distinguishing between the natural and anthropogenic sources of metals entering the Irish Sea through river inputs has been developed and tested for the DETR. Additionally, in conjunction with CEFAS and PML, an assessment has been made of whether metals in estuarine and coastal sediments are biologically available, and a means of distinguishing the relative contribution of anthropogenic and natural sources of metals to any biological uptake has been established. The project has used the BGS G-BASE geochemical database to determine the natural background geochemistry of the study catchments in the Mersey, Ribble, Wyre, and Solway Firth drainage basins. A programme of sampling and analysis of river and estuarine sediment has allowed the present fluviatile input of contaminants to the Irish Sea to be compared with the natural background and the contribution of anthropogenic metals to be calculated.

Julian Trick, BGS © NERC

Transport of pollutants beneath a cemetery

A project is being undertaken jointly by the BGS, the Robens Centre for Public and Environmental Health and the Environment Agency to investigate the presence and migration of inorganic, organic and bacterial contamination from the Danescourt cemetery in Wolverhampton. Results to date indicate the presence of high concentrations of faecal bacteria, ammonium and dissolved organic carbon down hydraulic gradient from the cemetery.

Sampling sediment on the Dungeon Banks, Mersey Estuary, to determine the input of contaminants entering the Irish Sea.

BGS © NERC

Science for all

Science and Society

A selection of popular publications produced during 1999/2000.

Tony Cooper, BGS © NERC

Alice in Wonderland

A presentation to the British Association for the Advancement of Science related subsidence caused by gypsum dissolution and resulting holes in the ground to the possible inspiration for 'Alice in Wonderland'. The association of Lewis Carroll with such features, both at Ripon and at Hells Kettles (above) near Croft, south of Darlington, where Carroll lived, was widely reported in the media.

Public understanding of science

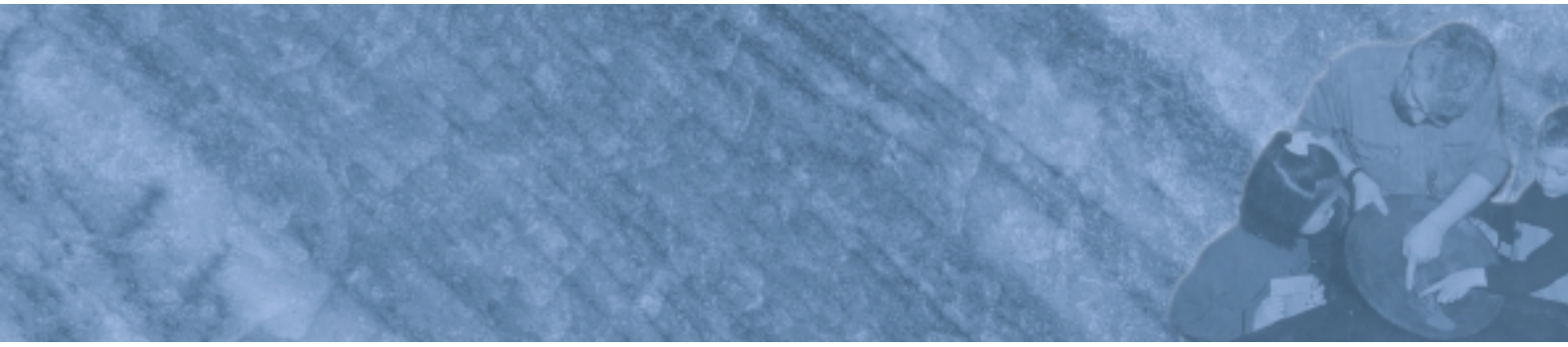
The BGS promotes the earth sciences generally and publicises its activities to as wide an audience as possible. Public understanding of science (PUS) activities included a series of evening classes on the theme *Geology and Man.* This was the ninth season of classes given in conjunction with the Department of Continuing Education at the University of Nottingham. Students have the opportunity to obtain credit towards certificates of higher education awarded by the university. The BGS also participates in national and regional PUS events such as National Science Week, and Scottish Geology Week. Survey staff take part in the NERC Schools Liaison and Communications Networks — this includes providing support for schools in the form of visits, talks and written materials. Presentations on the history and current activities of the Survey are regularly given to community groups, such as local history societies and the Women's Institute, as are guided tours of the BGS sites. The Survey also provides careers information, work experience placements, and Nuffield Bursary studentships. The BGS's national collections of British fossils, rocks, and minerals have played an important part in providing displays for Science Week, public exhibitions, and school visits.

Earthwise™ Publications

The following popular science publications were produced under the Earthwise™ label: six Fossil Focus guides — *Crinoids, Bivalves, Trilobites, Brachiopods, Fish,* and *Corals;* four Holiday Geology Guides — *Isle of Wight, Tower of London, Greenwich,* and *The Lake District Story;* and a Holiday Geology Map, *The Peak District.* An Earthwise™ book, *Catastrophes,* was published describing natural cataclysmic events such as the destruction of Pompeii by Vesuvius, the San Francisco earthquake of 1906, and the East Anglian floods of 1953, all captured in colourful and original illustrations.

BGS training and staff development

The BGS was successfully examined and had its Investors in People status renewed in July 1999. A new IT training room was brought on-stream in Wallingford, in collaboration with colleagues in the Institute of Hydrology. On average, 1448 staff spent approximately 3000 days in short-course training and some 35 persons were engaged in obtaining a further education qualification. The main functions of the training programmes were as follows. The scientific and professional training programme was maintained and new courses were brought on-stream in Geostatistics, Quaternary Processes, Clastic Sedimentology, Vitrinite Reflectance, and Groundwater Modelling. In addition a one-day workshop on the Portable Infrared Minerals Analyser was held. Individuals were sent to specialist courses dealing with Contaminated Land, DNAPL, Field Geophysics, and Seismic Lithology. Training for Library staff in using the online system OLIB was successfully completed as was the introduction of the entire financial staff to the new NERC ORACLE-based financial system. The established programmes of personal development and health and safety training continued while training in Information Technology continued at a high level of activity. Large numbers of staff passed through training courses in corporate standard software and specialists were increasingly sent to courses on advanced databasing, GIS, and Internet-based techniques.



Intranet Geoscience Data Index

The Intranet Geoscience Data Index (GDI) was completed and has been used successfully throughout the year. It shows the locations of major data-sets collected or acquired by the BGS both within the UK and overseas since 1835. The UK data-sets are drawn against an Ordnance Survey map backdrop. Details about individual sample points or survey areas can be listed. It enables BGS staff to see what data have been collected in the past and also to help answer data enquiries from outside the BGS. It is viewable by BGS staff only, but an Internet version accessible to all is being implemented in the next financial year.

The BGS Internet site

The BGS Internet site has continued to grow. Several BGS reports have been made freely available to download and additional products are constantly being added. An example is the BGS Rock Classification Scheme (RCS) which has been published as a series of open file Research Reports on the BGS web site during 1999. This is the new standard used within BGS for rock classification. The scheme has proved very popular externally and is regularly downloaded from locations all over the world. The RCS's popularity is based on the classification scheme being applicable to a wide range of geoscience disciplines. The scheme has been implemented as a series of hierarchical database dictionary tables. All new data with rock names entered into BGS databases conforms to this scheme and legacy data is being updated.

Library

A significant change in the Library was the implementation of the OLIB Library Management System supplied by Fretwell-Downing. The new system, known locally as GEOLIB, replaced LIBERTAS at the start of 2000. It contains bibliographical data in a user-friendly environment, which can be accessed via the Internet by both staff and external researchers. Some problems have been experienced with the transfer of the complex data relating to serial, book, and map holdings, and work is in hand to address these areas. Good progress has been made in converting earlier manual records into the database and bar-coding stock in preparation for the introduction of an automated loans system. Trials with linking text images to the bibliographical records have been successful, opening the way for a major programme of scanning text and images in the future. The 'virtual library' is emerging.

The SCRAN and JIDI projects to scan several thousand geological photographs have been completed and these digital images will form a basic input to the proposed National Archive of Geological Photographs. Expertise gained in these projects has led to the BGS winning further external contracts. The digital index to the BGS photograph collections, which has been compiled in the Library in recent times, is proving increasingly useful in answering enquiries on a range of topics and localities. The development of various digital indexes is improving the provision of information from a range of collections held in the BGS Library and Archives. Work in hand to link the index-level data and make it available over the World Wide Web via GEOLIB, together with images, will make the valuable information resource held by the BGS in its Library accessible to a much wider geological and non-geological audience.

BGS © NERC

Science and the media

Julia West wrote and presented a BBC Radio 4 programme for the 'Postmarks' series based on her work in Japan. The programme was transmitted in June 1999. She continues her liaison with the BBC Science Radio Unit providing geological stories which are used in both national and World Service programmes.

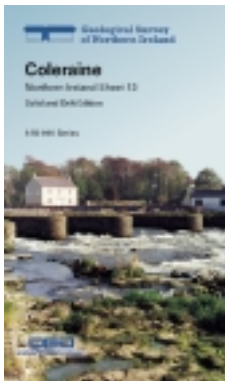
The BGS Press Office works in close cooperation with the media to raise the profile of the Survey and its science. Special attention is paid to keeping national, European and regional politicians aware of issues that may feature in their constituency media, and thus keep them aware of the impact of geoscience at voter level.

Northern Ireland

GSNI Highlights

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.



Solid and Drift geological map of Coleraine (Northern Ireland 1:50 000 Series, Sheet 13). The cover photograph is of The Cutts, Coleraine.

1:50 000 Map Series

The Coleraine Sheet was published. Conventional mapping techniques were used to complete the resurvey of the Dalradian, Carboniferous, Mesozoic/Cainozoic, and Quaternary deposits of the Dungiven Sheet. Resurvey of the Newtownstewart Sheet was started. Detailed mapping, rapid mapping, and desk compilation techniques were employed for the revision of the Maghera Sheet and Ballymena Sheet which, along with the Lisnaskea Sheet, are nearing completion. The Ballycastle Sheet was revised and restyled in the style previously employed in the innovative Causeway Coast map. Work began on a revised and restyled version of the *Regional Guide to the Geology of Northern Ireland.*

Landscapes from Stone

This project aims to provide resource material and promote landscape-related tourism in the north of Ireland. Phase I of the project was successfully completed with publication of *A Story through Time: The Formation of the Scenic Landscapes of Ireland (North)* later judged to be the 'Best Popular Publication from a Geological Survey' and awarded a prize by FOREGS (Forum of European Geological Surveys). Funding was obtained from the EU's Special Support Programme for Peace and Reconciliation for Phase II of the 'Landscapes' Project. Three 'Walks' packages and seven 'Explore Guides' were researched in the northern 12 county region of Ireland. Areas to be covered include: Sperrins, Sligo-Leitrim, Donegal, Lough Neagh, South Antrim, and Cavan-Fermanagh.

Earth science conservation review

The Environment and Heritage Service of the Department of the Environment contracted the GSNI to establish and describe a network of sites of special scientific interest covering the Late-Caledonian igneous complexes in Northern Ireland. Phase I of the project covered the Newry Igneous Complex and was successfully completed. Fieldwork and analytical work for Phase II (Tyrone Igneous Complex and miscellaneous intrusions) was completed and reporting commenced. A follow-up rock age-dating programme was initiated and samples submitted for U/Pb zircon analysis at the NERC Isotope Geoscience Laboratory, Keyworth. The main objective is to date key rock units and improve the chronology of late Caledonian events in Northern Ireland.

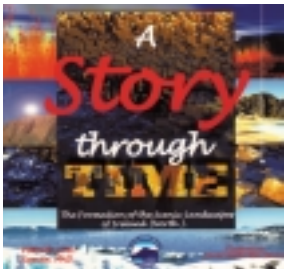
Resident hydrogeologist

The GSNI provides the Environmental Protection Division of the Environment and Heritage Service with geological and hydrogeological advice. The success of the long-standing Service Level Agreement between the GSNI and E&HS has resulted in the creation of a new hydrogeologist post in the GSNI for a three-year term wholly-funded by the E&HS in year one. The hydrogeologist represents the GSNI on cross-departmental committees planning detailed aspects of the implementation of European Groundwater Regulations (Northern Ireland) 1998 and is contributing to the development of new policies for groundwater abstraction and protection.

Information systems and database development

During the year the GSNI made substantial progress towards its objective of enabling digital access to its major geoscience data-sets. Two new databases were designed and largely populated: the site reports index complements the existing borehole database, whilst the abandoned mines database records potentially hazardous workings and remedial work undertaken on behalf of the Health and Safety Executive, DETI. A user-friendly GIS was designed to display a variety of geological databases including boreholes, mineral exploration data, exploration licences, quarries, mine shafts, and adits against the topographical map data of the Ordnance Survey of Northern Ireland. This system has already saved staff time answering enquiries and will be further developed with the addition of new data-sets and digital geological maps. The first products of the Digital Geological Map of Northern Ireland (DIGMAPNI) were completed this year. The 1:250 000 scale solid geology map of Northern Ireland was produced as a digitally-attributed vector data-set in two industry standard formats. The published 1:63 360 Dungannon sheet and accompanying 1:10 560 scale coalfield maps were also captured digitally in an area of particular interest in terms of natural resources and geohazards. A further set of published 1:63 360 and 1:50 000 scale maps were digitised this year and will be attributed in the next phase of DIGMAPNI.

A Story through Time, the award winning popular publication which promotes landscape-related tourism in the north of Ireland.



Enquiry service

GSNI staff continued to provide geoscience information and advice to the public and private sector in Northern Ireland. There was a continued growth in enquiries (11% increase) with a high demand for digital data and site specific advice. The GSNI advises the Planning Service under the terms of a long standing service level agreement and provides geoscience inputs and advice on matters including planning policy, minerals, and environmental impacts assessments.

Special projects:

The DETI commissions exploration, research, and data enhancement projects to help stimulate mineral and petroleum exploration by the private sector and attract applications for exploration licences. Three special projects were completed during the year.

- Investigations and analyses (in collaboration with BGS Mineralogy and Petrology Group) have proved significant cation-exchange mineral potential in altered Palaeogene basalts. Samples of waste basalt from quarrying operations in County Antrim possess properties necessary for use in clay-based landfill liners.

- Potential gold mineralisation was confirmed in parts of west Tyrone as a result of follow-up geochemical and geophysical exploration (in collaboration with BGS Analytical and Regional Geochemistry and Regional Geophysics Groups)

- Further study of fracture patterns in outcrop around the postulated location of the Draperstown Lineament confirmed the north–south orientation of this major fracture and its likely control on gold and base metal mineralisation. Grassroots exploration targets have been identified.

"... during the year GSNI made substantial progress towards its objective of enabling digital access to its major geoscience data-sets ..."

Isotope geosciences

NERC Isotope Geoscience Laboratory (NIGL)

Melanie Leng, BGS © NERC

Holocene-age laminated lake sediments cored from the Søndre Strønsjord region of western Greenland.

Determining the age of the Earth

Scientists at the NIGL have developed a technique which uses lasers to sample tiny areas of individual crystals and determine the age of the Earth. Samples reflecting the early to more recent magmatic, volcanic, tectonic and erosional history of the Earth have been dated by this technique which can also be used to investigate the origin and evolution of continental crust-forming rocks and the Earth's interior. Investigations of the geology of Scotland and Morocco have recently been completed using the laser, providing some surprising new insights into their geological past.

U-Pb chronology of ductile and brittle-ductile shear zones.

U-Pb dating of structures in complex metamorphic rocks is possible but success depends upon the analysis of growth and reaction textures of minerals affected by deformation. In this study we have dated mineral growth within the A'Chaillach ductile shear zone using syn-tectonic monazite preserved within mica 'fish'. The monazite has been dated at 818 ± 12 Ma and this age agrees with the ages of pegmatites in related shear zones. In contrast, brittle-ductile deformation resulted in no new growth of uranium-bearing minerals in the Eil Rig shear zone at higher crustal levels. Surprisingly, detrital titanite survived fragmentation and alteration, yielding a protolith age of 1725 ± 36 Ma. These results indicate that other structures, particularly lower–middle crustal shear zones, could be directly dated.

Isotopes and population migration studies

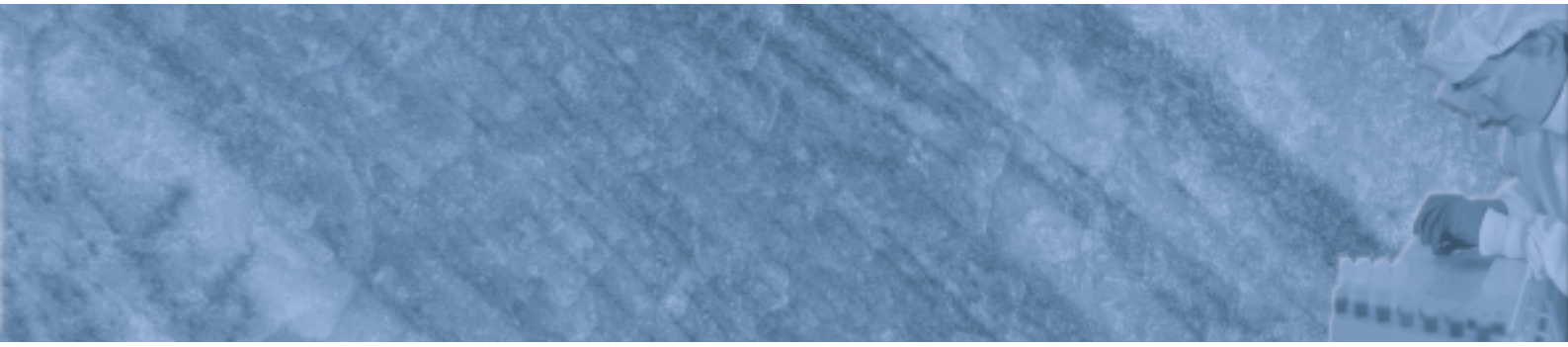
Populations migrate. Sometimes willingly and sometimes through necessity. As they do, cultures collide, interact, and assimilate, and these interactions can create turning points in history. But how can these migrations be traced? In archaeological studies how can 'outsiders' be identified within burial populations? The study of burial goods and artefacts is the traditional method but isotopic processes are shedding new light on migration studies. 'A person is what they eat' and a record of what an individual ate and drank as a child is locked into tooth enamel. This resistant material preserves the life signatures of strontium, oxygen, and lead isotope composition, which provide information about the area, climate, and culture in which a person was raised. Collaborative studies between the NIGL and Bradford University during the past couple of years have used these techniques to address such topics as the lifestyle of Neolithic people and the extent of Anglo-Saxon and Viking migrations into and within the UK.

The same techniques are being used to look at modern bird migration in a collaborative study between the NIGL and Stirling University.

Climate variability in west Greenland

Western Greenland has numerous lakes which have enormous potential for palaeoclimatic reconstruction. Oxygen isotope records from sediment cores contain authigenic calcite which provides information on climate. Authigenic calcites have $^{18}O/^{16}O$ ratios which essentially record the $^{18}O/^{16}O$ ratio of lake water, which is itself a function of the precipitation/evaporation balance. The isotope data show that apart from inferred wetter periods around 8500–7500 and 6000–5000 years BP, this area has always been drier than today. An extremely rapid change in the $\delta^{18}O$ data started at around 7500 years BP suggests a marked arid phase causing substantial evaporation and lowering of lake levels. The isotope data suggest that, at a regional scale, climate was quite dynamic in the early Holocene, perhaps representing an interplay between changing ice masses and processes in the Davis Straits.

The NIGL has joined researchers at the University of Nottingham and IACR-Rothamsted in a study of nitrogen fluxes in the Spitzbergen tundra.The project is funded through the NERC's Global Nitrogen Enrichment (GANE) Thematic Programme, and reflects growing concern that



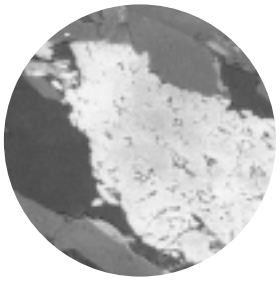
increased levels of pollutant-derived nitrogen compounds in snowfall to the high Arctic tundra may start to have a major impact on its sensitive, nitrogen-limited ecosystems. The NIGL's work will focus on using $^{15}N/^{14}N$, and newly-developed $^{18}O/^{16}O$ techniques to determine the fate of inorganic nitrogen released during snowmelt. How much of the nitrate (derived from atmospheric NOx gases), for example, is intercepted by the soil/plant system before running off to the surrounding sea?

Identifying the fingerprints of urban pollution sources.

The soil of derelict urban land can conceal a legacy of pollution from previous industrial occupants. To encourage safe redevelopment of sites with higher soil-lead concentrations, a better understanding of this pollutant's behaviour is required. A new procedure is being developed to determine the source of individual lead-bearing particles in contaminated soils. Lead-enriched particles from natural and anthropogenic sources are identified using scanning electron microscope image analyses. Then high-precision lead isotope analyses are made by laser ablation to determine the isotopic fingerprint of each lead-rich grain. This can be used to trace the mobility of lead in the soil, and can be compared with the isotopic signatures of potential pollution sources to trace the origin of the contamination. This work forms part of the NERC URGENT project *Studies into metal speciation and bioavailability;* a collaboration between the BGS, the NIGL, Imperial College and Nottingham University.

Clearance of old factories and heavy industry leaves a legacy of derelict land. Redevelopment of sites is desirable but there can be hidden pollution problems.

The bright region is a brittle-deformed titanite within the Eil Rig Shear zone. Enclosing micas experienced ductile deformation. The deformed rock is a pebbly psammite and the titanite (and associated allanite) is detrital.



E K Hyslop, BGS © NERC

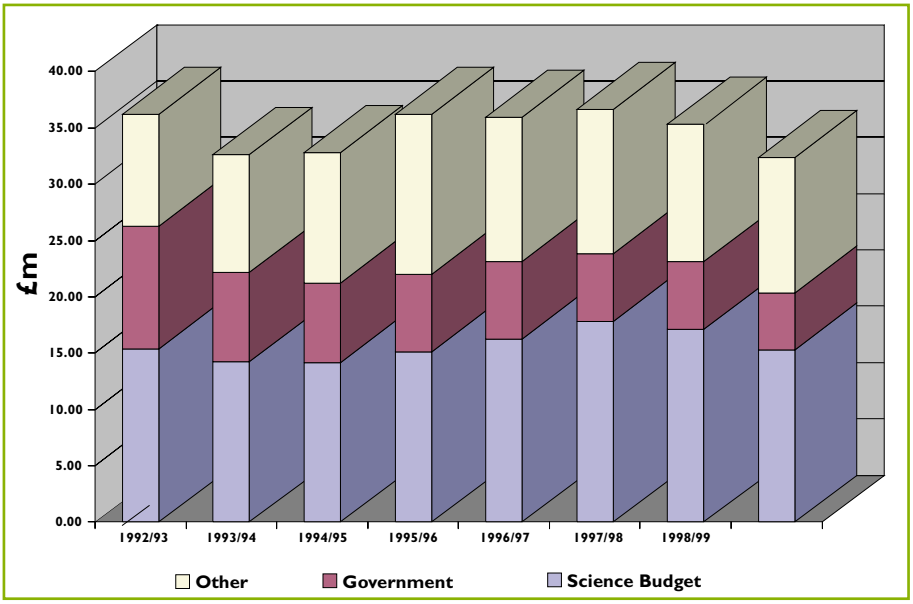
Lichens and purple saxifrage (the world's northernmost flowering plant) on the Spitzbergen tundra. $^{15}N/^{14}N$ and $^{18}O/^{16}O$ studies are to be used in assessing how this sensitive ecosystem may respond to increased atmospheric pollution.

Tim Heaton BGS © NERC

Vital statistics

The Financial Year 1999–2000

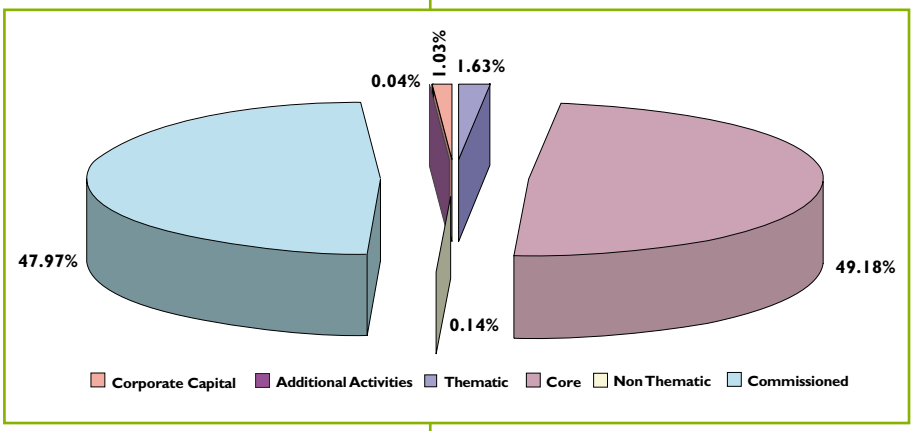
CORE ACTIVITY	
Onshore and geophysical surveys	£6,139,173
Hydrocarbons, offshore surveys and geophysical monitoring	£2,581,672
Mineral and geochemical surveys	£1,696,825
Hydrogeological and geotechnical surveys	£1,357,754
National geosciences information service	£4,564,118
Additional core activities	£85,167
Total Core	**£16,424,710**
Responsive	£16,022,613
Thematic	£545,193
Non-thematic	£47,868
Additional activities	£14,759
Corporate capital	£344,552
Grand total	**£33,399,695**



Sources of BGS income 1992/93–1999/2000 (at 1999/2000 prices).

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 research programme enhances the BGS Core Strategic Programme through funding, ideas, data, and review. It facilitates a more vigorous multidisciplinary programme than could otherwise be provided, including the development of expertise and the maintenance of critical mass within each project area. The Commissioned Programme enhances the relevance of the BGS's capability to meet the requirements of government, the community, and industry.



BGS expenditure — 1999/2000.

The BGS Board as at 1 January 2000

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 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

Dr E R Hassall CBE	Chairman
Dr D A Falvey	Executive Director, BGS
Mr C M Read	NERC Finance & Information Systems Director
Dr O A Bavinton	Senior Vice President — Exploration, Anglo American plc
Dr M J Carter	Managing Director of M J Carter Associates
Prof. A L Harris	Dean of Science Faculty, University of Liverpool
Dr J P B Lovell OBE	Senior Research Fellow, University of Cambridge
Mr J Mortimer	Independent consultant
Dr R A Scrutton FRSE	Reader in Marine and Applied Geophysics and Head of the Department of Geology and Geophysics, University of Edinburgh
Prof. G Walton	Senior Partner, Geoffrey Walton Practice
Dr B R Marker	(Observer) Department of Environment, Transport and the Regions

Secretariat:

Mr F G Curry and 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. The latter 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 academia. 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.

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