British Geological Survey

Annual Report 1998–1999

Natural Environment Research Council

Foreword

As Chairman of its Board I am pleased to contribute this Foreword to the British Geological Survey's Annual Report.

This year has seen significant decisions taken on organisational and programme restructuring and consolidation of management policies designed to equip the BGS to meet fully new and exciting challenges. This process is likely to continue into next year.

In managing these changes I express sincere gratitude to the Director, Dr Falvey, his executive team and the staff of the Survey who have contributed so much to the new strategic planning processes as well as the continuing operational programmes. I also appreciate the continuing support of members of the Board and particularly their contributions to Programme Development Groups.

Of course, change can bring uncertainty, but I am satisfied that all reasonable measures have been taken by the Director and his Executive to consult staff on the restructuring and the programme and management reorganisation. Indeed the proposed new Strategy for BGS has its roots in the strategic planning team drawn from the youth of the organisation, who conducted wide ranging consultation within BGS and outside. All successful organisations have proper regard for their human resources and I congratulate the Survey on its renewal of its Investors in People status.

This year, the BGS has continued to operate successfully against agreed programme objectives and has done much to redress the income losses resulting from the refusal of planning permission for the proposed underground storage of radioactive waste and the consequent decision by UK Nirex to suspend almost all research into underground disposal options.

In these and other sustainable development issues the British Geological Survey has a vital public service duty to provide expert knowledge, data and impartial advice to governments, academe, industry and the public. It must also confront budgetary and organisational realities faced by public sector bodies, research establishments and business. Against such a competitive background it is in the national interest for the BGS to continue to receive adequate funds through the NERC to maintain the highest levels of geoscience capability of its staff and facilities.

I see a BGS continuing to support, in significant measure, the Government's commitment to sustainable development through social progress, protection of the environment, prudent use of natural resources and enhancement of the quality of life of the nation.

This report sets out the progress the BGS has made during the past year and, in several areas, illustrates the contributions made to society in this country and overseas.

There is much to be done in the ensuing months to translate plans and good intentions into successful actions. I am confident that within the BGS, there is the necessary team spirit and high quality scientific expertise to ensure timely delivery of all programme objectives.

The Board and I look forward to continuing our work with the Director and the BGS staff to the benefit of all.

Eric Hassall CBE, DSc, CEng, FIMinE, FRICS, FGS
Chairman of the BGS Board.

Main cover photograph

Beachy Head Lighthouse, East Sussex. The photograph shows the debris pile resulting from a rock slide which took place on 10/11th January 1999, disrupting the electricity supply to the lighthouse. Beachy Head and other chalk cliffs in the area are receding episodically due to marine erosion at a rate estimated to be between 0.25 and 1.2 metres per year. As a result of the slide, the BGS were commissioned to advise The Corporation of Trinity House on the short- and long-term stability of the cliff before making a decision about the best way to maintain electricity supply to the Beachy Head Light. An engineering geological survey of the cliff and a geophysical survey of the cliff top, using high-resolution resistivity imaging, were carried out, and samples of chalk from the debris pile were tested in the BGS laboratories. Following the initial survey a second, minor, fall took place on the 8th April, removing a portion of the cliff identified during the survey as unstable. *(Photo by Paul Tod).*

Small cover photographs

Survey geologists J Horne, B N Peach and C T Clough at Tayvallich, Argyll. This picture, taken in the early 20th century, was used for publicising the BGS photographic exhibition *Hard Times*, which was displayed at several locations during the year, including the Natural History Museum in London. *(BGS photo: MNS557).*

Cave in cliffs of Whitby Mudstone at Runswick Bay, near Whitby, North Yorkshire. These 'hob-holes' show where the mineral jet was dug. This photograph is one of the illustrations from the new BGS Earthwise™ Publication Scarborough and Whitby-the Jurassic Coast. *(BGS copyright NERC).*

Apophyllite (Jalgaon, India, ca. 85mm long). Pure samples such as this are used to determine the rates of important mineralogical processes. The data are used in applications such as the disposal of mine waste and other pollutants. This sample was analysed by a student from Nottingham University as part of an M.Sc. project carried out jointly with the BGS. *(Photo by Paul Tod).*

Rother Valley Country Park, Rotherham. Previously an open cast coal mine, now reclaimed as a nature reserve. *(Photo by Paul Tod) (MN28125).*

Bibliographical reference

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Report of the British Geological Survey 1998–99

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.

Natural Environment Research Council

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P A Tod, BGS © NERC

Charles Kennedy, Liberal Democrat MP for Ross, Skye and Inverness, examining the BGS core collections from the high racking fork lift truck. During his visit in May 1999, he joined BGS scientists to discuss the synergy between science and industry, with special emphasis on European affairs.

P A Tod, BGS © NERC

Dr D A Falvey presents Professor S Sparks FRS with a print of 'View of Mount Etna, from Catania' (from Sir William Hamilton's Campi Phlegraei, published 1776) following his delivery of the 1998 Distinguished Lecture entitled 'The Eruption of the Soufriere Hills Volcano, Montserrat'.

British Geological Survey

Director's Introduction

I am delighted to introduce the BGS Annual Report for 1998/99. It gives me the opportunity to thank the BGS staff for their support during the year — a year that called for major changes in scientific culture and direction.

A major part of the year saw work continue on the new BGS Strategy, driven by the BGS Strategy Team. The work included internal consultation with all levels of the BGS staff through senior staff meetings, the BGS Intranet, e-mail consultation, newsletters and various presentations, alongside consultation with stakeholders outside the organisation. The final draft of the BGS Strategy was approved by the BGS Board at its meeting in March 1999 and is the result of eighteen months of work by staff at all levels. 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 set up following finalisation of the BGS Strategy to consider such issues as ongoing strategic planning, customer involvement, the BGS programme, the Digital Geoscience Spatial Model, the organisational structure, operational procedures, human resources and communication.

Another step towards a more customer-focused approach was seen in the setting up of Programme Development Groups. In recent years the structure and function of the BGS has been subject to periodic external reviews, which did much to create a structure that allows effective delivery of national geoscience programmes. The BGS Board agreed last year that further review over the next few years was not the best way to improve the effectiveness of the BGS. Instead, they accepted that the BGS programmes should be subject to systematic development by Programme Development Groups (PDG). The role of each PDG would be to look at a BGS programme area and consider how its objectives, approach and delivery of products to the user community could be improved.The first two PDGs, set up to consider the Coastal and Coastal Engineering Geology programme area and the Urban Environmental Surveying programme area, were introduced in 1998. These two PDGs have since been successful in consulting a wide customer base through extensive customer questionnaires, meetings and workshops and have recommended future plans for each of the programme areas.

Among the many highlights in the scientific work of the BGS, the year has seen the first phase of the Hi-Res project; an airborne geophysical and radiometric survey, which, it is hoped, will eventually extend to national coverage. Phase 1, undertaken in collaboration with World Geoscience Corporation Ltd, covered an area of 14 000 square kilometres, extending from the Mersey and Dee estuaries in the north-west, south as far as Shrewsbury and east to Lincoln. Although much work remains to be done, the project is already providing valuable data on diverse subjects such as the environmental baseline distribution of caesium-137 and deeply-buried geological structures in Charnwood Forest.

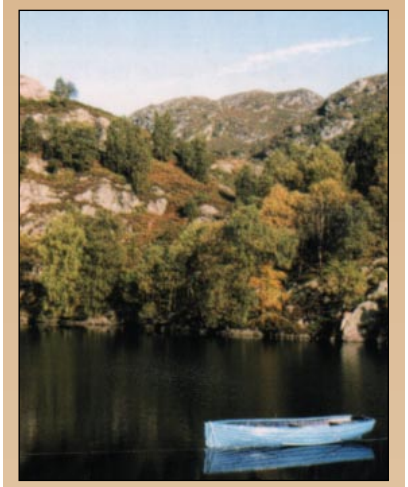
I cannot finish without expressing my regret that it has recently been necessary to declare a State of Redundancy in the BGS —the first time since its foundation in 1835. This arose out of an important exercise, carried out during 1998, in which the BGS reviewed its financial and expertise base and identified its future requirements in these areas. It has been a painful, but necessary, experience. I hope we can now put it behind us and move forward.

David A Falvey, PhD, FGS, CGeol
Director of the British Geological Survey
November 1999

J Evans, BGS © NERC

An aerial view of the BGS Headquarters at Keyworth.

The BGS is dedicated to provide, on maps and in databases and written accounts, geological information for all parts of Great Britain and her territorial waters, commensurate with the needs of the whole user community.



T S M Bain, BGS © NERC

Psammites and semipelites of the Southern Highland Group form a typically rugged mountain landscape. Ben Venue and Loch Katrine, Trossachs.

T S M Bain, BGS © NERC

Coarse feldspathic arenite with clasts derived from an ancient quartz-feldspathic hinterland, Southern Highland Group.

CORE STRATEGIC PROGRAMME

This, the principal 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.

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 178 resurveyed or revised 1:50 000 geological maps, 68 memoirs, two sheet explanations, three new editions of regional guides and three sub-surface memoirs. During the current year 4593 square kilometres were resurveyed or revised; 154 1:10 000 maps were released to the public and 43 technical reports written. Fifteen shallow boreholes, totalling 628 metres, were drilled.

Southern Highlands: the first 1:50 000 (Aberfoyle) map compilation for this project has resulted in the production of a detailed stratigraphical model of the uppermost Dalradian succession. Much of this Southern Highland Group developed as a complex anastomosing sequence of prograding and aggrading debris flows and turbidites, predominantly composed of channel and overbank wacke sandstones and arenites. The basin suffered relatively active and quiescent stages of deposition, reflecting differential crustal extension with time. At times, faulting resulted in basaltic intrusion, which was subsequently reworked as volcaniclastic sediments.

East Grampian: in north-east Scotland, a complex Late Devensian and earlier glacial history has been determined. Two major Late Devensian ice streams are recognised. These flowed from the Western Highlands through the Moray Firth and Strathmore, encircling the largely cold-based ice cap of the East Grampian Highlands. The East Grampian ice sheet retreated prior to the Windermere Interstadial (11 000 to 13 000 years BP), allowing movement onshore of marine-based ice streams, in places for up to 15 kilometres. Recent excavations at the Burn of Benholm in Kincardineshire showed that, prior to the Late Devensian, Scandinavian ice crossed the North Sea Basin and impinged upon the Scottish coast. This ice movement has been confirmed by studies of rafts of peat and shelly till locally exposed here beneath Late Devensian till and outwash.

Monadhliath: work has continued on defining the Neoproterozoic basin configuration of the Dalradian Grampian group of the Central Highlands. A provenance study mainly using the Sr–Nd isotopic composition of semipelites shows that detritus was derived largely from early and late Proterozoic sources. The proportions from each of these sources vary throughout the stratigraphical succession, both in the Central Highlands and throughout the Dalradian. Collaboration with the Greenland Geological Survey (GEUS) led to a project member spending two months in north-east Greenland, examining the Nathorst Land Group.

Ayr and Lanark: three-dimensional modelling using earthVision software has produced contoured surfaces of stratigraphical horizons within the

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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.

Carboniferous coal-bearing strata that can be correlated across the Midland Valley. Manipulation of the surfaces has enabled the construction of isochore maps and incorporation into a 3D model, which includes fault surfaces.

Southern Uplands: mapping has continued in the Leadhills district (Sheet 15E). Conodont faunas are more widespread than previously thought and should greatly improve biostratigraphical correlation of the chert successions. Temporary sections along the new M6 motorway have revealed numerous closely spaced tectonic discontinuities within thick greywacke successions of the Gala Group. A new stratigraphical scheme has been developed for the subdivision of the Permian rocks of the Lochmaben Basin.

North-east England: concern over the consequences of minewater outbursts in areas of rising groundwater highlighted the importance of BGS work in such areas as the Northumberland Coalfield. BGS staff contributed to the debate over a wide spectrum of related environmental issues. Revision mapping in the Warkworth and Alnwick areas has identified widespread landslips in till and glacial sand and gravel. Whereas most of the slips presently appear stable, they may be reactivated by a significant rise in groundwater level as a result of mine flooding. Completion of a research contract with the University of Durham has provided valuable insights into the sedimentology and stratigraphy of outliers of Coal Measures, adjacent to the Stublick Fault System, in the Tyne valley.

Lake District: field mapping, petrography and geochemistry have differentiated the products of several eruptive centres within the Ordovician Borrowdale Volcanic Group. The Haweswater intrusive complex has a genetic association with the volcanic rocks and was emplaced at a depth of about three to six kilometres. A major shear system cutting the volcanic rocks has been recognised, and a previously unsuspected early phase of Cu-Fe mineralisation, predating deformation, has been determined. Detailed studies of the late Silurian part of the Windermere Supergroup, in conjunction with two university mapping contracts, have quantified lithofacies variation in terms of overlapping turbidite fans. The bio- and lithostratigraphical problems of the Carboniferous succession in the Vale of Eden have been resolved.

Yorkshire: field mapping of the Huddersfield sheet was completed and good progress was made on the revision of the Leeds sheet. Considerable use was made of relief models, computer-generated from aerial photographs, for the revision of the Wharfe valley, north of Leeds. Field checking of areas of Millstone Grit, terrace deposits and landslips has proved the reliability of this approach.

Mid-Wales and Welsh Borders: work is continuing in the Builth Wells district to resolve the complex structures associated with the Twyi Anticline. Reconnaissance mapping of the Ross-on-Wye sheet has revealed a series of hitherto unknown major north-west-trending fractures that are linked to similar structures in the South Wales Coalfield.

West Midlands: following the completion of fieldwork on the Wolverhampton sheet, work on the revision of the Dudley sheet was initiated. Quaternary glacial buried channels are a feature of the area west of Wolverhampton, and one at Trysull was investigated by geophysical traverses. Preliminary results confirm a thick infill of Devensian (glacial) and pre-Devensian sediments.

A Howard, BGS © NERC

The Inch Mine Coal and overlying Warmden Sandstone (Lower Coal Measures), temporarily exposed during construction of the M65 Motorway, near Blackburn. Identification of this coal, and its distinctive fish-bearing roof measures, will lead to substantial revision and improvement of the forthcoming geological maps of the Preston and Rochdale districts.

D Wilson, BGS © NERC

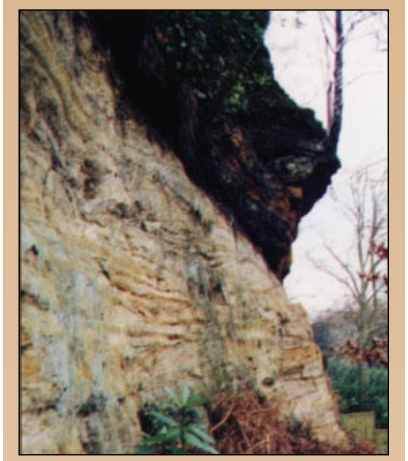
Thinly bedded Ordovician turbiditic sandstones and mudstones of the Nantmel Formation form much of the rugged coast of Ceredigion on the south side of Cardigan Bay. The view here is from Foel y Mwnt, north of Cardigan. The field survey of the district was completed during the year.

A McMillan, BGS © NERC

Ice wedge casts in glaciofluvial sand and gravel, Hallheath's Quarry, Lochmaben.

A Humpage, BGS © NERC

High-level Pleistocene gravel deposit at Caesar's Camp, west of Aldershot. The clast content is predominantly of flint.



A Humpage, BGS © NERC

Iron pan development in the Folkestone Formation at an outcrop at Tilford, Surrey.

R A Ellison, BGS © NERC

Extensive dissolution features in Upper Chalk at an excavation for the Channel Tunnel Rail Link, near Gravesend. The infill is mainly of Thanet Sand Formation.

East Midlands: the resurvey of the Melton Mowbray sheet continued. Mudstone-dominated formations of the Lias Group variously crop out or underlie drift across large areas. They contain numerous thin limestones and mapping has revealed local complex faulting. In the eastern and southern parts of the district, there is a thick Anglian drift sequence, which includes at least three mappable varieties of till. The drift overlies irregular bedrock topography with subglacial (tunnel) valleys. In the Wreake valley, to the south, the deposits of a major pre-Anglian drainage system were mapped (the Bytham Sands and Gravels). The precise position and extent of these fluvial deposits has long been a matter of conjecture in this part of the Midlands. However, the results of recent drilling by the BGS suggest that the trunk stream may have passed to the north of Melton Mowbray, rather than being everywhere coincident with the present course of the Wreake.

Cotswolds and eastwards: the first detailed survey of the Moreton-in-Marsh district was completed and a full set of 1:10 000 scale maps was released. The area includes the so-called Moreton Drift, a southerly occurrence of the Middle Pleistocene glacial deposits that are better developed further north in the Midlands. As well as including potential resources of sand and gravel, the succession of deposits throws some light on the Quaternary chronology of southern England. Field relationships support the controversial view that the Anglian glaciation, the last to affect southern Britain, was a composite, two-phase event. Survey work commenced on the Beaconsfield and Buckingham districts; no detailed geological map has ever been published for the latter.

East Anglia: in this region, identification and analysis of derived palynomorphs in silts and clays of the Crag are continuing to provide important information on provenance and palaeogeography. The technique has recently been extended, with university collaboration, to the analysis of tills, where it is being combined with the analysis of foraminifers within chalk clasts in the tills. Some data indicate directions of provenance which conflict with previously published accounts. In the Biggleswade district (Sheet 204) a selective revision survey was carried out, including a refinement of the Chalk stratigraphy. In the Woodbridge and Felixstowe district, mapping has identified complex glacial deposits along the former Anglian ice-margin. Deep solution hollows and faults in the Chalk were investigated by geophysical methods. Three boreholes were drilled to improve knowledge of the Holocene deposits.

London Basin: the revision survey of the Aldershot–Guildford district was completed, with attention focused in particular on the Quaternary deposits and the Lower Greensand Group. Two distinct ages of Head deposits, which accumulated during periglacial conditions, were recognised. Clay-dominated deposits cap the low hills formed by Weald Clay whereas younger sandy sediments mantle the valley slopes on the Lower Greensand. West of Godalming, extensive wet heathland, much of it important for nature conservation, may overlie a perched water table caused by an iron pan in the Sandgate Formation. This discovery may help to model the effects on the wetland of water extraction from nearby boreholes. Ongoing collaborative work at Sheffield University on the palynomorphs of lower Tertiary sequences has shown it is unlikely that the Weald was 'unroofed' prior to deposition of the Lambeth Group.

Hampshire Basin: in the Winchester and Salisbury districts, mapping has demonstrated significant structural control of lithofacies within the Chalk. This work was enhanced by ImageStation screen displays of 1:25 000 stereo aerial photography.

Wessex Basin: thematic maps were produced for the ball-clay deposits in the Wareham area. The sand and gravel resources were also reappraised by field mapping and trial pits. In the Ringwood district, mapping and geophysical log correlations have enabled improved integration

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of the Tertiary stratigraphy between the Wareham basin and the Isle of Wight. A refined Chalk stratigraphy has been mapped over the Dean Hill Anticline, a north-facing structure in the Upper Chalk, which may overlie an extension of the Mere Fault.

Lyme Bay: in the Sidmouth district, mapping of the Upper Greensand, using a refined stratigraphy, has enabled faunal records to be clarified for the first time. Detailed logging of previously unrecorded sections has revealed marked lateral variations in the Chalk, unusual elsewhere in the Anglo–Paris Basin.

South Devon: mapping of the Middle to Upper Devonian sequences in the Torquay district continued, providing valuable comparison with those of Plymouth. Hematite and baryte deposits near Sharkham Point are newly regarded as of a low-temperature cross-course type of mineralisation derived from Permo-Triassic basinal brines. Ongoing collaborative research between the BGS and the University of East Anglia seeks to identify the base of the Triassic in the red bed succession of Devon using magnetostratigraphical techniques but the results are, at present equivocal.

Continuous Revision Programmes: addresses the needs of the user community for up-to-date geoscientific 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 at 1:10 000 and 1:50 000 scales. In Scotland, 45 cored rotary boreholes from site investigations were examined and the results incorporated into the Correction Copy set of maps. Examination of temporary exposures, primarily from engineering excavations, continued in conjunction with the databasing of information from those mine plans, mine entries and quarries not related to coal extraction. In England, revised maps were made available for areas of South Yorkshire, Bristol/Bath and North London.

Southern and Eastern England Modelling Project: in parallel with the current 1:50 000-scale map digitisation programme, this project seeks to link with geo-environmentally important issues on a GIS system. The wealth of data relating to the geology of the London Basin has been integrated for the first time. Outputs from the system include geological maps at any required scale, graphical borehole logs, geological cross-sections, site-specific reports and derivative contour plots.

Land Survey Digital Research and Development: procedures were established for incorporating scanned map data, including mine plans and geological maps at 1:10 000 scale into a Digital Map Compilation System (DMCS). This system was implemented, enabling geologists, using MicroStation, to compile digital geological maps from field and archival data. The maps are geologically attributed and printed out as hard copy for checking and archiving. Borehole and geological map data were combined using earthVision software to produce a three dimensional model of the Permo-Triassic aquifer in the West Midlands.

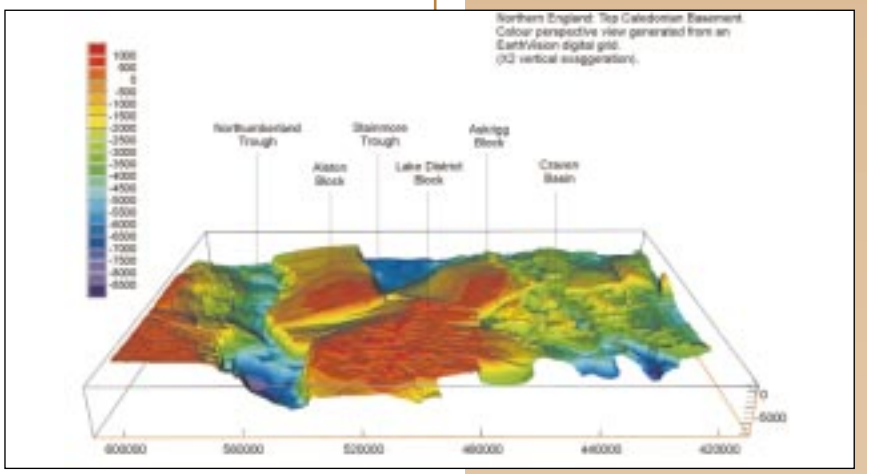
Carboniferous sandstone provenance Pennine Basin

This project underpins the BGS's capability in its leading-edge research, development and application of heavy mineral stratigraphy techniques. Applications include sandstone provenance identity, palaeoclimate, correlation, burial diagenesis, and exploration well geosteering.

UK 3D subsurface mapping and database

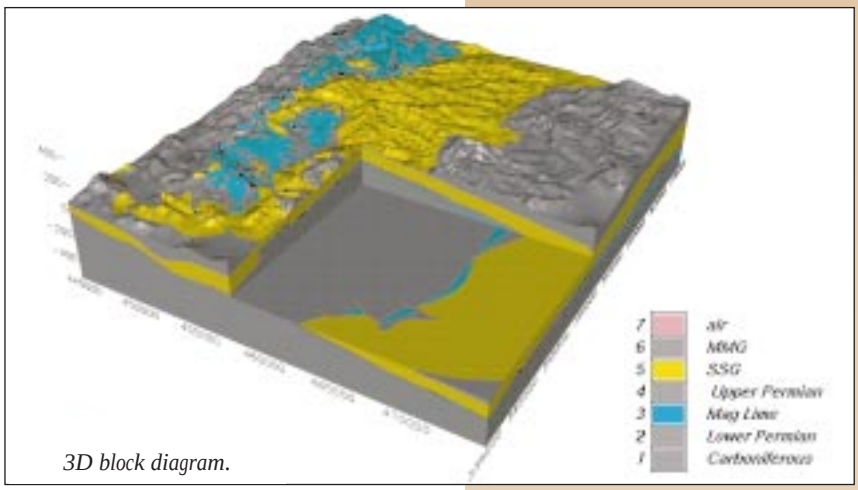
Subsurface mapping of the Cheshire–Staffordshire area is now complete. This is the third in a series describing the subsurface geology of large areas of the UK onshore area, concentrating on the pre-Mesozoic succession. The structure and evolution of the Northumberland Trough and adjacent areas is now published, and the structure and evolution of the Craven Basin and adjacent areas is with the publication unit.

An atlas of subsurface structures is being compiled. This is intended as a definitive publication on major structures in the UK, integrating surface and subsurface observations (boreholes, seismic etc.) to explain the development of the structures and their relationship to the stratigraphical development of different parts of the UK.



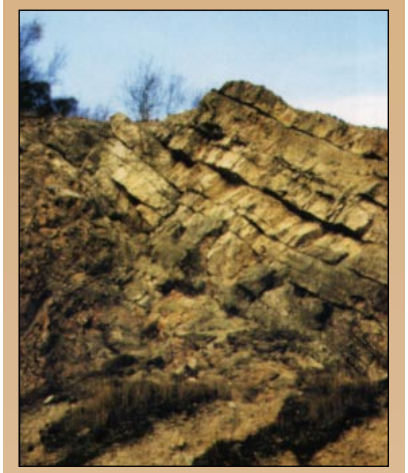
A Chadwick, BGS © NERC

A typical output illustrating a 3D perspective view of the top Caledonian Basement in northern England.



3D block diagram.

D Bridge, BGS © NERC



D Wilson, BGS © NERC

Ercall Quarry forms part of an important SSSI at the northern end of The Wrekin range in Shropshire. It is one of the few localities where an unconformable contact between bedded Cambrian quartzites (in the upper part of the view) and Precambrian granitic rocks can be seen. The latter have been dated at about 560 Ma using isotopic techniques.

Coastal and Estuarine Evolution Project

This project aims to examine the Holocene evolution of the UK Coastal Zone over a variety of timescales from decades to millenniums in order to better understand the long-term processes that drive coastal evolution. It will provide knowledge and data that will help in predicting the response of the coast to various scenarios of environmental change. During the year the project has been included in the BGS Programme Development Group Review. Objectives and deliverables have been market-tested by means of a questionnaire sent to members of the user community. The result was a strong endorsement for the project from the community and a clearer focus for its deliverables. These will include a series of reports on key British estuaries and a series of maps illustrating coastal change. The first of these reports will be completed by the end of 1999/2000. During 1998/99, 12 scientific papers have been presented at both national and international conferences and a number of internal reports have been completed. The project has involved working closely with, and received co-funding from, major research initiatives by the Environment Agency, MAFF and DETR.

D Wilson, BGS © NERC

The Wrekin (in far distance), the Lawley and Caer Caradoc form a line of impressive Shropshire hills of Precambrian volcanic rock. The valley containing the regionally important Church Stretton Fault Zone separates them from Precambrian sedimentary rocks of the Longmynd (in the foreground). (View north-eastward from above Carding Mill Valley near Church Stretton).

Engineering behaviour of British rocks and soils

- An advisory panel was established, comprising eminent engineering geologists from industry, academia and government, which will advise on the formations to be studied and ensure project outputs meet the needs of the user community.
- Keynote presentations were given at two CIRIA meetings on the geology of the Mercia Mudstone Group and the Lambeth Group. These will form part of CIRIA reports.
- Reports on the shrink and swelling behaviour of the Gault clay and the Mercia Mudstone Group have been completed.
- Initial development work on a new laboratory method to characterise the shrinkage and swelling behaviour of mudrocks has been completed. Testing results are promising and will be published soon. A second prototype test apparatus and a testing programme are planned in the near future.

Ground Level Change in the Thames Estuary area

This is an Environment Agency/NERC co-funded project with the Institute of Engineering Surveying and Space Geodesy (Nottingham University). Data from two years of monitoring three at continuous GPS reference stations, show that is now possible to determine time-averaged mean height changes in ground level to within 0.6 millimetres. Episodic GPS readings have been made at 22 monitoring stations sited with respect to known geological criteria. They show that the London Clay as a whole undergoes seasonal movement in the order of five millimetres. In addition, readings at several sites on the Chalk indicate a rising trend, perhaps in the order of one to two millimetres per year. If this trend were to continue, it would have important implications for the hydrology of the Thames Estuary and its interaction with global sea-level rise.

Namurian glacioeustatic marine bands (Realising Our Potential Award)

This is a NERC/OST-funded study of glacioeustatic flooding surfaces preserved in the Carboniferous of the UK. As with Pleistocene and Holocene examples, glacial/interglacial transition sea-level rise was catastrophically rapid and pulsed in

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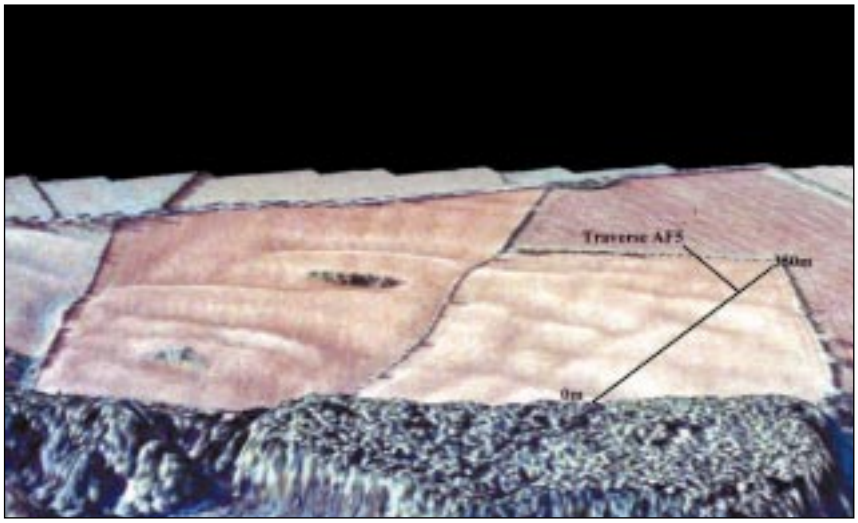


Doug Tragheim, BGS © NERC

View to SSW of orthophoto draped over a digital elevation model showing the network of cambered strata, and the location of geophysical traverse AF5.

the Carboniferous examples. Significant knowledge was gained during the year of the effects of these transitions on terrestrial equatorial palaeoflora

Digital Photogrammetry in support of the Land Survey

3D stereo models created using digital photogrammetry were produced as an aid for geological interpretation for all or substantial parts of the following 1:50 000 scale sheets: Winchester, Leeds, Ringwood, Melton Mowbray, and the Wirral Peninsula (Liverpool). An increase in mapping rates in some types of geological terrain, especially the Chalk, encouraged the BGS to invest in an expanded, distributed, Windows NT-based digital photogrammetric system.

Airborne Remote Sensing

A poorly understood ground instability problem called cambering was studied in the Cotswolds by a team of multidisciplinary geoscientists. It was investigated using airborne imagery to map the distribution of clay minerals and soil moisture, digital photogrammetry to look at surface geometry, electrical resistivity imaging and ground penetrating radar, to reveal geological structure at depth. Insights were gained into the way competent rocks like limestone move on clay layers and thus fracture. A paper on the work was 'best of session' at an international conference.

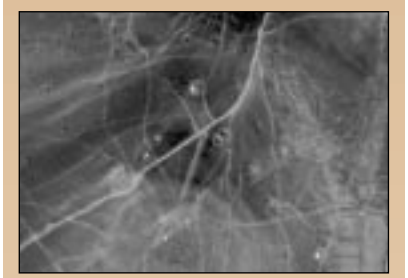
Research was also conducted to establish whether abandoned mine shafts could be detected using an airborne thermal scanner. Pre-dawn thermal data were collected over an area of mine shafts near Bradford. The temperature contrast between the shafts and their surrounds gave rise to detectable anomalies. In addition to known shafts, unknown shafts were also detected. The next step will be to verify the anomalies on the ground.

PARTNERSHIP PROGRAMME

Chalk Aquifer Study: in Sussex, a joint project with Southern Water seeks to apply the recently revised lithostratigraphy of the Chalk to an area between Worthing and the River Ouse, using aerial photography and selected fieldwork.

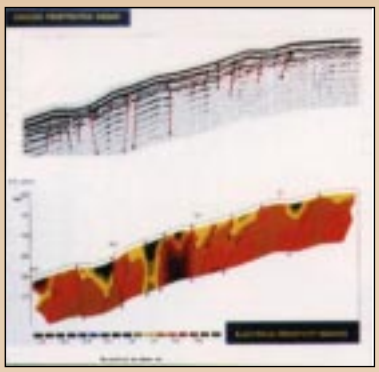
Geological Conservation Publications: in Scotland, joint projects were started with English Nature/Scottish Natural Heritage to produce Geological Conservation Review volumes on the Permo-Carboniferous igneous rocks and the Dalradian rocks of Scotland. A partnership was also established with Scottish Natural Heritage to produce the latest in their 'Landscape fashioned by Geology' series covering the islands of Mull, Iona and Staffa.

In England, work was carried out in collaboration with the Joint Nature Conservancy Council to compile a book documenting and describing over 40 Precambrian geological sites in England and Wales. Although much of the work was a desk study, some field visits were undertaken to sites such as the Longmynd and The Wrekin.



Gisela Agar, BGS © NERC

A pre-dawn thermal image showing abandoned mine shafts near Bradford.



Mike Raines/Doug Tragheim, BGS © NERC

Correlation of GPR faults (top) with graben/half-graben structures as shown by the 2D electrical resistivity image (bottom).

Minerals and Geochemistry

The BGS carries out systematic geochemical surveying of the UK and maintains national databases of geochemical, radiometric and mineral data.

Striking the balance between the need for a sustainable environment and the need for mineral products requires authoritative, systematic information. Technology Foresight has identified the problems and challenges associated with the stages of the natural resource cycle, from exploration, through the identification, extraction, processing and industrial use of resources, to the disposal of waste and the remediation and aftercare of contaminated land. Collectively, the projects that make up the Minerals and Geochemistry Core Programme offer the impartial expertise, knowledge and information on which sound economic and environmental decisions can be based at every stage of the cycle. They also provide fundamental data in support of geological mapping.

G-BASE

The Geochemical Baseline Survey of the Environment (G-BASE) provides baseline geochemical data for soils, stream sediments and streamwaters for economic and environmental applications. In 1998, suites of geochemical samples (stream sediments, stream waters and soils) were collected over an area of 5000 square kilometres in the East Midlands, including both rural and urban areas.

A hydrogeochemical atlas of Wales and the adjacent parts of England (the first of its kind) is nearing completion, containing data on streamwater chemistry at a resolution of one sample per two square kilometres. A companion volume, based on stream-sediment and soil geochemistry for the same area, is in preparation; the geochemical data on which this volume is based were released into the public domain.

On the international level, the BGS continued to take the lead in initiatives to harmonise geochemical maps and mapping in Europe and worldwide. Collection of samples for the UK component of the global reference network was completed.

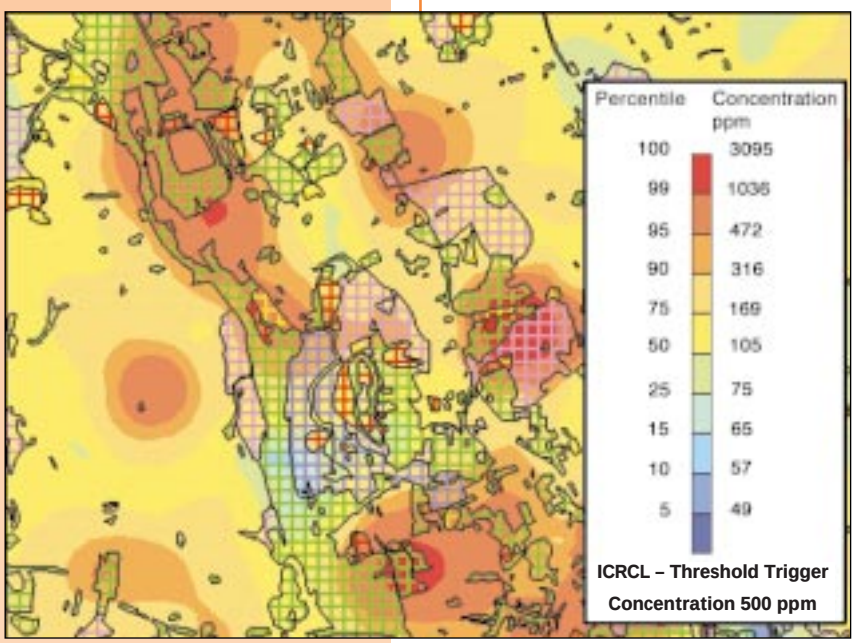
Natural Environment Radioactivity Survey (NERS)

Maps of radon potential based on solid and drift geology and gamma-ray dose based on solid geology for the Liverpool Bay area at 1: 250 000 scale were published, and are included for sale in the G-BASE volume *Regional geochemistry of parts of North-west England and North Wales.* The Lake District radon map was prepared in draft form, and data were analysed for gamma dose to prepare new maps for the Lake District based on solid and drift geology. A Geographical Information System is being developed using Lake District data. This will allow a much more flexible approach to presenting data on natural radioactivity.

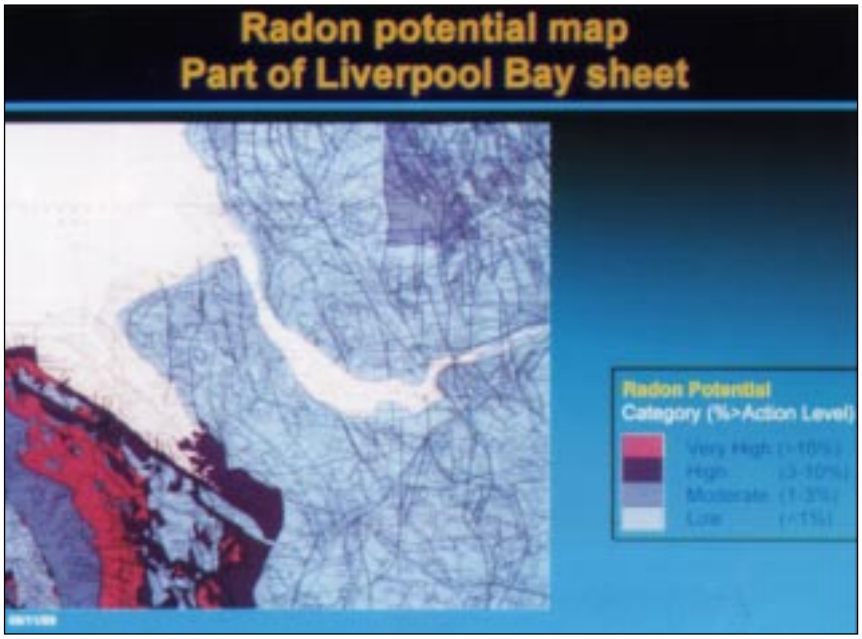
MINGOL (Minerals GIS On-Line)

Data from the DETR-commissioned County Mineral Resource Planning maps for Warwickshire, Hereford and Worcester, Shropshire, Staffordshire and South Wales are now incorporated into MINGOL to form a series of 'intelligent' maps for minerals planning and other purposes. Additional maps will be added as they are published. Mineral exploration areas have been updated, and information from the recently published Coal Map of Britain is now being incorporated within the MINGOL system. Work is continuing on the 1:250 000 mineral resource map series: the first map, covering the Lake

(Below) *Distribution of lead in soil samples from part of the Stoke-on-Trent urban area, shown in relation to various types of made ground.*



Marcello Di Bonito, BGS © NERC



David Jones, BGS © NERC

Part of the radon potential map for the Liverpool Bay area, showing estimated proportions of houses above the UK Action Level (200 becquerels per cubic metre) based on solid and drift geology.

District, is complete in draft, and compilation of the next map (Tyne–Tees) is in progress. Further chapters for Mineral Resources of Britain have been completed. A new edition of the *Directory of Mines and Quarries* was published in May 1998 and data capture for the Mineral Occurrence Database, which now contains over 4000 records and is linked into MINGOL, is continuing.

Gold in orogenic extensional basins

Integrated multidisciplinary field and laboratory investigations continued on this project, aimed at understanding the distribution of gold in the Dalradian of the Scottish Highlands. New mineral and fluid parageneses have been established which throw new light on gold enrichment processes in lode gold deposits. Petrogenetic modelling of late Caledonian intrusive bodies, using lithogeochemical and isotopic data, is in progress to compare intrusions that are related to mineralisation with those which are not.

Palaeofluid flow in resource development

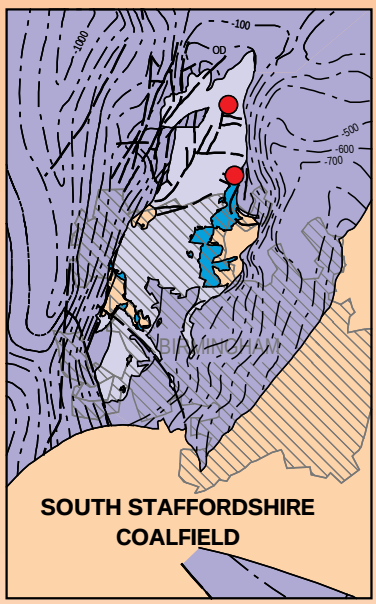
The highlight of the year was the successful analysis of fluid inclusions in Quaternary calcite from the Sellafield repository area by laser ablation, cold plasma ICP-MS. This allows reconstruction of the chemistry of palaeogroundwaters for comparison with the present-day waters. Initial results indicate a striking similarity—an important result for risk assessment modelling. Further development is in progress to apply this methodology to low-salinity, diagenetic waters to investigate their influence on hydrocarbon reservoir cementation and the remobilisation of precious metals.

Potentially toxic elements in air particulates

Rapid and cost effective methods for the chemical analysis of trace elements collected on air filters have been developed and successfully applied to samples collected within the city of Castellon, Spain. Potential sources of contamination were identified using the chemical 'fingerprints' of the particulates collected. An important achievement was the rapid measurement of lead isotopes using laser ablation multicollector ICP-MS to determine different environmental sources of lead contamination. This could have a profound effect on air quality monitoring in relation to legislation on lead in petrol.

Geochemical laboratories

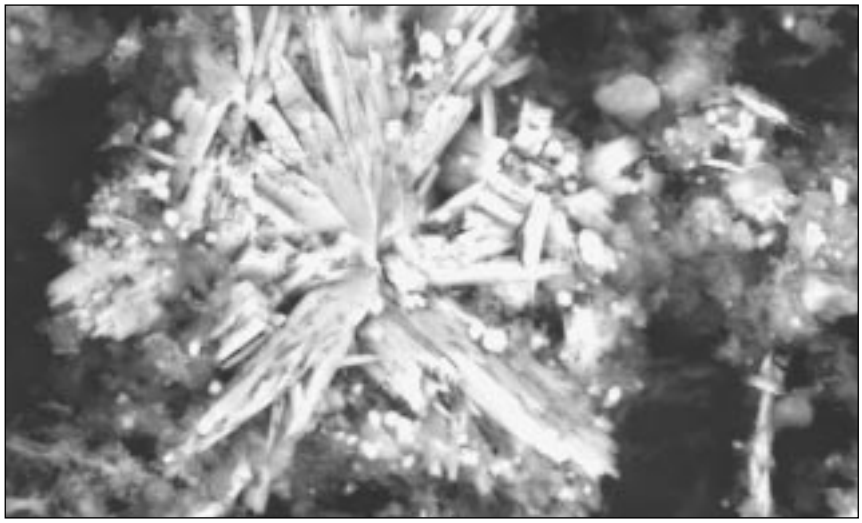
The laboratory capability was upgraded through the acquisition of new Energy Dispersive XRF and instrumentation. These instruments will provide analytical data for continuing in-house core programmes and permit greater flexibility when bidding for commissioned research projects. Detection limits will be improved and productivity will be significantly enhanced.



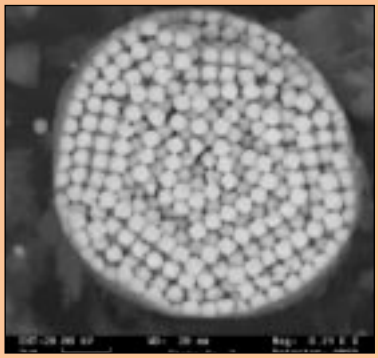
Niall Spencer, BGS © NERC

Coal Resources Map of Britain: detail. Purple, deep coal; mauve, shallow coal; blue, defunct coalfield; red circles, opencast coal mines; contours on the top of the Coal Measures.

(Opposite) *Diagenetic vivianite cluster in unconsolidated anaerobic urban canal mud (LV cryoSEM back-scattered electron image).*



A E Milodowski/P Wetton, BGS © NERC



A E Milodowski/P Wetton, BGS © NERC

Internal symmetry of an iron sulphide framboid growing in rural canal mud (LV cryoSEM back-scattered electron image).

Fergus MacTaggart, BGS © NERC

A prismatic crystal of gadolinite, 2.5 millimetres across, in a cavity in the Arran granite, Scotland. The first recorded in situ occurrence in Britain of the rare-earth-element minerals gadolinite and fergusonite is the result of an XRD, electron-probe and ion-microprobe study in collaboration with Edinburgh University.

PARTNERSHIP PROGRAMME

Coal Resources Map of Britain: This has been produced in collaboration with the Coal Authority. The map is on a scale of 1:1 500 000, with larger-scale insets of the main coalfields, and shows coal resources, subdivided into categories, and the locations of current mines. It illustrates the extent of coal resources onshore and offshore, with subsurface contours indicating the geometry of both coal and possible coal bed methane resources. Other insets provide information on resource classification, historic coal production, coal resources of post-Carboniferous age, and coal bed methane. The map is the first of this type prepared since 1947, when the coal industry was nationalised. Its objective is to provide a synopsis of the coal endowment of the country for the benefit of environmental guidance and resource management. All the data will be integrated into the BGS minerals GIS system (MINGOL).

Interlaboratory collaboration: a project supported by the EU has been set up to assist collaboration between the geochemical laboratories of European geological surveys (the Czech Republic, Estonia, Finland, Hungary, Lithuania, Netherlands, Poland, Romania, Russia, the Slovak Republic and the UK). The comparability of data provided by each laboratory for geochemical mapping purposes will be assessed to facilitate data interpretation across national boundaries. Laboratories compare data obtained from identical samples provided by an independent laboratory. Detailed investigation of *aqua regia* leaching procedures has also been undertaken. Exchange visits by project staff promote technology and information transfer.

Development of cryogenic SEM: in collaboration with the University of Nottingham, the low-vacuum and cryogenic SEM (LV cryoSEM) has been used to study the processes controlling the mobilisation and fixation of heavy metals, iron and phosphate in canal mud. Samples from an industrial environment in the West Midlands were compared with sediments in the rural environment of the Ashby Canal. LV cryoSEM enables the fabrics of the mud samples to be examined in a near pristine wet-state, reducing the physical and chemical disturbance associated with conventional SEM. CryoSEM specimens are rapidly frozen, limiting the oxidation of unstable fine-grained reduced phases such as sulphides in anoxic muds. As a result, it has been possible to follow the development of sulphide diagenesis, from amorphous metal sulphide gels associated with biofilms to more crystalline sulphide phases. The technique has also been used to test sequential chemical extraction schemes which are used to evaluate chemical speciation in contaminated soils and sediments. The cryoSEM observations demonstrated significant shortcomings in the interpretation of chemical extraction data.

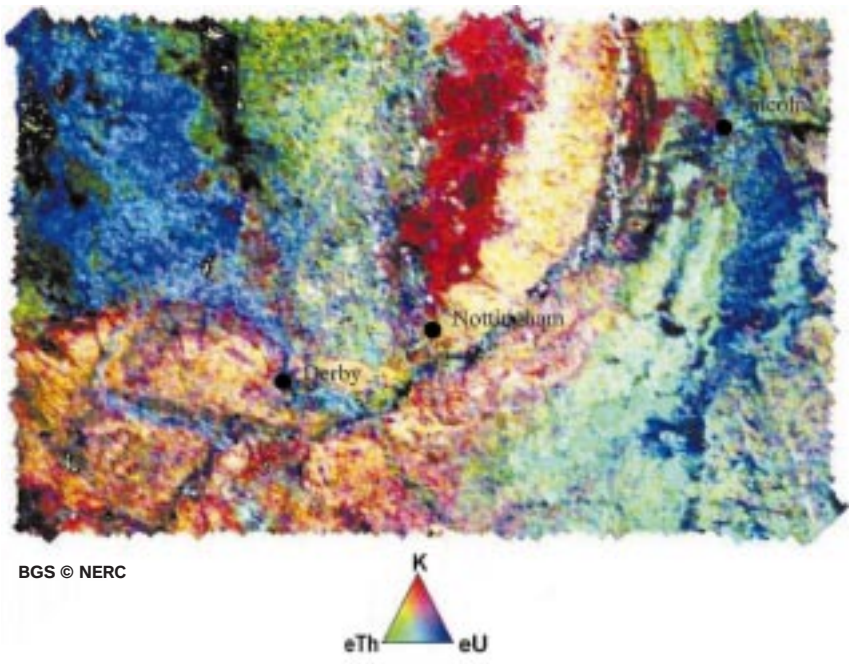
CryoSEM has also been applied to the study of rock–water interaction processes associated with organic contamination in the Sherwood Sandstone aquifer beneath an industrial site in the West Midlands. This work, in collaboration with the Universities of Sheffield and Leeds, under EPSRC funding, used cryoSEM methodologies developed by the BGS. Delicate fabrics providing evidence of rock–water interaction and microbial degradation and biofilm development were preserved and observed.

Tim Cullen, BGS © NERC

World Geoscience 'Skyvan' aircraft used for HiRES-1 airborne survey (see page 14) with concrete pads for calibrating gamma-ray detectors.

Fluoride reduction in groundwater

This new water quality improvement project is co-funded via the EU Inco-Copernicus programme and in collaboration with geological consultants in the Netherlands, Slovakia and Hungary, the Institute of Rock and Ore Mineral Formation in Ukraine, the Institute of Gerontology in the Ukraine, and the Association of State Geologists, Moldova. It will address the prediction of areas likely to have fluoride problems and will develop remediation technologies to remove fluoride from groundwater. The BGS contribution is in the development of a geochemistry and health risk prediction geographical information system.



BGS © NERC

Ternary gamma-ray (potassium–equivalent, uranium–equivalent, thorium) image of the eastern half of the HiRES-1 survey area (see page 14), showing features related to solid geology and overlying superficial deposits. The red and yellow areas NNE of Nottingham represent the differing signatures of the Sherwood Sandstone and Mercia Mudstone groups. The predominantly blue area NW of Derby largely reflects the Carboniferous limestones of the White Peak, an area affected by higher than average levels of the radioactive gas radon, a uranium decay product.

Tim Colman, BGS © NERC

View of the 18th century open pit at Parys Mountain mine, Anglesey, North Wales.

Portable Infrared Mineral Analyser

This field portable spectrometer has been used in mineral exploration, industrial mineral assessment, oil exploration, and stratigraphical studies. A review was produced describing all these applications. A paper describing the use of the instrument to identify minerals along borehole core, as an input to a 3D model of the mineralisation at Parys Mountain on Anglesey, was 'best of session' at an international conference.

Tim Colman, BGS © NERC

A BGS geologist measuring infra-red spectra of alteration minerals associated with volcanic massive sulphide mineralisation in the Parys Mountain open pit.

Geophysics

The studies of the physical properties of rocks are applied to the solutions of engineering, geotechnical, geomagnetic, and seismic problems, to the exploration for mineral deposits and hydrocarbons, and to the understanding of 3-D crustal structure.

Geophysical Monitoring

The UK magnetic observatories at Lerwick, Eskdalemuir and Hartland were maintained and improved back-up systems were installed to ensure data quality and continuity. Data were retrieved to Edinburgh by telephone and data products published in electronic form on the Geomagnetism Information and Forecasting Service (GIFS) accessible via the Internet. GIFS provides a seven-day, 24-hour service to academic, government and commercial users. Through the INTERMAGNET programme, data from a global set of magnetic observatories were exchanged in near-real time with agencies in the US, Canada, Japan and France. Geomagnetic measurements were made at 15 of the 51 sites in the UK repeat station network.

Improvements were made to the instrumentation and data collection hardware and software installed at sites in the 141-station UK seismic network. In particular, the recording of strong ground motions from nearby earthquakes was improved and this will provide data relevant to safety considerations for the nuclear industry. Recordings of seismic events were retrieved to Edinburgh automatically under computer control every six hours and analysed promptly to determine time, location and magnitude. The rapid exchange of seismic data on significant earthquakes in Europe was promoted through co-operation with several European institutions.

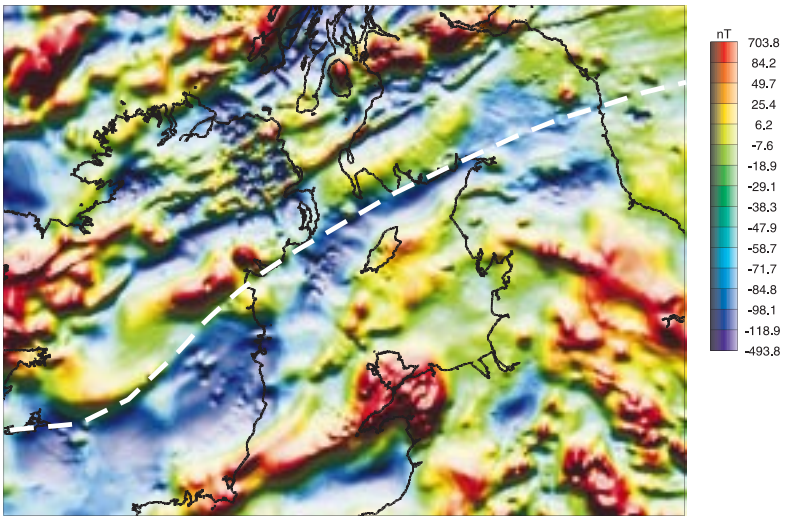
The National Seismological Archive, a repository for bulletins, seismograms and other papers from seismological observatories in the UK that have now closed, and other material of seismological interest, was maintained. A new catalogue of the Archive was completed and made available to users electronically. Research into the history of seismology in the UK to trace further collections of data uncovered chapters in the history of the subject previously unknown, including stations and bulletins never before used. Among the finds were a number of photographs of early seismologists and their observatories in the UK.

Multicomponent Seismology

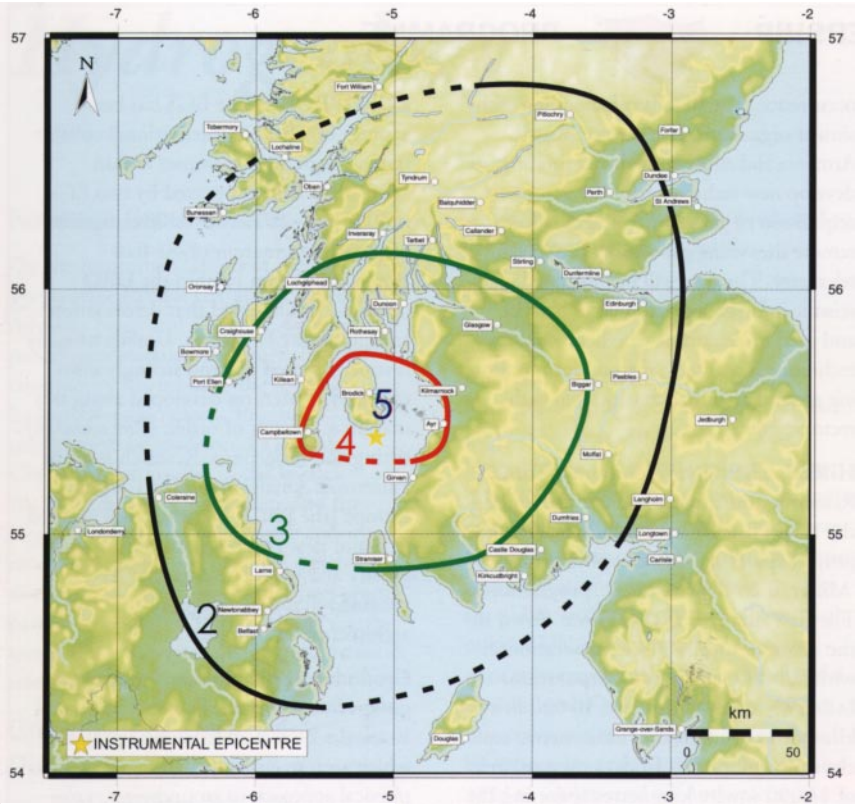
Research on seismic wave theory was carried out to investigate the effects of fluid-filled fractures on wave propagation. Synthetic modelling has shown the potential to describe the microstructural properties of fault gouge and assess the whether faults will act as conduits or barriers to fluid flow. In collaboration with Edinburgh University advances were made in the analysis and interpretation of multi-component sea bed seismic data in the presence of anisotropy.

National geophysical mapping and data management

The first two gravity anomaly maps in the 1:1 000 000 UTM Series (North Britain and South Britain) were published. Good progress was made in the development of on-line access to our substantial geophysical data holdings. All the regional aeromagnetic data for the UK land and offshore area were loaded into a revised line-based databank. Rock physical property data for the UK and information on more than 700 local geophysical surveys (some 13 000 individual geophysical traverses) is now accessible on-line. A database query system has been developed for the BGS Intranet, providing an effective, platform-independent interface with the data.



Imaging of regional aeromagnetic data over Britain and Ireland reveals the contrasting basement architecture to the north and south of the Iapetus Suture. The white dashed line indicates the position of the suture (at mid-crustal depth) as inferred from other data sources.



Davie Galloway, BGS © NERC

The Arran macroseismic survey. *The magnitude 4 ML earthquake near Arran on 4th March 1999 was the largest earthquake in Scotland for 12 years. The contours show the intensity with which the earthquake was felt according to the European Macroseismic Scale. The data were provided by more than 1000 members of the public who returned questionnaires published in the local and national press.*

Regional Crustal Structure

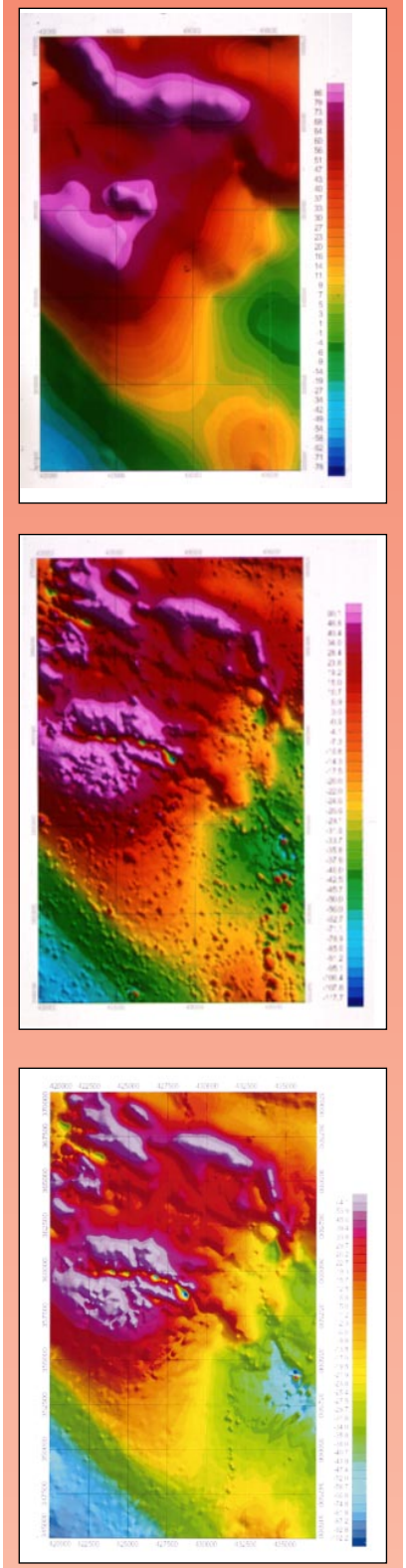
Investigation of the regional crustal structure of the UK has included three-dimensional modelling of magnetic basement structures in the Southern Scotland–Northern England region. This has provided insights into the contrasting crustal architecture on the northern (Laurentian) and southern (Avalonian) sides of the Iapetus Suture and has led to models for the evolution of these opposing margins and the nature of their subsequent convergence. Three-dimensional modelling methods have been used to compute the gravity effects of the post-Variscan cover sequence in south-east England: removal of these effects is aiding in the interpretation of structures within the underlying basement.

Interpretation software

Development of a new version of the GRAVMAG modelling program has commenced. Revisions include a redesigned user interface and powerful new model editing capabilities. Upgrades to the Wellog package were undertaken in order to support research into the effects of stress on geophysical log responses in fractured rocks. Typically most of the fluid flow through fractured rocks is concentrated in a small proportion of the fractures and a very important factor influencing the distribution of flow is the local stress field.

Geotechnical capability

- Contributions to a report by the Construction Industry Research and Information Association (CIRIA) and the Geological Society on Civil Engineering uses of Geophysics were completed.
- A Ph.D. was awarded with respect to 3D inversion research in collaboration with Bristol University.
- A paper was presented at a National Railways meeting regarding geophysical tomography of masonry structures.
- A presentation was made at a national conference describing a novel interpretation scheme for two down-hole resistivity logs used routinely by the Ocean Drilling Programme (ODP) and the oil industry.



R J Cuss, BGS © NERC

First results from the Hi-RES airborne survey. Aeromagnetic images from the Matlock area demonstrating the improvement in structural resolution. (a) previous low resolution data; (b) magnetic field measured by Hi-RES; (c) Hi-RES data after removal of anomalies due to man-made structures.

PARTNERSHIP PROGRAMME

Magnetic modelling: The production of the 1998 revision of the BGS Global Geomagnetic Model (BGGM), which incorporates geomagnetic data collected by organisations world-wide, was supported by the UK Health and Safety Executive and an oil industry consortium. The BGS magnetic stations on Ascension Island and in the Falkland Islands were maintained and provided data for the model. The BGGM is used globally to provide magnetic reference data for directional drilling, helping to ensure boreholes reach their geological targets and avoid well collisions. Under the terms of a new five-year agreement, magnetic data for compass users was supplied for publication on Ordnance Survey maps.

Seismic Monitoring and Information Service: The UK seismic monitoring and information service has been supported for ten years by a broadly-based group of customers led by the DETR, including the nuclear, water and oil industries, together with a number of public bodies. Seismic activity is monitored throughout the UK using a network of 141 seismic stations and information about significant earthquakes is disseminated rapidly to customers. The data are compiled into monthly and annual bulletins and reports, and are used to develop the database for seismic hazard assessment.

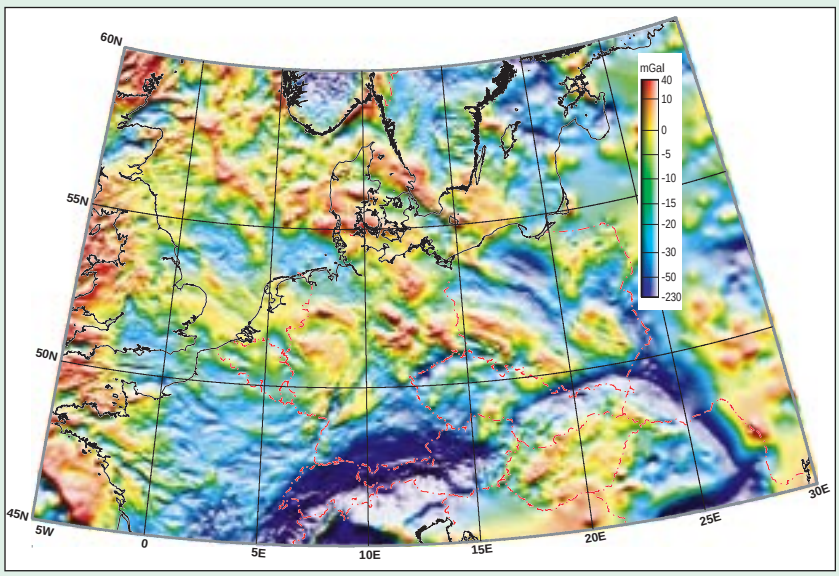
Edinburgh Anisotropy Project (EAP): The EAP consortium conducted research into advanced seismic methods with sponsorship from a consortium of 16 operating, service and software companies. Ideas on using converted shear waves to image beneath basalts, accounting for multiple reflections and other processing problems, were tested and applied to datasets supplied by sponsors. Amplitude versus direction processing of data collected using vertical cable, sea bed sensors and walkaway vertical seismic profiles was applied to datasets from the UK and Norwegian sectors of the North Sea, and from onshore in the USA. Techniques developed using vintage 2D and 3D azimuthal surveys to estimate fracturing in chalk fields were applied to other datasets.

Tectonic early warning system: Seismic activity is a potential threat to populations and commerce throughout the world, and even in the UK, generally regarded as an aseismic zone, earthquakes are a frequent occurrence. The BGS is collaborating with similar organisations in Greece, Russia, Armenia and Albania, with EU funding, to develop new techniques for the automatic acquisition of gas geochemical data from remote sites using gas-sensing probes and telemetry. The data will be integrated with seismic information acquired in parallel, and used to determine whether or not the technique is a suitable method for monitoring ground disturbance associated with tectonic events.

HiRES: The High resolution airborne Resource and Environmental Survey of the UK (HiRES) is a multidisciplinary project spanning the 'Geophysics' and 'Minerals & Geochemistry' programmes. The first survey (HiRES-1) was flown in the summer of 1998 in collaboration with World Geoscience Corporation Ltd. The survey comprised 50 000 line-kilometres of magnetic, radiometric and electromagnetic (VLF) data over an area of 14 000 square kilometres spanning the English Midlands. Preliminary data processing has been completed, and further research into advanced processing methods to extract the full geological and environmental information content is currently being undertaken. Removal of cultural 'noise' from the magnetic data is a particular challenge but initial images confirm a significant improvement in resolution over old surveys. See page 11 for details of radiometric data.

EUROPROBE: The BGS has been actively involved in international collaborative research programmes within EUROPROBE, supported by two EC-funded research networks. Investigation of the eastern margin of the East European Craton (within the URO network) has revealed that deformation relating to the Palaeozoic Uralide orogeny is superimposed on, and strongly influenced by, structures developed along this margin as a result of earlier (Precambrian) rifting and orogenesis. Research into the Palaeozoic Amalgamation of Central Europe (the PACE Network) has resulted in major new compilations of European gravity and magnetic data that have provided dramatic images of the crustal architecture of Europe.

Groundwater geophysics: Together with groups from Holland, France, Cyprus and Israel, the BGS is undertaking a project which aims to establish an integrated geophysical approach to groundwater exploration and management. Co-funding is provided by the European Commission's INCO programme. Field studies were undertaken in Cyprus employing the Electrokinetic Sounding (EKS) and azimuthal resistivity methods. Techniques have been developed for discriminating between homogeneous and heterogeneous rock in azimuthal resistivity surveys resulting in the enhanced mapping of sub-vertical, water-bearing fracture systems.



D Banka, BGS © NERC

An image of gravity anomalies over central Europe based on data compiled for the investigation of the Trans European Suture Zone. Land areas: Bouguer anomaly. Sea areas: Free air anomaly.

Hydrogeology

Research into Britain's groundwater occurrence, movement and quality is applied to groundwater assessment, development and management.

National Groundwater Survey

On the recommendations of the Programme Review Group, a National Advisory panel and Regional Advisory panels were initiated to ensure the user community has input to the regional hydrogeological reports. Progress continues to be made on the regional Chalk Aquifer Studies in the Wessex Basin, Yorkshire, Lincolnshire and the North Downs. The programme continues to attract interest and generate collaborative activities (see Partnership Programme panel). The interest from both the regulators and the water companies reflects the relevance of the programme.

Groundwater Data Dissemination

The BGS is the custodian of several groundwater datasets of national importance, including 100 000 water borehole records and data on aquifer properties, water level, chemistry and geophysics. The principal tool for managing this groundwater data is the WellMaster database, which has undergone further development during the year, primarily to improve integration with other key BGS datasets. The NERC Seedcorn programme has supported data entry to WellMaster, as have interested commercial users who have supported data entry in local areas, allowing an accelerated programme. In partnership with the Institute of Hydrology the dissemination of hydrological data continued, with monthly publication of summaries of hydrological and hydrogeological conditions across the UK. An annual hydrological summary was placed on the Internet and a register of monitoring stations and their associated hydrometric statistics for the period 1991 to 1995 was published.

Mathematical Hydrogeology

This project maintains expertise in mathematical hydrogeology, particularly in mathematical models. A number of responsive exercises were undertaken to develop techniques to solve particular problems in other projects. The major activity undertaken during the year was the initial development of a test-bed model facility. This is based on part of the Chalk aquifer of the North Downs and will be used to test new techniques and to validate new modelling codes.

Geophysical borehole logging

Interest and activity in geophysical borehole logging of aquifers continues to grow. This year, 80 boreholes were logged using the Hydrogeology Group digital logger of which 55 were commercially funded. These investigations were for the purpose of aquifer characterisation and determining water inflows, mainly for public water supply projects throughout the UK, or to investigate contaminant movement related to old industrial sites or landfills. An increasing number of mineral water and brewery boreholes have been logged this year reflecting the need to understand groundwater occurrence and movement and the integrity of the sources.

Geosphere waste containment

This project is concerned with fluid flow in faults and fractures. A radial array of instrumented boreholes in the Mercia Mudstone Group (which outcrops under the Keyworth site) was successfully used for a series of in-situ gas injection experiments. High quality test data match observations made previously in the laboratory. The field results have added to understanding of how gases move through mudrocks, and have demonstrated that the application of conventional two-phase flow theory does not best describe the transport of high-pressure gases through clay-rich media.

Fluid-rock reactions and properties

The rate and mechanism by which fluids and minerals interact have important consequences for both the extractive (e.g. hydrocarbons, metallic minerals) and disposal (e.g. landfill, nuclear) industries. To assess such interactions the BGS has assimilated information on the speed at which such reactions occur and developed new experimental equipment so that they might be better quantified. Such an understanding will assist the prediction of pollution problems and help to improve extraction technologies.

D Buckley, BGS © NERC

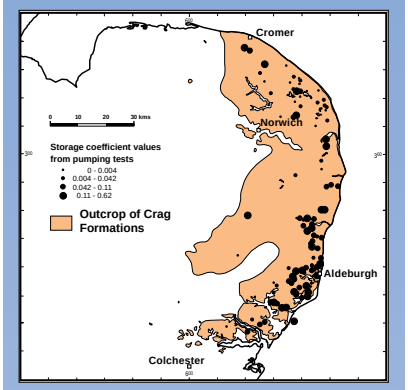
Access to water boreholes to be logged near Moffat was along the river course.

D Buckley, BGS © NERC

Installing submersible pump for testing water supply boreholes, Isle of Skye.

D Buckley, BGS © NERC

Running geophysical logging probes in artesian water supply borehole, Isle of Arran.



BGS © NERC

Distribution of storage coefficient values in the Crag minor aquifer of East Anglia.

Minor aquifers of England and Wales: The data available on the physical properties of the minor aquifers in England and Wales are being collated and reviewed. It is planned to publish the results in the form of a manual and a CD-ROM database. The project is co-funded by the Environment Agency (EA) and will complement the report on the major aquifers in England and Wales which was published in 1997.

PARTNERSHIP PROGRAMME

Fundamental Aspects of Metal Speciation and Transport in Metal-Contaminated Soils and Aquifers (FAMEST): This project, which is co-funded by the EU, is looking at the speciation and movement of metals at a variety of metal-contaminated sites in the UK, France, the Netherlands and Switzerland. The sites include smelter works as well as an agricultural field heavily contaminated by historically large applications of metal-contaminated sewage sludge. The aim of the project is to link laboratory methods of characterising the soil and aquifer materials with generalised chemical speciation models so that the present and future mobility of the contaminants in the field can be reliably assessed.

FRACFLOW: This EU FPIV project will address contaminant transport, monitoring techniques and remediation strategies in cross-European fractured chalk. The study is led by the Danish Geological Survey with partners in German and Israeli universities. Field sites in England and Denmark will be the foci of the programme which is described on www.fracflow.dk. The first year of this 3-year project was spent in producing state-of-the-art reviews of aspects of the study and establishing field sites.

Fracturing and the hydrogeology of the Permo-Triassic sandstones: This project was co-funded by the Environment Agency's National R&D Programme. The aim of the study was to review information concerning the hydrogeological effects of fractures in the Permo-Triassic sandstone aquifers in England and Wales. The project report provides an overview of the current concepts of fracturing in the Permo-Triassic sandstones and their implications for groundwater flow, and summarises existing hydrogeological data.

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 new project funded under the EC ENRICH initiative aims to assist in the creation of a database for existing information on groundwaters relevant to global change in several African Sahelian (Senegal, Niger, Nigeria, and Chad) countries in collaboration with partners in the UK, France, Italy and Germany. Many of the existing data for the African Sahel region have been obtained as part of bilateral north-south projects and the present initiative therefore gives the opportunity to collate and to compare data on groundwater from many individual projects to arrive at some standard for the region as a whole.

Nitrate in the Triassic sandstones of the Selby area: Following from a previous successful study on the East Yorkshire Chalk, an investigation of nitrate in groundwater of the Sherwood Sandstone aquifer of the Selby area has been undertaken with co-funding from the EA and Yorkshire Water. Existing time series of groundwater nitrate concentrations were reviewed for hydrogeological, climatic and land-use influences, profiles of solute concentrations in the unsaturated zone were obtained and a regional hydrochemical survey was carried out. Detailed borehole logging has helped in the interpretation of the near-source groundwater flow and hydrochemistry. A two-dimensional transport model, Multiple Analytical Pathways (MAP), which had been developed in the previous project, was used to predict future nitrate concentrations at selected public supply sources, for use by Yorkshire Water in planning requirements for blending and treatment.

Small licence exempt groundwater sources: A cost sharing exercise with the EA Groundwater and Contaminated Land Centre to develop a means by which the Agency can identify small groundwater sources that are exempt from current licensing regulations. This work is driven by the Agency's anticipated requirements with respect to the DETR Abstraction Licence Review, the Groundwater Regulations and the proposed Water Framework Directive. The BGS will benefit in the long term from increased holdings in the National Groundwater Archive.

Strategic survey in Scotland: A number of activities were completed for the Scottish Environment Protection Agency, including the publication of the first Scottish 1:100 000 scale groundwater vulnerability map, that for Fife. This is similar to maps already produced for the EA but has a modified approach to assessing the role of weakly permeable till cover over aquifer units. A second map covering Dumfriesshire is in preparation. A review of groundwater level and groundwater quality monitoring needs in Scotland was carried out. This recommends a series of networks aimed at

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deriving information on the regional picture as well as on local impact, for example, of intensive agricultural activity. Two groundwater basin studies were also undertaken: one for the Devonian aquifer of Stratheden in Fife and the other the Permian basin at Dumfries. Both of these studies provide better understanding of the two aquifers through the development of conceptual groundwater flow models and preliminary water balance calculations. The studies also highlight the need for further comprehensive investigation as a necessary preliminary to rigorous groundwater management.

Transport of halogenated solvents in the matrix of the Permo-Triassic sandstone aquifer: Halogenated solvents are common contaminants 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 sub-surface pools of solvents means that they may act as long term sources of groundwater pollution. Historical contamination of groundwater by halogenated solvents is particularly common in the Permo-Triassic sandstones of central and north-west England. There is a need to understand the movement and sub-surface 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 the 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.

UK Groundwater Forum: The Forum promotes the wider understanding of groundwater issues and provides a creative environment to determine national research priorities. It is currently producing an educational video about the interaction between groundwater and surface water features.

Effect of old landfills on groundwater quality: Boreholes into the Middle Chalk outside a landfill continue to be sampled bimonthly and are automatically logged for water levels and electrical conductivity in order to calibrate a contaminant transport model. The boreholes were used for pesticide monitoring for the EA.

Natural attenuation of organic pollutants in groundwater: In conjunction with the University of Sheffield and the Institute of Freshwater Ecology, redox zones have been mapped out in the contaminant plume in the Triassic Sandstones aquifer beneath a coal distillation plant in the Midlands. The factors controlling microbial activity and organic degradation have been studied in laboratory microcosms using groundwater and sediment acclimatised in the plume. Evidence for biodegradation is being sought by monitoring systematic changes in the stable carbon isotope ratio within specific compounds in conjunction with Leeds University. The results will help identify favourable situations for natural attenuation of groundwater contaminants.

Hydraulic conductivity in tills: In the Cottingham area of East Yorkshire, groundwater is abstracted from adits in the Chalk. Tills overlie the Chalk and work, co-funded by the EA and Yorkshire Water, is in progress to evaluate their ability to mitigate risks that might arise from pollution. An array of piezometers was installed to determine the hydraulic characteristics of the till, and a core sample was obtained for physical and mineralogical testing with a view to defining the flow processes through the till. The regional character of the till was evaluated, to provide the regulator and operator with information on clay thickness and clay persistence, enabling them to assess which areas might have a higher pollution potential.

Mineralogy of reservoir rocks: Work was commissioned by Shell UK Exploration and Production to evaluate the variation in modal determinations by different analysts using point counting under the optical petrological microscope, and to compare the results of this with modal mineralogy determined by BSEM combined with computer image analysis techniques. Core Programme funding was used to develop a sophisticated modal analysis package using image analysis of integrated and simultaneously acquired BSEM, SEM-cathodoluminescence and energy-dispersive X-ray microanalysis images.

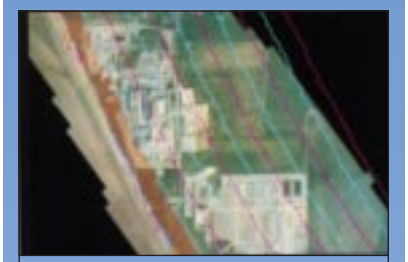
BGS © NERC

Probable extent of the European landmass around 10 000 BC showing glaciation maximum and PALAEAUX study areas.

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.

Marine and Coastal Geology

Geological studies of Britain's coasts and beneath her seas are important for the economic development and environmental planning of the nation.

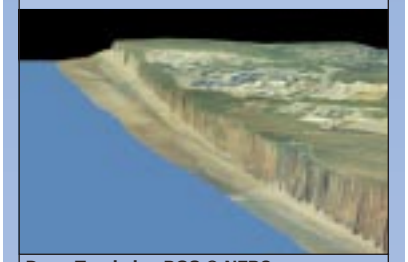


Doug Tragheim, BGS © NERC

Orthophoto mosaic of a 1km wide strip of land at Easington Gas Terminal, SE Yorkshire, with calculated (2m/year) erosion contours at 50 year intervals (blue) and 100 year intervals (red).

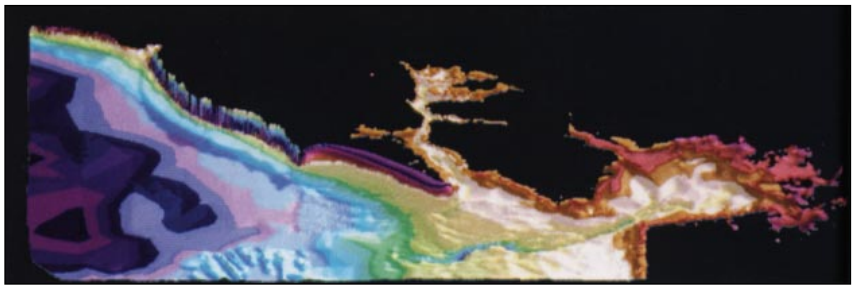
Holderness coastal erosion

Digital photogrammetry was used to model coastal erosion near Holderness on the east coast. A detailed 3D model was produced and used to study the likely effect of different amounts of erosion on the nearby Easington industrial complex. It enabled the threat to this expensive development to be clearly visualised. The output from the study was used in an interactive multimedia exhibition to mark the opening of one of the new Earth Galleries at the Natural History Museum in London.



Doug Tragheim, BGS © NERC

Perspective view (looking south) of a digital terrain model (DTM) created using digital photogrammetry draped with a 2D orthophoto of the Holderness cliffs at Easington, Yorkshire.



BGS © NERC

Model of the North Sea as viewed from the east towards the Humber Estuary about five thousand years ago. The coast at the time is shown in yellow. Created within the integrated modelling phase of LOIS.

LOIS integrated modelling

The bathymetry and levels of sediment erosion in the western North Sea have been modelled at thousand-year intervals through the Holocene. The chemostratigraphical sequence of the Holocene fill of the Humber Estuary is also being used to calibrate models that 'hindcast' sediment delivery to the estuary by rivers and sea. The work is being carried out in partnership with Durham and Leeds Universities and Proudman Oceanographic Laboratory.

GIS development

Work is in hand to develop a scheme for the attribution of geological information within the GIS that will form the basis of the 3D digital model. This is being applied to the Tertiary basalt terrain of the Rockall area and in a pilot study for the Midland Valley Project that will integrate onshore and offshore data for Fife and the Firth of Forth.

Structural controls on igneous emplacement

Mapping of Palaeogene strato/shield volcanoes has revealed an association between a strong north-east-trending Caledonoid lineament and a chain of Palaeogene igneous centres. A lineament running from the east Faeroes shelf to the north-east Rockall trough is interpreted as a major feeder dyke, the source of the Darwin and Faeroe Bank Channel and the newly recognised Wyville-Thompson and Munkagrunnur strato/shield volcanoes. Earlier interpretations favoured north-west-trending lineaments as the control on the emplacement of the Palaeogene igneous centres but this new evidence emphasises the influence of old Caledonoid trends.

Sea bed maps and images

The Sula Sgeir solid geology map has been completed and the sea bed sediments map of the Shetland area has been published. An image of the eastern slope of the Faeroe–Shetland Channel has also been prepared. The image has been constructed using the first signal return from conventional exploration 3D seismic data and appears similar to an oblique aerial photograph. Because the image is compiled digitally it can be viewed from any angle or elevation. It provides a very powerful new tool for the study of sea bed morphology and sediment dynamics.

Sea bed stability

As part of our ongoing studies of sea bed stability on low-angle slopes the BGS led an international investigation, using Japanese research vessels, to examine sea bed failures induced by a major earthquake immediately offshore Papua New Guinea. This generated a devastating tsunami resulting in the deaths of over 2000 people.

Palaeogene sills

The architecture and age of Palaeogene sill complexes along the Atlantic margin of Ireland and Scotland has been investigated. The features include saucer-shaped and transgressive sills, thick amorphous sill swarms with poor internal definition and non-conformable steeply-inclined sheets, with or without associated mounds of sub-aqueous lavas. Traditional models of emplacement do not fully explain these observations. Ongoing Ar–Ar dating studies are further refining the chronology of intrusive events within the Faeroe–Shetland Basin.

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Gdansk Gulf Basin: This two year project, co-funded by the EU and with partners from Lithuania, The Netherlands and Poland ended in March 1999. The programme, aimed at the harmonisation of marine environmental monitoring methods between Central and Eastern European Countries (CEEC) and EU member states, compared sampling, analytical and interpretational techniques in the Polish and Lithuanian sectors of the Gdansk Gulf Basin. Major findings of the programme were presented at a workshop in Gdansk in October 1998.

US Navy: An invited paper was presented to the American Acoustical Society regarding 3D heterogeneity of sea-floor sediments and the evaluation of sediment tortuosity in collaboration with the US Navy.

Leicester University, Enterprise Oil, Lasmo, Core Labs: Three papers have been published regarding the assessment of fine-scale heterogeneity and its impact on petrophysical properties, through integrating novel laboratory techniques with downhole geophysical logging data. A presentation was made at Geoscience '98 regarding the mapping of fine-scale open fractures.

1st Ground Investigation & Broad and Gloyens: 3D cross-hole seismic techniques have been developed and demonstrated at a property where subsidence due to solution features in chalk was suspected. The 3D tomogram indicated the area of affected ground was too extensive to warrant remediation. Two reports were completed.

Rockall Consortium: BGS manages, and is a partner in, a consortium with 14 oil companies. A complex two ship seismic experiment, with an additional string of ocean bottom seismometers (OBS), was successfully conducted across the margin of the Tertiary basalt in the Rockall Trough. The objective was to image the structure beneath the basalts and initial results suggest significant improvements to existing seismic methods can be made. In addition high resolution, pre-site, seismic surveys were carried out over planned shallow drilling sites for safety reasons. A small survey over part of the Hatton–Rockall Bank confirmed that there are windows in the basalt cover where pre-Palaeogene sediments can be sampled.

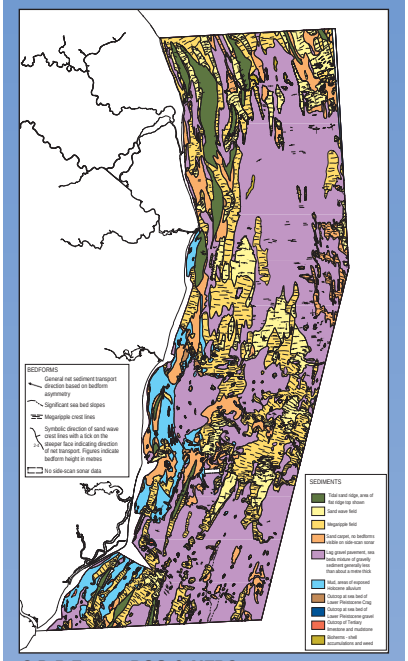
Western Frontier Association: The WFA has continued to support a portfolio of projects including seismic monitoring, the distribution of hydrates and shallow gas and the maintenance of databases. A bibliography of published data and reports on the shallow geology and environment of the north-west margin, was produced on CD for members. Regional sea bed images using 3D exploration seismic data, have been used to constrain interpretations of sea bed morphology and sediment distribution, geotechnical properties and habitats for benthic fauna. Low cost sea bed and downhole temperature probes have also been developed to obtain thermal curve data for gas hydrate modelling studies.

Stratigraphical Nomenclature: A sequence stratigraphical nomenclature of the Mid-Late Cenozoic on the north-west margin has been published completing the three volume stratigraphical series for the area. The volume was supported by a six-company consortium and describes the Cenozoic development and build-out of the shelf margin.

Millennium Atlas: This is being funded by the oil industry as a benchmark publication to celebrate the exploration of the North Sea. Groups of oil companies have undertaken to prepare individual chapters and the BGS will contribute to a number of these as well as providing overall editorial control. The Atlas will describe the whole stratigraphical sequence from the Precambrian to the Recent for the central and northern North Sea, including Danish and Norwegian waters as well as the tectonic framework of the basin and a review of legislation and oil exploration.

European collaboration: The BGS has played a leading role in the very successful European North Atlantic Margins (ENAM) I and II Programmes along with eight European partners. The project is investigating sediment dynamics along the shelf margin and integrates well with the BGS's studies on the development of the shelf margin north-west of the UK. Two new projects have also been initiated. These are the HYACE programme (involving seven European partners), to design and build a down hole autoclave to sample gas hydrates at depth and recover them at ambient temperature and pressure. The other project is EUMARSIN, which involves 14 European countries with BGS providing the secretariat. It aims to develop a meta-database of sea bed sediment information for European seas to facilitate collaborative ventures and promote common standards.

Speculative seismic surveys: In a collaborative venture with Geoteam, BGS has provided assistance with survey design and interpretation of surveys in the North Sea and on the Atlantic margin. These high quality data have provided new insights into the structure and geology of the area and contribute to the development of new models of the 3D geology of the UKCS.



C D R Evans, BGS © NERC

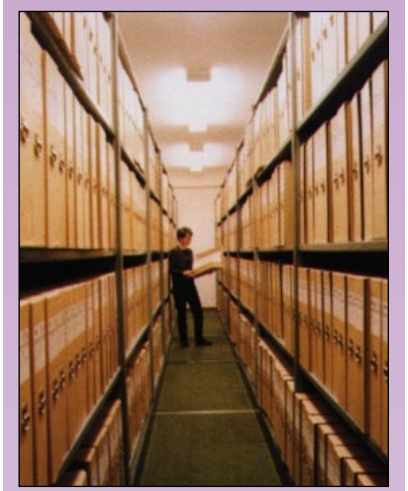
Part of the Inshore Seabed Characterisation project digital map of seabed facies off the Suffolk coast.

Nearshore Strategic Survey

The co-funded project with the DETR was completed early in 1999 with the holding of a workshop in Keyworth and production of two major reports. The digital mapping at the heart of the project has proved of interest to a range of external bodies, though third party copyright licences are hindering wider dissemination of the data. Specific take-up has come from the MAFF laboratories (CEFAS) who are using the mapping of sea bed facies to integrate with the fisheries information. Work on shoreface profiles along the southern and eastern England coast has shown that modern rates of retreat probably did not apply through the Holocene, and that the form of many shorefaces is inherited and a function of Pleistocene rather than Holocene erosion.

Records and Databases

The National Geosciences Information Service provides access to, and data and advice from, collections of bibliographic and cartographic material, records, samples, and digital databases.



Paul Tod, BGS © NERC

Borehole records in the National Geosciences Records Centre.

HOLOSTRAT

The first output of this project (Silurian, Ludlow Series) was posted on the BGS web site as a free download in January 1999 and the site is already well-visited. Holostrat is an "evergreen", browsable database, endorsed by the Geological Society, and provides the most comprehensive data on UK stage stratotypes. It is a community project encouraging the involvement of all researchers on UK and international stratigraphy to develop the database. Several stages are in preparation, including two in the Mesozoic (the Albian & Oxfordian).

Geochemistry databases and software development

There was further consolidation of the databases for mineral occurrences (MOD), mines and quarries (BritPits), petrological samples (BritRocks) and Geochemistry. They all have user-friendly Access front-ends and most are linked to ORACLE server databases. Expertise gained on these projects has been useful in gaining contracts in the Czech Republic, Ecuador, Namibia and Zambia, as well as in the UK.

GIS and Information Systems Research and Development

Work continued on developing an interface to the Digital Geological Map of Great Britain (DIGMAPGB). This involved refining the map index database that describes the availability of individual digital map sheets and designing a graphical interface to it.

The development of the Digital Report Generating System (DRGS) continued with the adoption of SGML technology for tagging text. The Glasgow and Airdrie memoirs were marked-up using SGML and workshops held with authors.

A prototype graphical application was developed showing correlations between biostratigraphical zones, the BGS Chronostratigraphical Index and the BGS Lexicon of Named Rock Units.

Intranet

During the year the BGS developed its first Intranet. In the short term it is designed to speed up internal communication and information dissemination. A wide range of basic information has been made in the first release including basic static information essential to the organisation. In the medium term the Intranet will provide access to the major BGS Corporate Database in both graphical and tabular formats. The overall goals are to reduce the costs of disseminating information to staff and to make information easier to locate, thus saving staff time.

BGS-geoIDS Project

The BGS-geoIDS Project is a three-year project that aims to integrate the BGS's diverse data holding. The BGS has numerous database and data collections compiled over 160 years. However, many of these databases are project-oriented. The project is designed to make the information more widely available, integrated where appropriate, and of a high quality. This is being achieved by formally documenting the existing digital data model prior to revising it where necessary, capturing the technical and discovery metadata, establishing corporate data management policies, defining corporate data standards and investigating methods of disseminating the data on the BGS Intranet and Internet sites.

Collections Administration

The main activity has centred on the integration of borehole material into the permanent collection. This included previously acquired onshore material from major oil companies, material transferred from the DTI Hydrocarbon Core store in Edinburgh and newly acquired material including a major donation from Candecca Resources. In total, material from over 312 boreholes were added to the collection.

Work continued on the development of the enhanced borehole material database, which includes lithostratigraphical details of the drillcore, to enable improved access to specified material. The final version of the database will be available once the 106 000 boxes of core are indexed using individual bar codes.

Work started on sorting and archiving the major collections received from the ex-British Coal archives. A new database was created for these archives and other data

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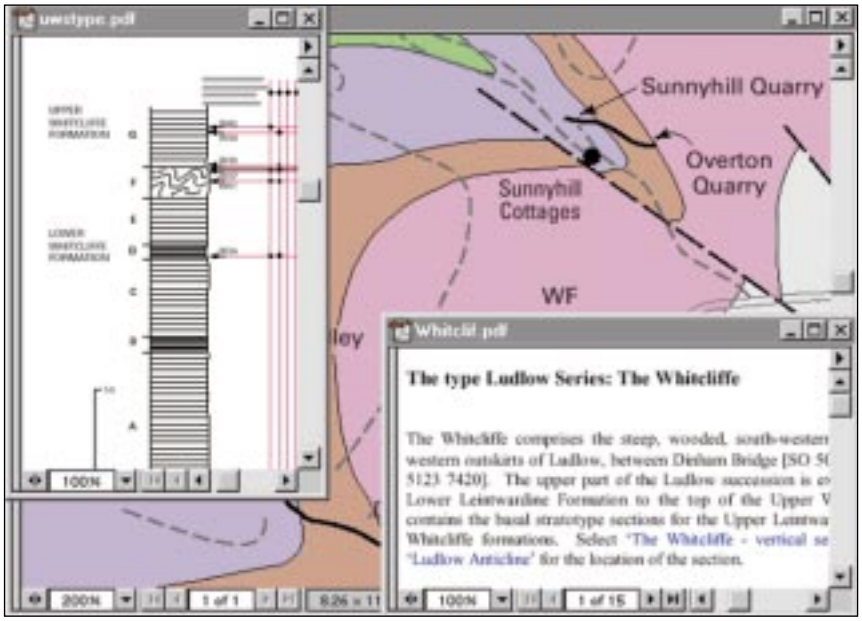

Patrick Bell, BGS © NERC

HOLOSTRAT is a BGS initiative that makes geological information available via the World Wide Web, fulfilling NERC's mission to disseminate knowledge relevant to its areas of responsibility. Text files, maps and diagrams published on the BGS website explain and illustrate aspects of UK stratigraphy (http://www.bgs.ac.uk/free/holostrat/holostrat.html), and are linked by means of hypertext and bookmarks.

received from BP. Over 1000 individual documents have now been indexed. Some 20 000 plans were also collected and these are being indexed and incorporated in the collections on a project basis.

The level of routine donations was up by 39% on the previous year with over 50 000 records received in 3,500 separate donations from some 80 separate organisations.

The successful introduction of an automated standard enquiry response from the Geoscience Data Index produced using MS Word has helped the enquiry service meet its performance targets and improve the information provided to enquirers.

Borehole Database

A major achievement during the year was the completion of the merger of the four main BGS digital borehole indexes into the Single Onshore Borehole Index (SOBI). Complex merger protocols had to be written and thousands for entries examined and corrected before the new Index could be produced.

As part of the ongoing programme to reduce the backlog of borehole registration some 125 000 boreholes were processed and the backlog reduced to less than 80 000. The SOBI now contains over 825 000 entries.

Database Development

During the year the content of the BGS Lexicon of Named Rock Units was expanded and improved significantly, as the database took on a crucial dictionary role in the 1:250k and 1:50k DIGMAPGB projects. Lexicon entry application forms were made available via the BGS Intranet to facilitate compilation of new or revised rock unit definitions.

A new database system to hold details of BGS Discovery Metadata was designed and built, together with a Web-based browsing system that will, when fully populated, allow users to establish the existence, whereabouts and availability of all significant BGS geoscience datasets.

The year also saw the compilation and adoption of the first formal BGS Corporate Data Policy (as part of the BGS-geoIDS initiative) and the drafting of the high-level BGS Corporate Data Management Plan.

Aquifer geometry

The BGS's subsurface database has been invaluable for the supply of information on the geometry and nature of major aquifers in the UK subsurface for the Environment Agency. There is a growing demand for this type of information from the UK water industry.

Environmental databases

As an aid to marine environmental studies in UK waters, the BGS and CEFAS are being funded by the DETR to develop and compile a database of geochemical and related studies on the UK continental shelf, including the estuarine and coastal zones. The work follows an earlier project to prepare a database for the Celtic Seas region and will involve making recommendations for future database and GIS development in the marine environmental field.

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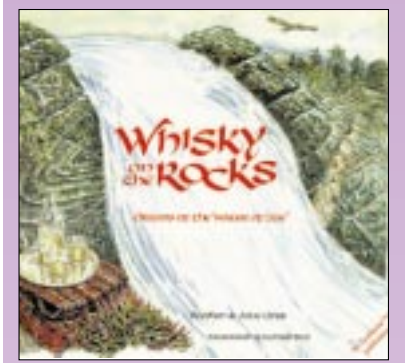
GEIXS

This was the second year of the project which aims to set up a web-based metadatabase of geoscience data holdings of all 15 European Union Geological Surveys, all of which are project partners. The BGS is the overall project co-ordinator. During the year, the web site and retrieval applications were implemented and the data loaded. An extension to the project was made to include nine new partners: Armenia, Bulgaria, Estonia, Hungary, Latvia, Lithuania, Norway, Poland, and Russia. A workshop was held, in Orleans, to disseminate the early results of the project.

The BGS is pledged to bring science to the people.



A selection of popular publications.

Science for All

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 activities included:

- A series of evening classes on the theme Geology and Man. This was the eighth 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 awarded by the University.
- Participation in national and regional PUS events, such as National Science Week and Scottish Geology Week.
- Participation in the NERC Schools Liaison Network, including support for schools in the form of visits, talks and the provision of information.
- Talks on the work of the BGS to community groups, such as the University of the Third Age and Probus.
- Numerous guided tours of the Keyworth site including an introduction to the history and current activities of the Survey.
- Careers information and attendance at careers fairs.

The BGS's National Collection of British Fossils has played an important part in providing displays for Science and Technology Week (SET99) and school visits.

Earthwise™ Publications

The following publications were produced under the Earthwise™ label:

- Three more Fossil Focus guides — *Plants, Echinoids* and *Crinoids*
- Two Holiday Geology Guides — *Scarborough and Whitby* and *Cornish Pebbles.* The latter was the first holiday guide designed for children.
- The book *Whisky on the Rocks,* which tells the story of malt whisky and geology. It sold over 2000 copies in the first year.

Customer Services

New flyers, New Releases and catalogues continue to be produced to promote new products. Emphasis has been placed on promoting the more popular Earthwise™ Publications in advertisements in magazines. Innovative promotions such as magazine-led competitions and prize draws, sponsoring and the use of "advertorials" have taken place. Sales stands have been taken to a number of special events, such as geology fairs to raise the profile of BGS as a publisher of popular publications.

Popular BGS and Earthwise™ Publications have been made increasingly available to bookshops through ten national and regional book wholesalers. The existing Approved Suppliers network has been re-evaluated. Three new suppliers were appointed and several non-productive appointments were terminated. The number of Approved Suppliers is now 42. In addition, the role of national Agents, who stock a comprehensive range of BGS and Earthwise™ titles was expanded during the year with 15 book and map suppliers now providing this service.

Information and Advice

During 1998 approximately 29 000 enquiries were handled. Of these 18 200 were dealt with by the Information Services Enquiry points in the Library and records sections in Keyworth and Edinburgh, London Information Office and Central Enquiries at Keyworth, providing a comprehensive service to members of the public, industry and the geoscience community.

The total number of chargeable enquiries has remained approximately the same as the previous year at 3167. However, there has been an increase of 9% in the total income derived from chargeable enquiries.

Library

The two externally funded projects digitally to scan geological photographs have progressed during the year. The SCRAN project is nearing completion with some 3000 images digitised and indexed. The JISC/JIDI project is still in progress and will be completed in FY 1999/2000. There is evidence that the

Tim Cullen, BGS © NERC

David Falvey, Director of the BGS discusses a mammoth molar with young visitors to Science Week at Keyworth.

facility established within BGS as a result of experience gained from these projects is leading to the BGS being asked to take on digitisation work for external organisations. The index database to the BGS photograph collections now contains over 75 000 entries and is in regular use in answering enquiries. It is hoped to link this index with the new library management software in the coming year.

Following a review of software on the market, the OLIB library management software from Fretwell Downing was purchased early in 1999. This software will enable the Library to extend the range of automation in its services and move to a Windows-based environment, which will be more user-friendly to BGS staff and external customers. The new system will also allow the storage and retrieval of digital text and images and represents a significant step towards a "virtual library".

External sources of funding are being investigated to support a programme of digitisation of material in the Library collections based on the trial scanning carried out over the past year.

Copyright

Continuing priority has been placed on enforcing the Survey's rights under the Copyright, Designs and Patents Act 1988 (CDPA 1988) and subsequent Statutory Instruments. An increasing number of companies and educational concerns are recognising the legal necessity of acquiring BGS copyright licences for the use of analogue and digital materials.

There has been an increase in the number of copyright permits issued. Over 60 copyright and other IPR related requests are now being processed a month, and income has increased by over 10% over the year.

As part of the recent government consultation exercise, BGS contributions with respect to our copyright experience were submitted. These were acknowledged in the HMSO report "The Future Management of Crown Copyright".

The BGS Web Site

The number of visitors to the BGS Internet web site has continued to grow steadily. The World Maps Register, which gives a listing of maps held by the library and available from the BGS Sales desk, remains popular. There has been particular interest in the increasing number of free BGS products available as downloadable files. These include the BGS Lexicon of Named Rock Units, the BGS Map Symbols and Lithological Ornaments, a guide to environmental geology in land use planning, BGS Stratigraphical Framework Reports, BGS newsletters and magazines, etc. An important new product is HOLOSTRAT, a joint venture with the Geological Society of London's Stratigraphy Commission. It establishes an area on the BGS web site for the geological community at large to obtain and exchange information on the stratigraphy of the UK (see Records and Databases).

Training

In 1998/99, more than 2, 200 attendances were recorded at some 332 training events; 58 staff were involved in Further Education. There was considerable expansion in IT training, reflecting the introduction of the corporate IT standard.

BGS in the Media

Staff have been involved in TV programme production for the BBC and Discovery channels. The BGS has continuing links with the BBC Radio Science Unit and is called on regularly to assist in programmes with a geological content for both domestic and World Service broadcasts. Programmes include *Frontiers, Life at the Edge, Postmarks* and *The Works.* The estimated weekly global audience for World Service radio broadcasts is around 140 million.

.. Press Office .. Press Office ..

The BGS Press Office continues to work in close co-operation with the media to raise the profile of the organisation 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.

A total of 60 news releases were issued and coverage was obtained in all media.

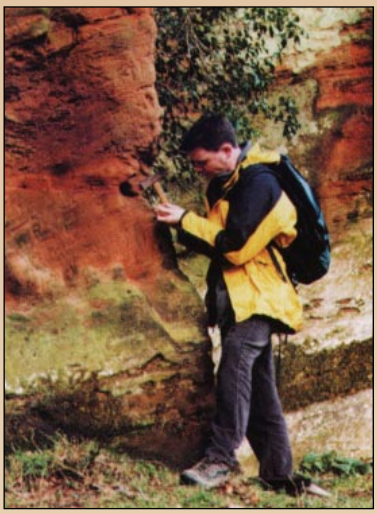
The Press Office also fields incoming enquiries and encourages the background briefing of journalists who wish to feature earth sciences in their work without necessarily focusing on a particular organisation. This generic use of science information relates closely to PUS work, and also results in the BGS being used as a primary source by most major media.

Northern Ireland

The Geological Survey of Northern Ireland (GSNI) is an office of the Department of Economic Development. It is led and staffed by BGS scientists under an agency agreement which also enables GSNI to draw oon expertise in other parts of the BGS.

© GSNI

The Hon. Adam Ingram, Minister of State (far right), presented with the new Causeway Coast geological map by (l to r) John Arthurs (director GSNI), Patrick McKeever and Mark Cooper, authors of the map.



© GSNI

A GSNI geologist examining an outcrop of Triassic Sandstone Hannahstown, County Antrim.

Causeway Coast

In May 1998 the revision of the 1:50 000-scale geological map of the Causeway Coast (Sheet 7) was completed. The map style is innovative in that, in addition to the standard information, it includes information of use to walkers, tourists and amateur geologists. It has received critical acclaim in specialist publications and is now GSNI's fastest selling map.

Investors in People

The Investors in People Award was presented to the GSNI in December 1998. The award recognises the GSNI's commitment to its staff. The support given in personnel matters generally and the IiP bid specifically by both DED and BGS is gratefully acknowledged.

Derrygonnelly and Marble Arch

The Sheet Memoir for Derrygonnelly and Marble Arch (sheets 43, 44, and 56) was published in March 1999. The re-survey of the area resulted in a major revision, including a modern synthesis of the Carboniferous stratigraphy and structure of the district. The memoir describes the natural resources of the district, including a major deposit of dolomite, as yet the only source in Northern Ireland. The publication is timely given the current interest in hydrocarbon prospectivity, not only in south Fermanagh but also in many other parts of Northern Ireland.

Landscapes from Stone

In a cross border initiative, GSNI and the Geological Survey of Ireland have collaborated since 1995 in promoting landscape tourism in the northern counties of Ireland. The Landscape Tourism project promotes and delivers products of earth science interest for tourists and student geologists visiting the Twelve County region including Northern Ireland and the border counties of the Republic of Ireland. It is funded by the EU's Special Fund for Peace and Reconciliation and the Interreg Programme, together with significant contributions from local government in the region. Phase I was completed during the year. Specific achievements include:

- *A Guide to the Scenic Landscapes and Rocks of Ireland (North).* A map and guide was published in December 1998 by the Geological Survey of Ireland.
- *A Story Through Time. The Formation of the Scenic Landscapes of Ireland (North).* A colourful account of the geological history of the Twelve County region of the northern part of Ireland, published by GSNI in March 1999.

Antrim Plateau

The Solid and Drift edition of the 1:50 000 Geological Map of the Coleraine Area (Sheet 13) Plateau Projects was published during the year. The area between Coleraine, Maghera and Ballymena in the north-central part of the Antrim Plateau is an expanding population centre set in an agricultural landscape. Geoscientific issues relating to mineral resources, environmental management and aquifer protection are significant for the local communities. The geology of much of the Antrim Plateau, which is underlain by basalt lavas of the Antrim Lava Group, is relatively homogeneous and well documented. It has therefore been possible to map the area more rapidly at a scale of 1:25 000, compared with conventional field surveying at 1:10 000 scale.

Earth Science Conservation Review

Funded by the Environment and Heritage Service (E&HS) of the Department of Environment, this is a series of contracts designed to identify and record details of sites of special scientific interest for earth science. It forms an enduring record for scientists and conservationists. The Precambrian Site Network was completed and a major report presented to E&HS in September 1998. The Caledonian Site Network is in progress in collaboration with Queens University. Phase 1, covering the Newry Igneous Complex in Co. Down, is now complete.

Enquiry Service

A comprehensive review of the GSNI Enquiry Service was carried out during the year and resulted in improvements to management and recording procedures. Demand for borehole and other site-specific data remained high and there was a significant increase in the number of requests for geological reports related to Environmental Impact Statements. This represents a 14% growth in the year and is a continuation of the steadily rising trend begun in 1993.

Isotope Geosciences

Diatoms reveal past climates

Although diatoms are widespread and extensively studied for other purposes, technical difficulties in the $^{18}O/^{16}O$ analysis of diatom silica have generally prevented its use for isotope palaeoclimate studies. NIGL, in collaboration with the University of Lancaster, has now established the method for their analysis. This capability proved crucial in the study of sediments from a high-altitude glacial lake in Turkey, where the carbonates usually used for isotope work were absent from key sections of the core. The diatom $^{18}O/^{16}O$ data show long-term (20 000 years) changes attributed to inputs of glacial melt water during warm phases, and the core may be one of the first terrestrial records showing evidence of orbital forcing of climate variability.

Hydrocarbon characterisation

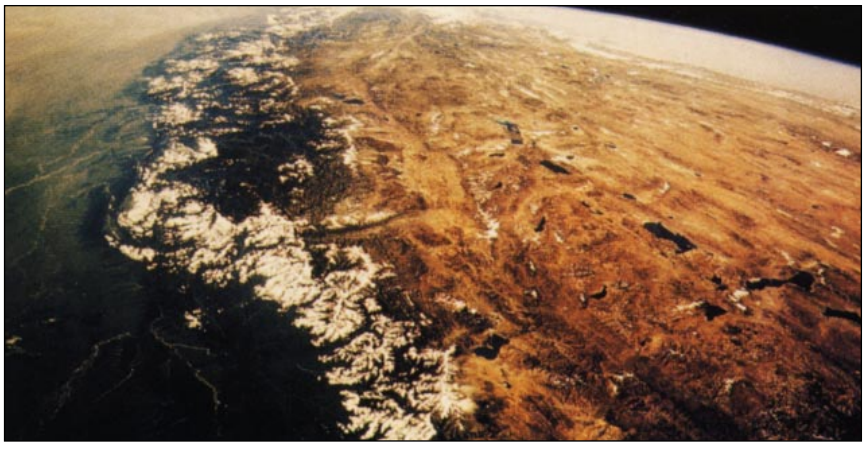
Organic matter is associated with the porphyry copper deposit at Recsk and epithermal deposits of Lahoca, bordering the petroliferous Pannonian Basin in northern Hungary. In a study with the Natural History Museum and Imperial College, GC-MS characterisation and compound-specific $^{13}C/^{12}C$ analysis show that the hydrocarbons occurring in the metalliferous rocks were derived from the Pannonian Basin. The isotope data support the hypothesis that the organic matter was formed by condensation. The $\delta^{13}C$ values of the same n-alkanes occurring in different environments may be distinguished, providing confidence in the use of compound-specific $^{13}C/^{12}C$ analysis for correlating hydrocarbon occurrences.

Fluid inclusions

Gold deposition in hydrothermal deposits may be associated with boiling. In one of the first studies of the D/H and $^{18}O/^{16}O$ ratios of fluid-inclusion water, a consistent relationship was found between isotope composition and depth in an epithermal mineral deposit on Milos, Greece. The data, obtained in collaboration with the Geological Survey of Greece, are proof of isotopic fractionation by boiling. This technique for directly determining the composition of inclusion fluids replaces the current, and in this study demonstrably unreliable, method of calculating fluid compositions from mineral data.

Antarctic ice sheet

Recent ice core research with the British Antarctic Survey has focused on Dolleman Island on the Antarctic Peninsula and Berkner Island on the West Antarctic ice sheet. The core is returned frozen to the UK for detailed investigation including analysis of $^{18}O/^{16}O$ and D/H ratios using high-precision mass spectrometry. The Dolleman Island core (spanning the years between 1650 and 1980) shows that the temperature at this site was relatively stable. The middle to late nineteenth century was only slightly warmer than the late eighteenth century, but there was a cooler period in the early twentieth century. The two warmest summers were 1974 and 1975. The 550-year climate record from the Berkner Island core has been measured for both $^{18}O/^{16}O$ and D/H—thus enabling the 'deuterium excess' factor to be calculated. This is used in the determination of the moisture source for the precipitation. At Berkner Island, the temperature of the source region has remained the same over much of the period.



NASA

The NERC Isotope Geoscience Laboratory (NIGL) is administered by the BGS and funded from the NERC Science Programmes Directorate.

Philip Barker

Diatoms from Lake Pinarbasi, Turkey.

The uplift and erosion of the Himalaya is currently thought to be responsible for initiating and sustaining the south Asian monsoon. In a collaborative study with the Universities of Cambridge, Leicester and Mainz, precise U-Pb dating at NIGL provides key constraints on these processes. Detrital monazite ages for foreland basin deposits in front of the rising Himalaya indicate that the high-grade rocks of the Greater Himalayan series were only exposed to erosion very recently (less than 10 million years ago). Supporting evidence for this surprising conclusion is provided by a U-Pb age of 11 million years for monazite in the Main Central Thrust Zone of Bhutan.

(Left) *As portrayed in this space shuttle photograph of the Himalayan foreland, the western Himalaya (Nepal, India and Pakistan) and southern Tibet, the Himalayan Range is one of the most prominent features of the terrestrial Earth. Its uplift since the middle Cainozoic has hastened global cooling, poured vast amounts of sediment to the Indian Ocean, and modified the regional climate of south Asia by intensifying the Asian monsoon. NIGL isotopic studies with colleagues from several universities have quantified its erosional and tectonic history with specific field studies in Pakistan, India, Nepal, Bhutan, and Tibet.*

The synergy between UK-based work and overseas operations is one of the BGS's greatest strengths.

DFID Knowledge and Research programme

The BGS has a long history of involvement in the DFID Knowledge and Research (KAR) programme and its predecessors. Applied research projects carried out under this programme are directed towards solutions in the geoscience and water/sanitation sectors that contribute towards poverty alleviation. All have a strong emphasis in practical take-up. In broad terms, the strategic aims of the KAR programme are to:

- Improve the livelihoods of poorer people
- Provide better education, health and employment opportunities and
- Protect people from natural and man-made hazards

During the year, the BGS led or participated in more than 20 projects at various stages of completion. These covered such topics as landslide hazard preparedness; evaluation of mine wastes; artisanal mining; industrial minerals; the gathering, use, and evaluation of geoscience data; environmental arsenic exposure; and groundwater resources, quality, protection and management. Several of these projects are briefly described in the International Development and Assistance section of this report.

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.

International Development and Assistance — Mapping and Minerals

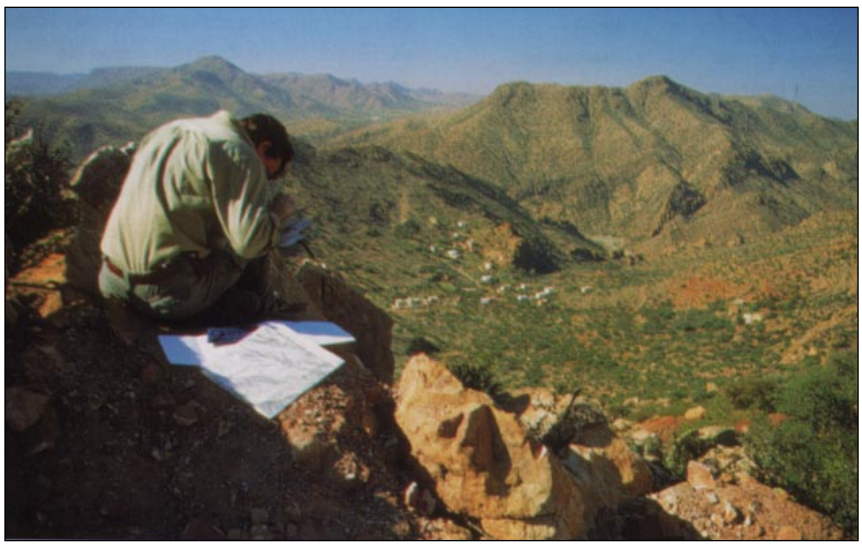
Effective development of offshore aggregates in south-east Asia

The aims of this project, which was undertaken for DFID, were to provide guidelines for the planning and execution of offshore aggregate resource surveys and encourage the adoption of long-term planning, surveying and monitoring methods. An important requirement was the encouragement of environmentally sensitive and sustainable methods of offshore sand and gravel extraction. The project report was presented at workshops conducted at UN ESCAP in Bangkok in association with CCOP and also at the Mines and Geosciences Bureau in Manila.

Zambia

A two-year project supported by EU/SYSMIN funding to edit, produce and publish a backlog of geological maps and reports has been successfully completed, and a follow-on project is underway. Publication of the 1:100 000 scale colour-printed maps and accompanying reports are aimed at development of the mining sector in Zambia and for land-use planning. On-the-job training of local counterpart staff in the Zambian Geological Survey is an important part of the project.

A multidisciplinary geoscientific survey of northern Zambia, supported by the World Bank, is being undertaken jointly by the BGS and the Zambian Geological Survey Department. The project forms part of the reform of the Zambian mining sector, and involves geological mapping, geochemistry, remote sensing, development of minerals databases, training, and assessment of the mineral resources and economic mineral potential of the region to encourage inward investment in the mining sector. Training forms an



M Gillespie, BGS © NERC

Geological survey of a granitic terrain in the Anti-Atlas range, Morocco.

A G Gunn, BGS © NERC

BGS geochemist with Ecuadorian counterparts carrying out a soil survey at 4000m in the Western Cordillera of southern Ecuador for the Assessment of Ore Districts project.

important component of the project and is provided by the two-man residential team with specialist short-term support.

On-the-job training in remote sensing image analysis was provided to a group of Zambian geologists in Lusaka. Landsat TM data obtained from the School of Mines, University of Zambia and a mineral exploration company were processed. This was followed with reconnaissance field verification of the satellite imagery in eastern and north-eastern Zambia as a contribution to the mapping programme.

Morocco

Geological Mapping: The BGS is carrying out a two-year geological mapping contract on behalf of the Moroccan government (Ministry of Energy and Mines). The project covers three areas of the Anti-Atlas Mountains with mineral potential, and will produce eight 1:50 000 geological maps, accompanying reports and digital databases on the geology and mineral resources. The survey involves geological mapping, remote sensing, geochronology, and geochemical and mineralogical analyses. A principal aim of the project is to enhance the attractiveness of Morocco to the national and international mining sector.

Regional geochemical mapping: In addition to the geological mapping described above, a two-year geochemical mapping project in the Ouarzazate area of the Anti-Atlas range, is being carried out by the BGS under contract to the Moroccan Ministry of Energy and Mines. Mapping is carried out using stream sediments collected at a density of 1 sample per square kilometre over an area of 15 000 square kilometres. Following an orientation survey in November 1998, sampling teams consisting of four BGS personnel, and 25 Moroccan geology graduates started a six-month sampling campaign. Most of the 27 elements to be determined are being analysed using the new Spectro X-lab ED(p)-XRF 2000 machine at the BGS's laboratories in Keyworth. Single element geochemical maps at 1:100 000 scale will be produced as hard copy and in digital format for five map sheets, together with thematic regional maps at 1:250 000 scale, and geochemical atlases. Technology transfer for both the geological and geochemical mapping projects is being achieved through on-the-job training and specialist short-term courses for Moroccan counterpart staff.

Ecuador

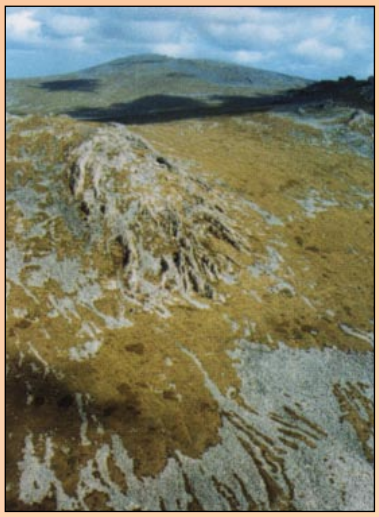
This was the fourth year of five for the DFID-World Bank co-funded Western Cordillera Geological Information Programme. Three of the five geological quadrangles, covering a total of 20 000 square kilometres, were published at a scale of 1:200,000 and each was complemented by a 36-element geochemical package. The information is available in both hard copy and digital format, the latter on sale as a CD-ROM. In addition, relevant open file reports were placed with the Ecuadorian authorities. Three residential staff based in Quito are presently assigned to this project, two others are working on a separate but related project: The Assessment of Ore Districts. This involves the detailed investigation of epithermal, volcanogenic massive sulphide and porphyry and intrusion related epi-mesothermal deposits in the Eastern and Western Cordilleras of the Ecuadorian Andes. Both projects make use of short-term specialist support from the BGS.

Falkland Islands

Two 1:250 000 scale geological maps covering the islands and comprising East and West Sheets, complemented by a detailed geological report, were compiled and printed at Keyworth. An unpublished map of superficial deposits is available at the same scale. The report and maps are products of the Falkland Islands Geological Mapping Project (1996–98) undertaken by a BGS resident geologist in co-operation with the first Falkland Islands geology graduate. The Falkland Islands Government provided the funding. As well as the maps the information is provided in digital format as a CD-ROM.

Ecuador remote sensing

Radarsat and Landsat TM data were processed for the BGS's World Bank/DFID-funded Mineral Assessment project in the central Cordillera region. As part of this exercise, all Ecuador project satellite data were transferred to CD-ROM and passed to the Ecuadorian counterpart organisation. The Portable Infrared Mineral Analyser was also used to study mineralisation, measuring samples from 80 boreholes located at numerous sites. This has provided insights into the alteration associated with the mineralisation at each site.



Don Aldiss, BGS © NERC

Folded Devonian quartzites of the Port Stanley Formation with stone runs in the Wickham Heights of East Falkland. These folds represent a lateral continuation of the eastern Cape Fold Belt of South Africa.

Adrian Walker, BGS © NERC

Dense vegetation can make landing, even in a helicopter, hazardous. Regional gravity survey of Northern Botswana.

Regional gravity survey in Botswana

The BGS participated in a major regional gravity survey of Northern Botswana in collaboration with Poseidon Geophysics (Pty) Ltd and under contract to the Government of Botswana. Our input involved data processing, quality control and the training of local counterparts. The survey is designed to improve the geological understanding of a large, poorly-exposed area including the Okavango Delta and Moremi and Chobe game reserves. The results will help in the formulation of government policy relating to exploration for mineral resources, water supply and land conservation.

Adrian Walker, BGS © NERC

A pilots-eye view of the Okavango Delta, Botswana.

Hong Kong

The Head of the Geological Survey and one other staff member continue to be on extended 'leave of absence' from the BGS and working under contract to the Geotechnical Engineering Office of Hong Kong Special Administrative Region of China. They will continue to work under contract until 2000.

The BGS has provided mineralogical and petrological expertise for several geological investigations in Hong Kong. One of these involved a study of the unusual analcime- and aegirine-bearing sedimentary rocks of Ping Chau, and concluded that they were generated by low-temperature thermal alteration. A petrological analysis of fault breccia from beneath Western Harbour identified two movement events within a 10 metre-wide fault zone intersected by a sewer. Other work included a mineralogical and microtextural study of the Lai Ping Road landslide, and a literature review of methods for characterising clay-rich saprolite.

Pacific islands

Since 1997, the BGS has provided a Training Co-ordinator to the South Pacific Geoscience Commission (SOPAC) based in Suva, Fiji, funded by the CFTC. His role is primarily to co-ordinate training and distance learning across the 16 member states of SOPAC, especially via the Earth Science and Marine Geology course which is run in association with the University of the South Pacific. He also provides advice and support in hydrogeology. CFTC support for the post has now been extended until mid 2000.

Appropriate technology for low-cost geological mapping

This DFID KAR-funded project was in its start-up phase. A visit was made to Georgetown in Guyana to set up the project in liaison with the Guyana Geology and Mines Commission. The study area was selected and preparation for a field visit was initiated. Radarsat and Landsat TM data were acquired and processed for the project area.

Strategies and systems for maximising geoscience data value

The cost of developing a geoscience information system from first principles is large and the skills and experience required are scarce. The project will provide a standard data structure to assist first in the organisation of geoscience data and subsequently in the development of a geoscience information system. The project will develop GIS applications for data access, querying and integration, and WWW links for data dissemination and sharing. It will also use the WWW in conjunction with distance learning methods to train users. The project is working in partnership with the Geological Survey Organisation of Malaysia, Botswana and Malawi.

Small-scale gemstone mining

The BGS in conjunction with Intermediate Technology Consultants has been working on the development of best practice guidelines for small-scale artisanal gem mining in Asia and Africa, in particular Sri Lanka and Zambia. An increasing number of people in developing countries are turning to small-scale gemstone mining as a source of income in times of drought, job loss or other hardship. Many have little or no experience and this can result in inefficient and dangerous mining methods as well as causing significant environmental damage. The project aims to research best practice techniques in prospecting, production, safety and environmental management and explore cost-effective ways to educate gemstone miners and the institutions that could support them. A series of 'How To' field guides and other appropriate material will be aimed at the miners and supporting institutions and organisations to assist in promoting safe and effective mining practices.

Industrial minerals

DFID-funded contracts have been awarded to the BGS to investigate the use of volcanic rocks for construction in Costa Rica, Ecuador, Tanzania and Kenya. The BGS has also been funded by DFID to assess the effective development of marine aggregates in south-east Asia. The same source of funding has sponsored Industrial Minerals Workshops in Angola, Columbia, Tanzania, Jamaica and Mozambique.

Paul Henney, BGS © NERC

Gem miner washing and sorting gem-bearing gravel, Sri Lanka.

International Development and Assistance — Groundwater and Pollution

P J Chilton, BGS © NERC

Trained village caretakers (men and women) repairing a handpump in Tamil Nadu, Southern India. At least 2.8 million public handpumps provide domestic water supplies from groundwater in India.

Bangladesh

A BGS hydrogeologist took part in a UNDP review and evaluation of the major five-year Flood Alleviation Project, which sought a solution to the problem of disastrous flooding during the monsoon. The evaluation reviewed institutional inputs and groundwater data management provided by a range of donors.

Assessing Risk to Groundwater from On-Site Sanitation (ARGOSS)

This is a three-year project due to be completed in September 2000. The deliverables are a scientific review of the risk to groundwater supplies from on-site sanitation and a manual of guidelines for field-workers. The research is based around two major case studies in Bangladesh and Uganda as well as a number of associated case studies in Africa, Latin America and Asia. Results to date show that widespread microbiological contamination of aquifers is not occurring. Where serious contamination is found, it is due to localised sources. However, the long-term impact of chemical contamination has been highlighted.

Groundwater pollution threats in urban areas

Many cities in developing countries are dependent on groundwater as a source of water supply. However, uncontrolled groundwater development and waste disposal is leading, in many places, to serious groundwater degradation. Against this background the BGS, with four overseas partners, has just finished work on a DFID-funded project entitled *Tools for assessing and managing groundwater pollution threats in urban areas.* The project has developed a number of multi-disciplinary tools which urban decision-makers can use to help assess and manage groundwater pollution threats. The tools—both computer based and manual—are designed to be low-cost, rapid, locally managed and participatory.

Groundwater protection and management for developing cities

This project, funded under the DFID KAR Programme, is producing groundwater pollution risk assessments for groundwater-dependent developing cities based on typical hydrogeological/developmental settings. From these a range of practical and appropriate protection plans and urban water management policies will be developed. Case studies are being carried out with local project partners at Bishtek in Kyrghyzstan and Narayanganj, near Dhaka, in Bangladesh.

World Bank paper on groundwater issues in rural development

Following from the production in 1998 of the World Bank Technical Paper 390 on groundwater in urban development, the BGS are working with staff of the World Bank to produce a companion paper on groundwater issues in rural development. This draws heavily on recent BGS experience in the development and management of groundwater for domestic, livestock and agricultural use, particularly in Nigeria, southern Africa and south Asia.

UNICEF review of water and sanitation in India

Based on our extensive experience of rural water supply, the BGS Hydrogeology Group were invited to provide the groundwater expert in a five-member, international and multidisciplinary team evaluating the UNICEF water and sanitation programme in India over the past 30 years. Much of the rural water supply provision in the country is from groundwater, and usage has increased dramatically over this period. A key issue was the sustainability of these supplies, given the adequacy of groundwater resources, competition from industrial and irrigation users, groundwater quality deterioration, and the technical and financial issues of operating and maintaining so many individual supplies in ways which fully involve local communities. Following successful completion of this assignment, the evaluation team may be asked to extend their work to other countries with major UNICEF programmes.

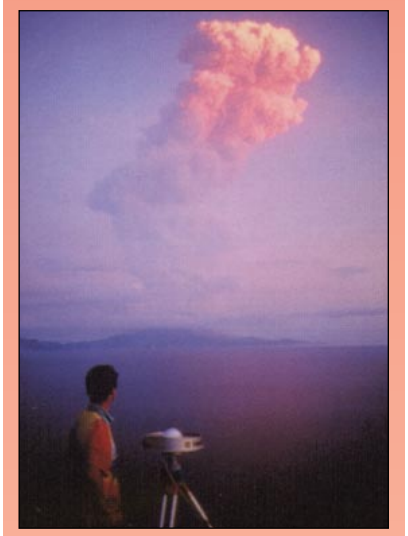
P J Chilton, BGS © NERC

Rehabilitation of a public supply borehole by hydraulic fracturing in Tamil Nadu, Southern India. In the crystalline basement area, this technique can open fractures and increase borehole yields.

International Development and Assistance — Geohazards

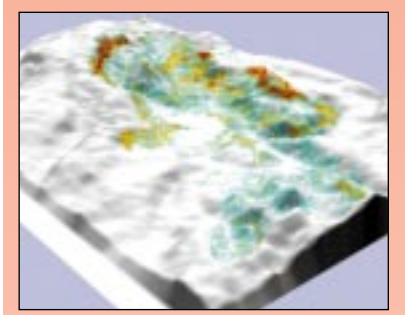
A H Cooper, BGS © NERC

Damage to an historic building in Calatayud (Northern Spain), caused by gypsum dissolution-induced subsidence.



Simon Young, BGS © NERC

Vulcanian explosion Montserrat, October 1997. Viewed from Redonda with the University of Puerto Rico temporary GPS site in foreground.



Colm Jordan, BGS © NERC

Perspective view of the Rio Minho area of Jamaica showing landslide hazard susceptibility.

Montserrat

The BGS, under contract to the Department for International Development, continued to manage scientific inputs to the Montserrat Volcano Observatory throughout 1998 and early 1999.

By March 1998, the growth of the magma dome at the summit of the Soufrière Hills Volcano had ceased, but the instability of the existing dome and sporadic gas explosions continued to pose significant hazards. Careful monitoring of the volcano therefore continued throughout the year. Plans are now in place for the construction of, initially, a forward observation post and, eventually, a purpose-built observatory to replace the current observatory accommodation.

A wealth of scientific information on the eruption has been gathered by the many international geoscientists who continue to participate in the monitoring programme and a large number of scientific papers have now been published in international journals.

Implementation strategy for landslide hazard preparedness

This DFID KAR-funded project involved the production of landslide distribution inventory maps of the Jamaica and Slovakia study sites using aerial photography and satellite optical imagery. These were collated with geological data and a Digital Terrain Model in a geographic information system. Probability models based on the concept that the past is the key to the future were then used to create landslide hazard maps.

Northern Spain

The BGS is participating in the EU-funded Risk Of Subsidence due to Evaporite Solution (ROSES) project co-ordinated by Newcastle University, in collaboration with Zaragosa University (Spain), Tubingen University (Germany) and the Ukraine Academy of Sciences. (EU contract Nos. ENV4-CT-0603 & IC20-CT97-0042).

Gill Norton, BGS © NERC

Rainwater and sulphur dioxide monitoring site, upper Amersham, Montserrat, 1997.

International Development and Assistance — Environmental Geoscience

Mercury pollution

The final summary report for a DFID-funded project on the mitigation of mining-related mercury pollution hazards brings together the key results and recommendations of a series of BGS Technical Reports. These describe in detail the results of:

- Six site monitoring and impact assessment studies carried out in the Philippines and Ecuador
- A review of gold recovery methods
- Laboratory and field testing of a gravity separator designed to improve gold recovery methods and reduce the need for the use of mercury.

The results of the research programme were disseminated through workshops held in Bolivia and Ecuador, and a symposium in Hong Kong. The summary report conveys the most important results in an accessible form which can be readily understood by government, agency and mining company personnel.

Mayak project

Under its EC-funded Mayak project with AEA Technology, Harwell, the BGS is helping Russian experts to assess the radioactive waste arising from previous nuclear programmes and disposal options at a large nuclear fuel reprocessing site, formerly Chelyabinsk-65, in Russia, east of the Ural Mountains.

Arsenic Contamination of Groundwater in Bangladesh

There is a widespread and serious problem of arsenic contamination of groundwater in the deltaic plains of Bangladesh and West Bengal, India. Groundwater is used extensively for the rural drinking-water supply as well as for irrigation. The arsenic is of natural origin and has probably been present in the groundwater for thousands of years. However, most of the wells have been drilled in the last 10–30 years. The problem was first observed in West Bengal in the 1980s but it is only in the last couple of years that an extensive arsenic testing programme has been undertaken in Bangladesh. In terms of the population exposed, the Bengal Basin is the most serious groundwater arsenic problem in the world with many millions of people exposed to arsenic in their drinking water.

The BGS first became involved in Bangladesh in late 1996 under a programme to study groundwater arsenic problems in Argentina, Bangladesh and Thailand, funded by the Department for International Development (DFID) (see panel). In February 1997, a groundwater survey of Chapai Nawabganj confirmed the severity of the arsenic contamination with concentrations being found up to 2.4 milligrams per litre. Since that time, a larger BGS study has been commissioned by DFID in collaboration with the Government of Bangladesh. A six-month Rapid Investigation Phase began in January 1998 in collaboration with Mott MacDonald Ltd. The priorities were to collate existing arsenic data and to carry out a survey of those areas believed to be the worst-affected. This survey covered about two-thirds of Bangladesh and collected over two thousand samples at an average sample density of one per 37 square kilometre. The median arsenic concentration found was 0.011 milligrams per litre, just above the WHO recommended drinking-water limit and some 35% of samples were above 0.05 milligrams per litre (the Bangladesh drinking-water standard). Wells more than 150 to 200 metres in depth were hardly affected. There is a distinct regional pattern in the arsenic-affected areas with the most contaminated area to the south and east of Dhaka. Phase two of the project is continuing with an extension of the regional survey area to cover the remainder of northern Bangladesh and more detailed studies on the origin of the arsenic.

Don Appleton, BGS © NERC

Geochemical sampling of mercury contaminated stream draining small-scale gold mining area, Ponce Enríquez, Equador.

Environmental problems cause increasing concern to developing countries and the BGS is well qualified to carry out research and seek solutions.

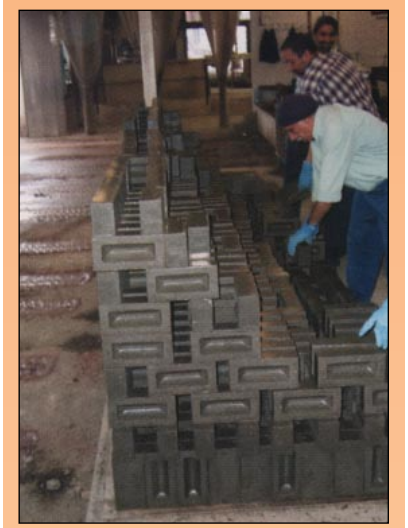
J M Trafford, BGS © NERC

Sampling groundwater for arsenic from a village handpump in Bangladesh.

Environmental Arsenic Exposure: Health Risks and Geochemical Solutions

Arsenic in the environment poses a serious threat to human health. The most important routes of exposure are naturally contaminated groundwaters and water and soil close to sulphide mining operations. Arsenic problems in groundwater can be extensive. Some of the worst affected aquifers identified occur in Bangladesh, West Bengal, China, Argentina, Chile and Mexico. Problems in mining areas can be severe but are typically more localised. This project, which is funded by DFID, involves geochemical, hydrogeological and health investigations of arsenic problems in some of the worst affected aquifers and mining areas. Investigations have been carried out of major aquifers in Argentina, Bangladesh and China (Inner Mongolia) and of mining areas in Thailand, Argentina and Brazil. The project involves assessment of the causes of arsenic contamination, mechanisms of arsenic mobilisation and retention and assessment of suitable mitigation strategies.

Resources — Minerals



Don Cameron, BGS © NERC

Bricks pressed from Lower Oxford Clay are 'set' prior to firing at the Hanson Brick Stewartby works in Bedfordshire. This plant was one of a number visited during a review of brick clay resources commissioned by DETR.

Minerals of east Dorset

Work continued on this multidisciplinary project on behalf of the DETR to provide information on the mineral resources of the Wareham Basin of east Dorset. The area contains nationally important ball clay resources as well as regionally important sand and gravel resources. It is also highly valued for its habitats of national and international significance, particularly heathlands. A wide range of geological, geochemical, planning and environmental data sets have been brought together for the purposes of the project.

David Highley, BGS © NERC

Ball clay extraction in east Dorset occurs in close proximity to environmentally-sensitive sites.

Mineral resource information

The DETR-funded project Mineral Resource Information for Development Plans involves the collection and display of data on mineral resources together with the environmental constraints that may affect their extraction, providing information that is essential for the preparation and review of Mineral Local Plans. Maps and reports on West Sussex and Shropshire were published during the year. Work on another four counties is at an advanced stage and a further four counties are in preparation. All the data are held in digital form enabling easy revision and customisation, including incorporation within a GIS, to meet individual user needs.

Brick clays

The BGS was commissioned by DETR in early 1999 to undertake a review of the resources and supply of brick clay. Whilst resources of clays suitable for brick, tile and pipe manufacture seem to be widespread, options for extraction are limited by technical, environmental and commercial factors. Data on resources, reserves and production units will be hosted within the MINGOL GIS system to enable analysis of the relationship between the industry and its resources. This exercise involves close liaison with the structural ceramics industry and mineral planning authorities. The aim of this one-year project is to improve the understanding of the issues involved in planning for the provision of brick clays.

Mineral resource information in Scotland

The BGS is contributing to minerals planning in Scotland through the provision of mineral resource information to local authorities, in both digital and hard copy forms. A comprehensive review of minerals in Perth and Kinross identified an urgent requirement for the release of land to maintain a ten-year land bank of hard rock aggregate. The review also drew attention to the continuing strategic and local needs for baryte production at Aberfeldy, whilst recognising the need for minimal impact in this environmentally sensitive area. Reports on sand resources and alternative uses for dormant quarries were prepared for Orkney Islands Council, to underpin a policy framework for future sustainable sand extraction.

Gemstone prospects

A review of gemstone prospectivity in Scotland was carried out for Cambridge Mineral Resources using the BGS's data archives coupled to GIS-based analysis of multiple data sets and informed by the latest geological models for gemstone formation. The contract was stimulated by recent discoveries in Ireland and a BGS Mineral Reconnaissance Programme report. The northern and western parts of the country were considered to be the most fertile for new discoveries of sapphire, and possibly diamond, and a number of target areas were identified.

Gold in Devon

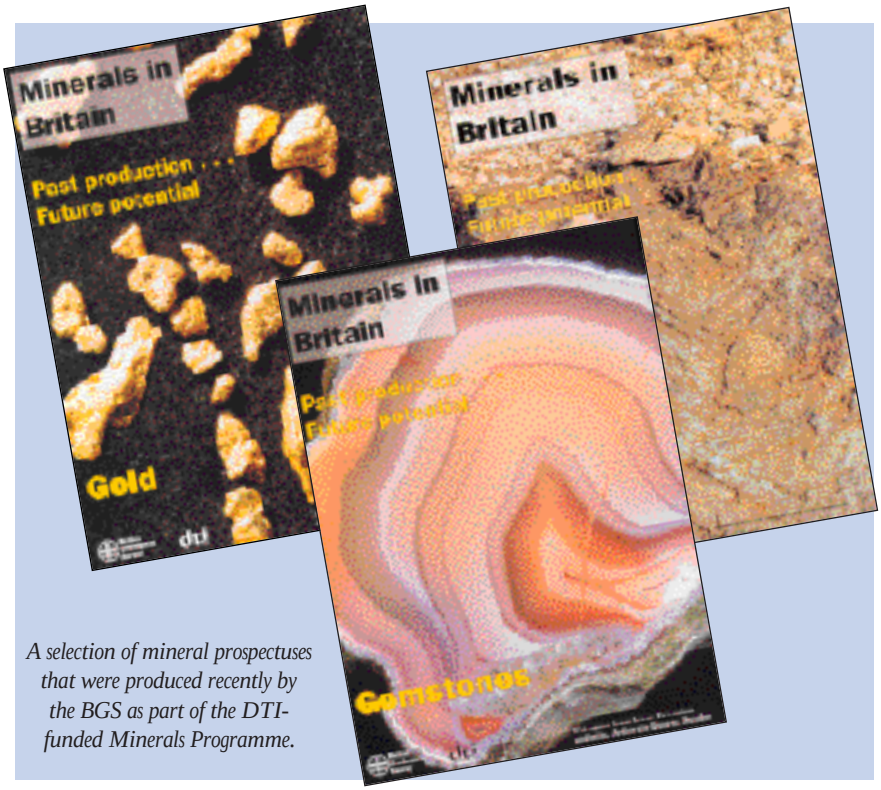
The BGS has continued as technical advisors to Crediton Minerals plc for their gold exploration programme in the Crediton Trough. A total of 16 cored boreholes have now been completed in the target area and elevated gold values have been demonstrated in a body of alkaline basalt of Permian age. Various techniques have been used to investigate the gold mineralisation, including fluid inclusion and electron probe studies. Use has also been made of the VULCAN 3D modelling system to assist with interpretation of the mineralised structures.

Computer-based 3D modelling

Computer-based 3D modelling using VULCAN software has continued to be used to aid SMEs in the interpretation of data sets collected at surface and from boreholes. The models generated by this powerful system assisted clients by helping to resolve geological problems, highlighting information gaps, and estimating the resources present.

Minerals Programme

This DTI-funded Programme comprises a minerals information and advisory service plus activities aimed at stimulating the creation of wealth from Britain's mineral resources. Information on all aspects of minerals exploration, development, production and trade are provided to government and industry, making extensive use of databases supported by the programme.



A selection of mineral prospectuses that were produced recently by the BGS as part of the DTI-funded Minerals Programme.

These include principally the World Mineral Statistics (WMS) database, which is compiled from official sources and in consultation with major producers, traders and other international organisations, and the mineral exploration database, which largely contains data collected by the Mineral Reconnaissance Programme between 1971 and 1997. Participation in meetings of the International Strategic Minerals Issues Working Group and an International Consultative Group on Non-ferrous Metal Statistics assisted in updating the WMS database and production of the annual publication World Mineral Statistics 1993–97.

A new web site (www.mineralsUK.com, *Minerals in Britain and the World)* provides improved access to minerals-related information available from the BGS and other sources as well as giving news of events affecting minerals exploration and development in Britain.

A new series of brochures entitled *Minerals in Britain: past production, future potential* was launched and the first four, on gemstones, gold, copper and lead and zinc, were issued. Each six-page colour leaflet provides basic information on Britain's mineral production and potential for the commodity described. The draft of a new Year 2000 edition of the *Guide to exploration for metalliferous minerals in Britain* was completed and work continued on prospectivity mapping and the modelling of epithermal gold prospects in northern Britain.

Northern Ireland

The BGS was commissioned by the DED to undertake geochemical exploration in areas prospective for gold and base metal mineralisation in West Tyrone.

Gold mineralisation

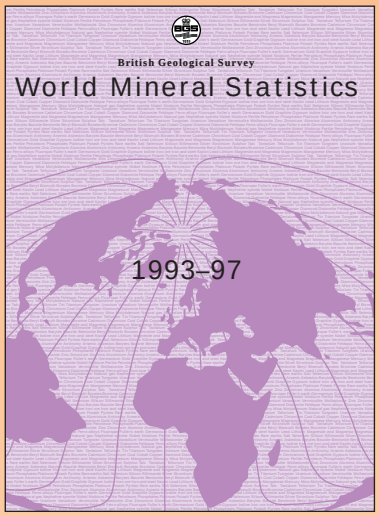
A two-year project, jointly funded by the EC and a consortium of SMEs, has been awarded to the BGS to investigate the processes responsible for the formation of high-grade gold deposits and the development of 3D geostatistical models for resource evaluation. This will allow greater confidence in grade estimation and better optimisation of selected mining. Work has commenced in four European countries, involving a multinational team of geochemists, mining engineers and geostatisticians.

Building Stones

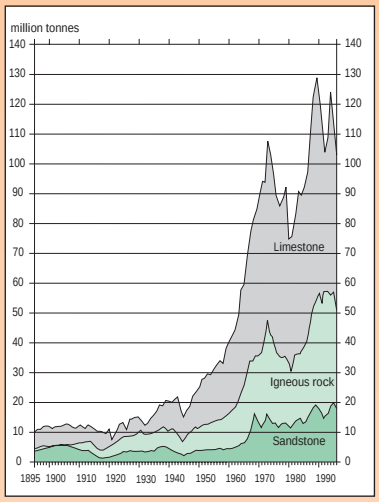
Several commissioned projects have been undertaken to identify UK building stones and their sources for local authorities and the owners of listing buildings. Stratigraphical correlation of limestone cores has been provided to a UK company as a component of reserve estimation and future development for quarrying operations. Expertise has also been provided on evaporite (halite) and bedrock sand and gravel resources for County Minerals Resource studies.

The United Kingdom Minerals Yearbook

The Yearbook for 1998 was published. It contains detailed statistics on minerals production, consumption and trade, with commentaries on current developments in the chief sectors of the minerals industry. The usual range of graphics is included, with the addition of a new map of coal resources and production sites. The BGS has been awarded a four-year contract by the DETR to review all aspects of UK minerals information, including the media through which it is made available.

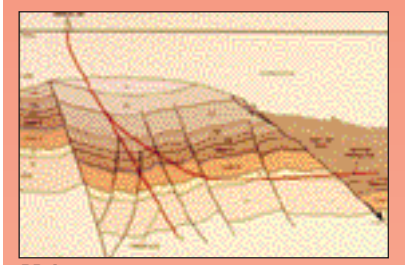


Front cover of World Mineral Statistics 1998.



Detailed graph showing the UK production of sandstone, igneous rock and limestone (including dolomite) 1895–1997.

Resources — Oil and Gas



BP Amoco

A well in the Clair Field, West of Shetland which was geosteered using heavy mineral stratigraphy.

Stratigraphical Services

The BGS provides stratigraphical expertise for hydrocarbon exploration and production applications, both in the UK sector and internationally. This involves the supply of biostratigraphical, sedimentological, petrographical, and stratigraphical mineralogy techniques to industry. Projects include well geosteering, well completion reporting, license block reviews, well and field stratigraphy appraisal, hydrocarbon reservoir characterisation, provenance studies and basin modelling inputs. In co-operation with Wardell Armstrong, the BGS has produced a research needs assessment for coal bed methane in the UK. This study was commissioned by the DTI and Coal Authority. New issues of the biostratigraphical "Masterpack" series have been developed covering the Lower Palaeozoic and Permo-Triassic of North Africa and the Middle East. These can be supplied in "expert system" CD format.

Interpolation In-Field Referencing

The Interpolation In-Field Referencing (IIFR) technique aims to provide accurate estimates of the strength and direction of the geomagnetic field at drilling locations to improve the accuracy of well-bore surveys made using magnetic survey tools. For offshore oil fields this is achieved by using local aeromagnetic survey measurements to estimate local crustal fields, data from the BGS magnetic observatories to account for ionospheric fields, and the BGS Global Geomagnetic Model. The technique has been developed in collaboration with Sperry Sun Drilling Services and IIFR services are marketed under the terms of an Alliance Agreement. In 1998 IIFR was applied in drilling 31 wells in 12 offshore oil fields around the UK continental shelf (UKCS). A visit was made to Sable Island off Newfoundland to assess the feasibility of establishing a magnetic observatory there to provide IIFR services for oil industry operations.

Commercial Geophysics Engineering Survey

Earthquake hazard assessments have been made for British Gas, predicting effective ground accelerations as a function of geological setting, return period and soil properties.

Basin maturity

A reconnaissance basin maturity study of the Nama Basin, Namibia using clay mineral and organic matter maturity indicators was carried out for NAMCOR, the National Petroleum Corporation of Namibia. Clay mineral and organic maturity data were used to derive burial and uplift estimates for Neoproterozoic– Mesozoic sequences as part of a prospectivity assessment.

Caspian Basin

A review of the petroleum potential at a basin and field level has been carried out for SOCAR, the Azerbaijan National Oil Company. This study was conducted in collaboration with a reservoir engineering company and was aimed at investigating the older fields in the western Caspian, developing a stratigraphical basis for inter-field correlation, the development of play concepts and the identification of targets for future exploration.

Falkland Islands

Following the issue of licences and the fast track seismic programme, the operators have now drilled six exploration wells in the North Falklands Basin. During the drilling programme the BGS monitored activities on a daily basis and provided technical advice to the Falkland Islands

N Fannin, BGS © NERC

Part of a 200 km network of causeways (estakadas) that link about 1500 wells drilled on the Neft Dashlary Oil Field in the Caspian Sea. Each platform is the location for several production wells. Development of this field began in 1949, making it the first offshore oil field. Neftdashlary is one of five fields studied as part of an offshore rehabilitation project for SOCAR (State Oil Company of Azerbaijan), sponsored by the World Bank.

Mick Lee, BGS © NERC

A page from the FieldBank gravity and magnetic database.

Government (FIG) on the management of the drilling process. The wells were successful in demonstrating that there was a working petroleum system within the basin though economic reserves of oil have yet to be found. The BGS also continued to provide the FIG with technical support in ongoing talks with Argentina on the licensing of the Special Area of Co-operation, to the west of the islands.

DTI Geological Advice

The BGS continues to provide geological advice to the Oil, Gas and Licensing Division (OGLD) of the DTI in support of the UKCS exploration programme. During the year the contract to provide the computing support for the programme was also won allowing better integration of databasing activities and support of the geological team. The BGS team are located at the DTI site at Gilmerton in Edinburgh and all of their work is conducted under strict conditions of confidentiality for the OGLD.

Environmental Impact Assessment

A meta-database of environmental data has been prepared for an oil licensing partnership in the Rockall Trough. The project involved collaboration with other biological and oceanographic organisations and provided a 'one stop shop' for the companies in identifying data sources needed for the preparation of the environmental assessments required for drilling sites.

High Resolution Deepwater Studies

A number of studies of deep-water sediment systems and hazards have been carried out for oil companies along the West African margin and for pipeline studies in the Black Sea.

Antarctic rock drilling:

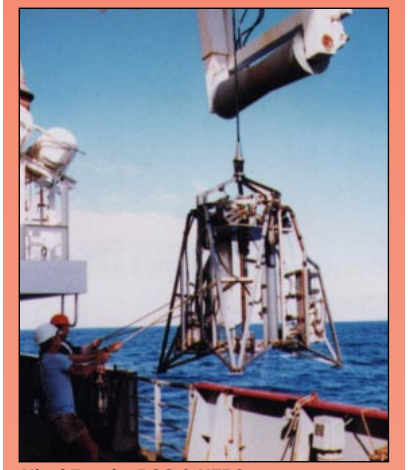
The BGS five-metre rock drill was commissioned to carry out a rock coring programme off the Antarctic Peninsula as part of the British Antarctic Survey's offshore programme. 36 sediment cores and 26 cores of Cainozoic rocks were recovered adding considerably to the knowledge of the offshore geology around the Peninsula.

FieldBank

The FieldBank gravity and magnetic database is managed on behalf of oil company clients by the BGS in collaboration with Ark Geophysics Ltd. User interfaces were developed, clients' data were loaded and the database is now fully operational. Company exploration staff can browse their data holdings remotely, either over the Internet or using fast ISDN links.

Gravity and magnetic studies

Imaging and modelling of gravity and magnetic data from the Irish Rockall Trough were undertaken for the Petroleum Infrastructure Project (PIP), funded by the Irish Petroleum Affairs Department and a consortium of 18 oil companies. Similar work was carried out elsewhere along the Atlantic margin for a variety of customers. Image Atlases displaying magnetic data from the southern and northern North Sea were developed under an agreement with the owners of the aeromagnetic data for this area. The BGS now acts as an agent for the Hydrographic Office in the provision of their marine gravity data to the hydrocarbon industry.



Nigel Fannin, BGS © NERC

The BGS oriented rock drill being deployed.

BRIDGE Oriented Rock Drill

The one-metre oriented rock drill developed for the UK BRIDGE project successfully underwent its proving trials during a UK / American / Canadian expedition to the Atlantis Bank. The trials were a complete success coring 13 sites and recovering Cainozoic carbonates overlying basic rocks, including gabbros. The orientation of each core was marked by a lengthwise score, allowing palaeomagnetic measurements to be made. Core was also successfully recovered at 29 sites using the BGS five-metre drill.

Papua New Guinea

The petroleum exploration and development technical assistance project funded by the World Bank in Papua New Guinea has provided institutional strengthening to the Papua New Guinea Petroleum Division since 1995. It is due to be completed in September 1999. The BGS has managed a multidisciplinary programme involving experts in petroleum geoscience; pipeline, drilling, and production engineering; legal, fiscal, and human resources; and information technology. The focus has been on capacity building through training with an emphasis on policy formulation, the regulatory framework, the evaluation of proposals and data, and monitoring ongoing exploration and development. Attention has also been given to human resources development in all areas of management and administration.

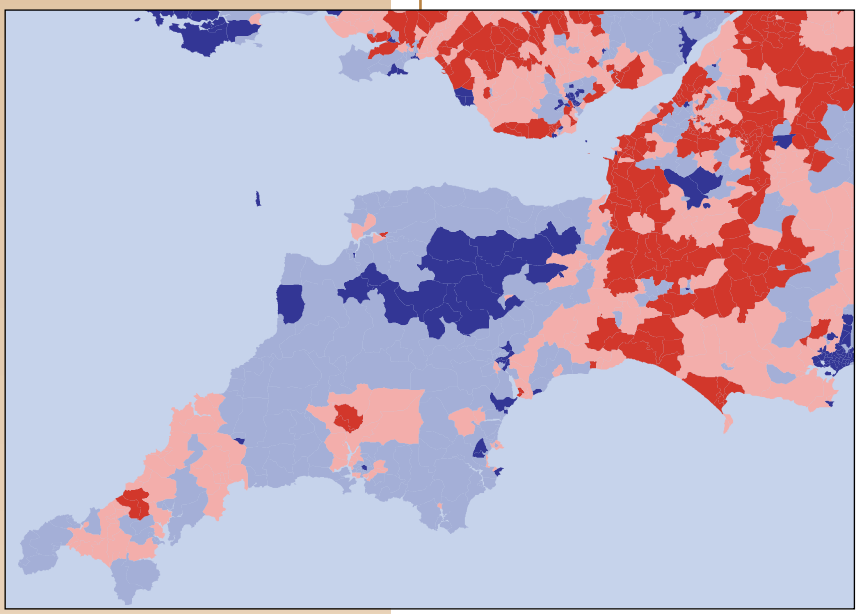
Geology and Geohazards

Identifying homes likely to have high radon

The BGS, working in collaboration with the NRPB, has produced on behalf of the DETR a series of twenty provisional 1:50 000 scale geological radon potential maps covering the most radon prone parts of Derbyshire, Northamptonshire, Nottinghamshire, Leicestershire, Lincolnshire, Oxfordshire, Shropshire, Somerset and Yorkshire. The purpose of the maps is to identify the location of homes likely to be above the radon Action Level.

The BGS also carried out a 1:250 000 scale geological radon potential assessment of England and Wales on behalf of the DETR. This formed the basis of a map showing where basic and full radon protective measures may be required in new dwellings. A demonstration version of a Radon Protective Measures GIS was also completed.

(Below) *Subsidence risk levels, colour coded in postcode sectors, from Residata Subsidence: this BGS product is used extensively by the insurance industry to set rates for household insurance.*



David Ovadia, BGS © NERC

GHASP

GHASP (marketed as Residata Subsidence) is an integrated database and mapping system that supplies geohazard information, principally on subsidence, to the insurance industry, which uses it for risk assessment and risk selection. The system uses interpreted geological map data describing shrink-swell clay, mining for materials other than coal, gulls and cambering, subsurface solutions, compressible deposits, and landslip potential. It delivers the hazard as numerical values at a unit postcode (approximately 15 houses) level for England, Wales and most of Scotland. The geographical information system (GIS) interface is ArcView.

South Devon

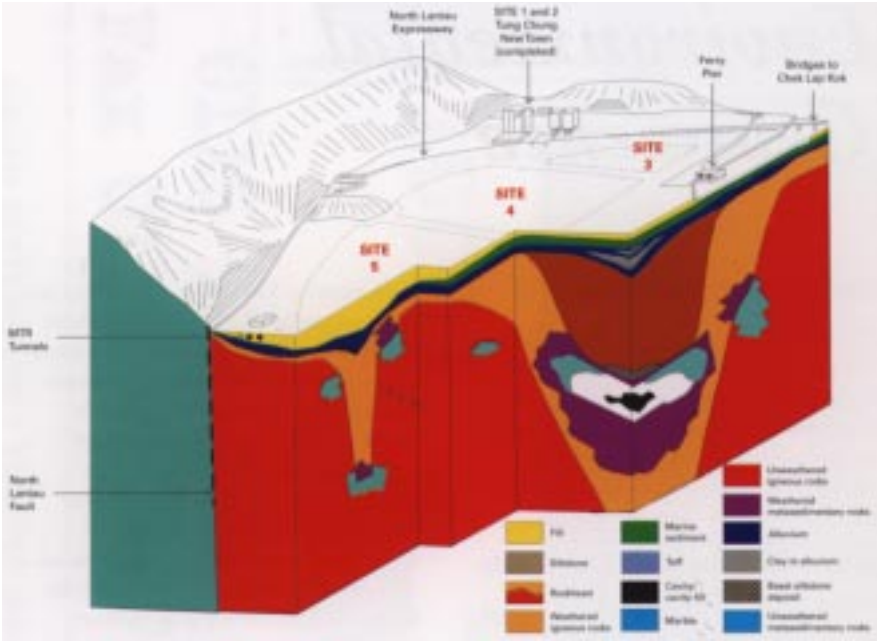
Work of national strategic importance has been undertaken at a site intended for the servicing of Trident nuclear submarines, for Devonport Management Ltd. The study included detailed geological interpretation and structural modelling. Geoscience reports were made to the Seismic Hazards Working Party, concerning geological matters relating to site safety.

Structural damage management

The BGS has been investigating the use of remote sensing of surface movement for structural damage management under the BNSC LINK earth observation project R4/019. The objective of the project is to use satellite-borne synthetic aperture radar interferometry (InSar) to map the seasonal swell/shrink behaviour of the London Clay in Greater London. The resolution of the current system is currently about 2.5 centimetres. Data have been gathered from the ERS1 and ERS2 earth observation satellites since 1992. Repeat data are obtained every month, so that 12 annual views of the same 100 kilometre wide swathe can be directly compared. It is hoped that the results of the study will enable Thames Water Plc, and other major users, to plan and predict near-surface engineering hazards caused by seasonal volume changes. The engineering geological input to the project is important and will be based on the LOCUS project data. Collaboration at Nottingham University includes state-of-the-art terrestrial surveying to provide control for the remote sensing data. Exploitation plans for techniques and data are to be drawn up by all members.

Hong Kong

A project to investigate areas of 'complex ground', revealed by site investigations at Tung Chung New Town, was completed for the Hong Kong Government. Cores and/or logs from 1750 boreholes were examined, revealing that igneous and metasedimentary rocks are weathered with variable intensity and to varying depths. In places, rockhead is deeper than 160 metres below ground surface. The project concluded that the complex ground originated when blocks of metasedimentary rock up to 350 metres in diameter, including beds of marble, were detached and incorporated into rising magma. Later, the advance of weathering was particularly penetrative through these zones, resulting in dissolution of marble and development of depressed rockhead.



Adrian Humpage, BGS © NERC

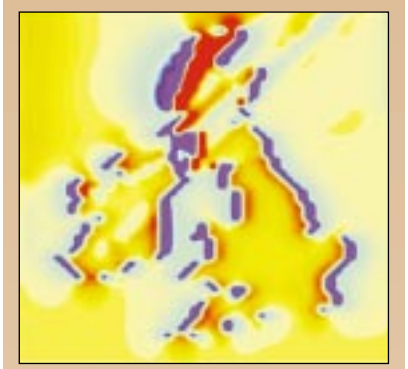
Schematic block diagram illustrating some of the geological relationships encountered at Tung Chung New Town (not to scale).

A hazard to power transmission

A hazard to power transmission in the UK stems from geomagnetically induced currents (GICS) which are induced in the Earth and in the grid by solar disturbances. During magnetic storms GICs may cause transformers at the end of power lines to overheat or even trip safety devices. In March 1989, close to the last solar activity maximum, GICs induced in the Hydro-Quebec system caused a catastrophic failure, leaving the whole region without electricity for many hours. In the UK, the BGS has carried out two GIC-related studies for the National Grid Company (NGC). One study used 15 years of recordings of magnetic variations from the three BGS observatories in the UK to provide statistics of storms resulting in noticeable GIC effect in the grid. The second study developed a 3D model of earth conductivity around the British Isles to a depth of 1000 kilometres, which is used by the NGC for computing the surface electric field that drives GICs in the power grid. The prediction of magnetic storms has been helped by data from a satellite between the Sun and the Earth monitoring 'space weather'.

Martin Gillespie, BGS © NERC

A BGS geologist examining borehole core during site investigations at Tung Chung New Town, Hong Kong.



D Beamish, BGS © NERC

During a magnetic storm electric fields are induced in the ground causing electric currents to flow. This illustration of modelled electric fields during a storm shows that the fields are intense at the coast where there is a large contrast in electrical conductivity.

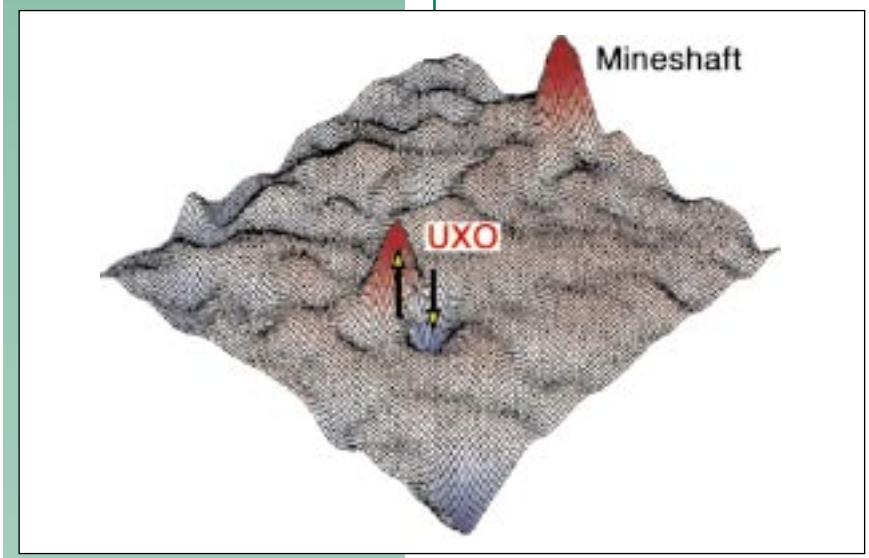
Paul Tod, BGS © NERC

Magnetic storms may have detrimental effects on electricity transmission systems.

Environmental Geoscience

Detection of buried hazards

(Below) *Developers of brown-field sites increasingly use geophysical surveys to identify potential hazards. The illustration shows the magnetic field measured across an area of 100x100 metres in urban north-east England. There are two main anomalies (high values in red). The smaller up-down anomaly is due to a large Second World War bomb (UXO); the second anomaly is due to a concealed mineshaft. In both cases remedial work was successfully carried out to allow development of the site.*



D Beamish/S Shedlock, BGS © NERC

Carbon dioxide emissions

The BGS is involved in a DTI and industry funded study on the subsurface disposal of CO_2. This ongoing research addresses CO_2 sequestration strategy for the UK/EU hydrocarbon industry as a response to reducing atmospheric emissions of CO_2 to counteract the threat of global warming.

Monitoring the Test Ban Treaty

The BGS has established the UK National Data Centre to monitor the Comprehensive Test Ban Treaty (CTBT) by seismic identification of possible underground explosions. Data are acquired from a global network of seismometers, by a largely automated retrieval system, and recorded events are processed and analysed by BGS seismologists. Multi-station seismic arrays, such as the UK array operated by the BGS at Eskdalemuir, are particularly useful for the detection and analysis of small seismic signals. The work is commissioned by the Ministry of Defence through the Atomic Weapons Establishment (AWE). The BGS collaborates with AWE Blacknest and the International Data Centre of the United Nations CTBT Organisation in Vienna.

Irish Sea metals

The BGS, in collaboration with the Plymouth Marine Laboratory (PML) and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), has been commissioned by the DETR to develop a methodology for distinguishing between natural and anthropogenic sources of metals entering the Irish Sea through major river systems. The work relies heavily on the use of the BGS onshore geochemical database (G-BASE) to identify and model the natural geochemical signatures of major catchment basins. Urban and industrial inputs are being assessed through a programme of major river, estuary, and offshore sampling and analysis. Stresses on biota, from both natural and anthropogenic metal sources, are being examined by field and mesocosm studies on marine bivalves.

Cryptosporidium hazard

The hazard to public drinking water supplies from the protozoan parasite *Cryptosporidium* is ranked by the UK water industry as the most significant microbiological threat to safe supplies in recent years. This is because the parasite is hardy, widely found and resistant to common water disinfection methods. The potential public health problem was demonstrated by an outbreak on the outskirts of north London in 1997. The BGS advised the Drinking Water Inspectorate on this incident and also contributed to the Expert Group that produced the influential Bouchier report on *Cryptosporidium* published in 1998. The BGS has been commissioned to conduct hazard assessments for a UK water utility and has developed a practical assessment procedure applicable to waterborne *Cryptosporidium*.

Aquifer Storage and Recovery

Interest in the Aquifer Storage and Recovery (ASR) method of water resource management has continued to increase. Surplus potable water is injected into aquifers in periods of excess capacity for recovery when other sources are limited or demand increases. The BGS has been active in an advisory capacity to ongoing field investigations in the Chalk and Lower Greensand aquifers. A proposal for a Foresight LINK award, in collaboration

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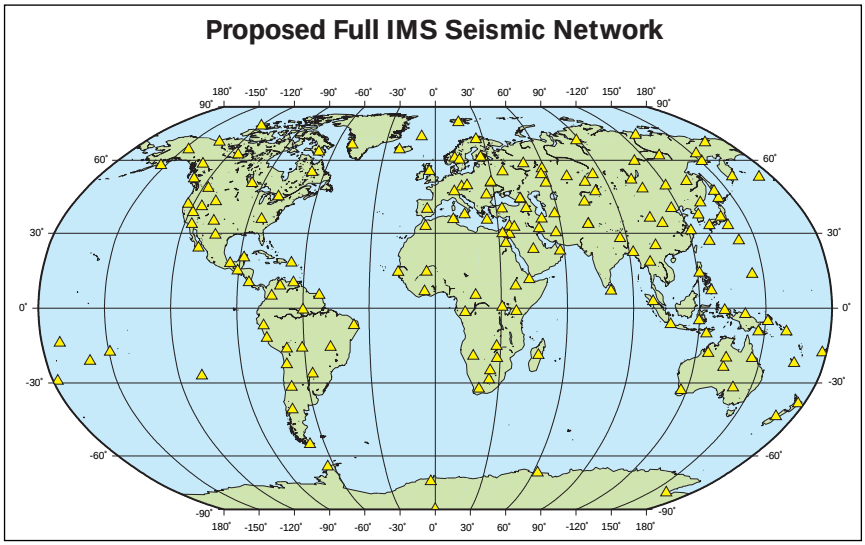


D Booth, BGS © NERC

The world-wide network of seismometer stations in the International Monitoring System.

with UK Water Industry Research Ltd (UKWIR), was successful and a 30-month national project will run from April 1999.

Groundwater vulnerability maps

The final sheets of a series of 53 Groundwater Vulnerability maps covering England and Wales at 1:100 000 scale have been published. These were compiled for the Environment Agency (EA) in collaboration with the Soil Survey and Land Research Centre. The *Groundwater Vulnerability Map of Fife* for the Scottish Environment Protection Agency was also published and the compilation of a groundwater vulnerability map for Dumfries was completed. These were both prepared in conjunction with Macaulay Research and Consultancy Services Ltd.

Site-specific groundwater vulnerability

This project was a necessary precursor to the implementation of the Groundwater Regulations 1998 by the EA. The Regulations require that any application to dispose of List I and List II substances must be accompanied by a 'prior investigation' report. Proposed discharges include applications for the disposal of agricultural pesticides for example, sheep dip, as well as industrial wastes, and contaminated run-off from out-of-town shopping centre car parks.

The 'prior investigation' outlines the risks of contaminating groundwater from a proposed site-specific discharge. To this end, the project advised on the most appropriate methods of analysis and prepared a protocol comprising tiered actions with which regional officers of the EA could assess the risk to groundwater. A comprehensive guidance document was prepared, describing the requirements for investigation and data collection when undertaking a 'prior investigation' of groundwater vulnerability.

Vapour monitoring in the Triassic sandstone

The BGS has been involved in the design and installation of a network of vapour monitoring boreholes at a site where industrial chemicals had been disposed of many years previously. The purpose was to evaluate the risk posed to the environment by volatile chemicals present in the unsaturated zone of the Permo-Triassic sandstones beneath the site. The work was undertaken for ICI in collaboration with Geosyntec (a consulting company based in Canada). The boreholes were successfully installed and the monitoring programme is now under way.

Impact of farm wastes stores on groundwater quality

This MAFF-funded project focuses on the potential threat to groundwater quality from unlined slurry lagoons. Nationally there are more than 10 000 such wastes stores, many of which overlie the major Chalk and Triassic sandstone aquifers. Pore waters from core material obtained from directly beneath active stores by inclined drilling techniques have been analysed for potential chemical and microbial contaminants.

Results so far have shown that the stores on Chalk tend to leak, especially in the early part of their lifetime before an impermeable mat of solid slurry has been able to form on the lagoon floor. Visual inspection of the cores has revealed evidence of raw slurry penetrating to depths in excess of ten metres through fractures. Microbial examination of the core has revealed the presence of *clostridium*, a bacterium that thrives in anaerobic environments, but no *Cryptosporidium* oocysts.

Minimal leakage has been detected from sites on the Triassic sandstones as the drift cover is generally thicker and less permeable than on the Chalk. Modelling studies at both the catchment and national level are currently being undertaken to assess risk to groundwater resources.

D C Gooddy, BGS © NERC

Chalk core taken from ten metres beneath a farm waste lagoon showing raw slurry on fracture faces.

Marine survey, California

A successful survey of sea-floor radioactivity at the Farallon Islands Radioactive Waste Dump Site was completed using the BGS Deep Tow EEL (towed sea bed gamma-ray spectrometer) system. During the survey the EEL was towed to record depths (1500 metres). The results suggest that some leakage of radioactivity has occurred from barrels of waste, but levels of artificial radionuclides in the sea bed sediments are very low. The project was carried out in collaboration with the USGS, the Gulf of the Farallones National Marine Sanctuary and the National Oceanic and Atmospheric Administration , and funded by the US Environmental Protection Agency.

David Jones, BGS © NERC

Deployment of Deep Tow EEL (sea bed gamma spectrometer) on board NOAA ship McArthur off California.

Irish Sea pollutants

Work commenced on a new three-year project to assess the relative importance of physical, chemical and biological processes on the transport and speciation of pollutants, particularly radionuclides, in the Irish Sea. This contract, funded by the MAFF, was won in open competition by a consortium of the BGS and two other NERC establishments, the Plymouth Marine Laboratory and Proudman Oceanographic Laboratory, both part of the Centre for Coastal and Marine Sciences.

Analcime dissolution kinetics

The construction of caverns for the deep underground disposal of radioactive waste is likely to use significant quantities of cement. The interaction of highly alkaline cement pore fluids with clay minerals is likely to form the mineral analcime. The BGS is currently conducting experiments, funded by the Power Reactor and Nuclear Fuel Development Corporation, Japan (PNC), to determine the rate at which analcime reacts over a range of temperatures and fluid compositions.

Commercialisation of BGS borehole seismic sources

The BGS has developed borehole seismic sources for the generation of compressional and vertically polarised shear wave signals. The designs are unique to the BGS and a marketing agreement has been concluded with Allied Associates Geophysical Ltd to promote and sell these devices for site investigation surveys, including cavity detection, fault and fracture delineation, rock mass characterisation for the radwaste industry and the determination of in-situ geomechanical properties. Seismic sources were recently sold to institutes in Greece and the USA.

Uranium and thorium in groundwater

Under its EC and EA-funded 'Humics' project, involving collaboration with several European partners, the BGS has continued to determine the effects of fulvic acids on the migration behaviour of uranium and thorium in groundwaters. This experimental information is important for more accurate modelling of radionuclide migration from radioactive waste repositories.

Contaminated land

Under a joint EA–BGS project entitled *Development of guidance on the use of digital environmental data*, three local authority areas are being investigated: Newham in London, Leicester City and the East Riding of Yorkshire. Demonstration GISs are being produced for each area to show how digital information can be used to identify potentially contaminated land.

Redox experiments (REX)

Work has continued for the Japan Nuclear Cycle Development Institute, examining the effects of bacteria on redox processes in granites. This project has formed part of an international study at the Äspö underground mine in Sweden and final results will be presented to the scientific community at a series of workshops in autumn 1999.

Review of microbiological contaminants

A review was undertaken by the BGS and the Robens Institute (University of Surrey) for the EA on microbiological contaminants in groundwater. Among the topics covered were the role of indigenous organisms in groundwater quality, pathogen transport, the presence of genetically modified organisms in aquifers, and bioremediation. An assessment of microbiological risks to groundwaters was also included.

Transport of pollutants beneath a cemetery

A report was prepared with the EA on the investigation of of a cemetery site in Nottingham listing transport properties associated with the movement of organic and inorganic signatures derived from burials. The work assessed the impact of pollution from a long term cemetery site on groundwater under an urban environment.

Gas migration in clay liners

This project is a component of the EPSRC/NERC Waste Management and Pollution Programme (Landfill Practice). The partners are the BGS, University of Wales (at Cardiff) and MJ Carter Associates. The project focuses on the performance of landfill clay liners as currently constructed to the EA standard in acting as barriers to gas migration. The BGS has developed a new piece of field apparatus, the 'Envirotest Module', a robust, self-contained unit designed to monitor environmental parameters under difficult site conditions with no mains electricity supply. The unit has been successfully deployed at an operational landfill in central England where it was configured to monitor the response of a mineral liner during a gas injection experiment.

A E Milodowski, BGS © NERC

BSEM image of a polished section of finely interbanded, poorly crystalline and well crystallised cryptomelane-hollandite mineralisation from Lecht Mine, Scotland. Ageing, crystallisation and replacement of poorly crystalline (duller bands) manganese oxyhydroxide gel by more crystalline cryptomelane-hollandite results in the remobilisation and loss of trace elements such as barium, zinc and lead. However, significant amounts of these trace elements are also strongly fixed within the crystalline structure during this process.

Properties of bentonite

The BGS, sponsored by the Swedish company SKB, has developed a state-of-the-art gas permeameter which is used to simulate and study the processes occurring in a hard rock repository for nuclear waste, including resaturation and rehydration of the clay barriers and the migration of gases liberated from the waste container. The apparatus can measure the changes in stress and pore water pressure that occur when gas pressure is slowly increased in a porous filter placed at the centre point of the specimen. The results of these experiments are used in the development of process models for repository safety analysis.

Palaeohydrogeology

Studies of the changes in deep groundwater at potential repository sites, related to climatic and hydrogeological conditions during the Quaternary, have continued as part of the EC-supported international project EQUIP (Evidence from Quaternary Infills for Palaeohydrogeology). The work is a development of BGS studies for UK Nirex Ltd at Sellafield, west Cumbria, and uses mineralogical features to provide information on how modern deep groundwater systems have evolved. Integrated petrological, morphological, microchemical and fluid inclusion studies of late-stage calcite mineralisation, together with geochemical data from Sellafield, are used to model fluid evolution. Parallel studies have also been made on calcite mineralisation from Äspö Island and Laxemar in Sweden, under contract for the Swedish radioactive waste management company SKB (in collaboration with Terralogica AB). Both of these studies have demonstrated close relationships between modern deep groundwaters and mineral fabrics and fluid inclusion characteristics of late-stage calcite mineralisation.

Japanese nuclear research projects

A detailed study of the Tsukiyoshi Fault in the Tono Uranium Deposit, in Japan, employed mineralogical, geometrical and distribution characteristics of fractures associated to identify the potential groundwater flow paths around the fault zone. These features were used to help evaluate the influence of the fault on groundwater flow and hydrochemistry. The study forms part of the Japan Nuclear Cycle Development Institute's generic research at their Tono Geoscience Research Centre, related to the underground disposal of radioactive wastes in Japan.

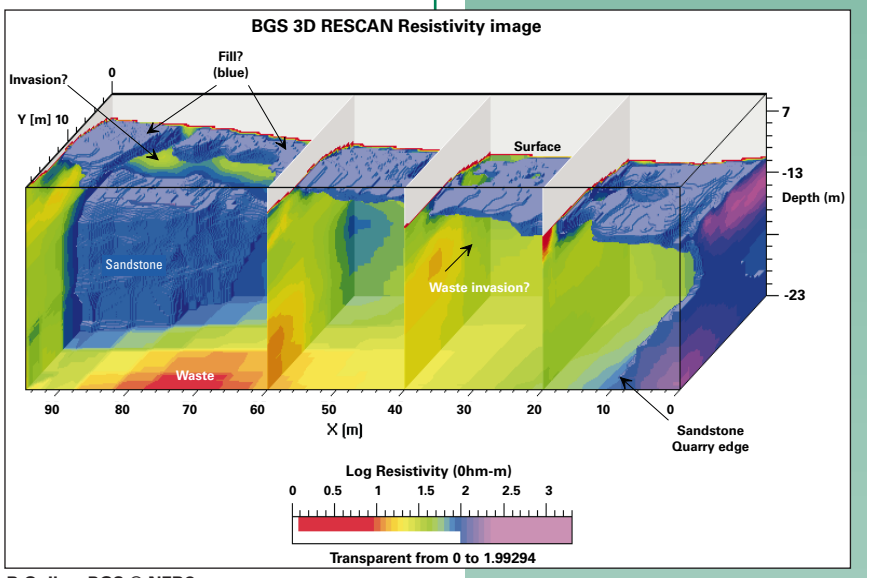
Limestone resources

The impacts of the industrial use of limestone resources on biodiversity and

RESCAN resistivity tomography

The BGS-designed RESCAN resistivity imaging system has been further developed for mapping contaminated and derelict land. Surveys can now be undertaken which take account of the full 3D spatial heterogeneity of the subsurface as well as variations in surface topography. Advanced mathematical inversion code has been developed which permits the automatic reconstruction of 3D volumetric images or tomograms.

The RESCAN system has been widely used to characterise landfills and industrial waste repositories. A 3D survey to map industrial waste in abandoned sandstone quarries confirmed that where fluid invasion of the quarry walls is negligible, the strong resistivity contrast with the confining sandstone provided a basis for mapping the concealed quarry boundaries and depth to bedrock. Elsewhere the low resistivity values (colour-coded red-yellow) are considered to reflect infiltration of the quarry walls by waste fluids. 3D visualisation software allows interactive slicing and viewing of iso-resistivity volumes.

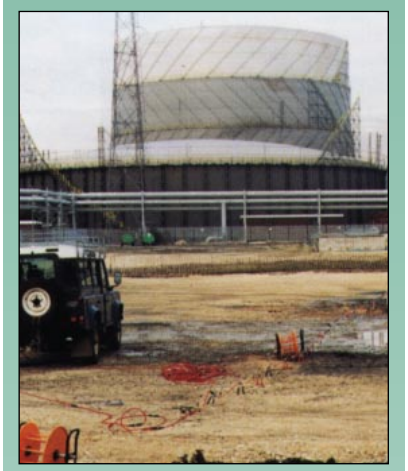


R Ogilvy, BGS © NERC

RESCAN 3D resistivity image showing the spatial distribution of industrial waste and possible fluid pathways in an old sandstone quarry. Opaque 3D volume reflects sandstone and surficial fill material (resistivity greater than 100 ohm.m).

R Ogilvy, BGS © NERC

Use of PC-controlled IPT system in the field.



R Ogilvy, BGS © NERC

Cross-borehole IPT survey being carried out a former gasworks site to help locate a buried coal tar tank.

cultural heritage in south-east Asia were assessed as part of a project funded by the World Bank. Technical assistance was provided to compile geological summary maps showing the distribution and stratigraphical age of limestones.

Rock matrix diffusion

Rock matrix diffusion can retard transport of radionuclide solutes in fractured rocks. Laboratory scale aqueous diffusion experiments are very time consuming, with individual experiments lasting several months, and provide information at a small scale (core plug). The BGS has completed a preliminary study to evaluate the use of geophysical wireline logs to infer the *in situ* rock matrix diffusion properties of low permeability and low porosity fractured rocks over much larger scales. This work was carried out for Nirex UK Ltd under sub-contract from AEA Technology.

Induced polarisation tomography

A prototype Induced Polarisation Tomography (IPT) system has been developed which measures the electrical resistivity and polarisability of the ground. This research is co-funded by the EU, ABEM Instrument (Sweden) and BG Technology plc. The system was designed to assist the non-invasive mapping of contaminants such as oils, solvents and coal tars. These Non-Aqueous Phase Liquids (NAPLs) are difficult to detect by conventional geophysics, as they are sparingly soluble and invariably occur as capillary trapped residuals in the pore-space. If highly resistive NAPLs displace the pore water and change the ion mobility in the rock matrix then a diagnostic IPT response could be expected.

The system is PC-controlled and permits the automatic acquisition of thousands of measurements, using both surface and borehole arrays. The system's cross-borehole capability is needed to scan beneath buildings and buried storage tanks in the built environment where conventional surface sampling is either impractical or ineffective.

Migration of radium

In collaboration with AEA Technology, the BGS has studied radium interactions associated with manganese oxyhydroxide mineralisation in shallow groundwater systems. This work is part of the Nirex Safety Assessment Research Programme and is investigating the processes affecting the migration and retardation of radium in the geosphere.

The geochemical and mineralogical changes occurring during the ageing of natural manganese oxyhydroxide minerals, which are common in shallow groundwater systems, will be investigated. These minerals have a strong affinity for radium and other metals (e.g. lead, zinc, barium, calcium). The BGS studies have followed the behaviour of these minerals with respect to barium uptake, as a natural analogue for the behaviour of radium in the natural environment.

J Harrington, BGS © NERC

The Envirotest Module in action.

Appendix 1 Acronyms

AAPG	*American Association of Petroleum Geologists*
ACSAD	*Arab Centre for the Studies of Arid Zones and Dry Lands*
ANDRA	*Agence Nationale pour la gestion des Déchets Radioactifs*
ARGOSS	*Assessing Risk to Groundwater from On-Site Sanitation*
ASR	*Aquifer Storage and Recovery*
AWE	*Atomic Weapons Establishment*
BGGM	*BGS Global Geomagnetic Model*
BGS	*British Geological Survey*
BNSC	*British National Space Centre*
BODC	*British Oceanographic Data Centre*
BRIDGE	*British Ridgehe Netherlands*
BSEM	*Back-scattered scanning electron microscopy*
CASE	*Collaborative Awards in Science and Engineering*
CBI	*Confederation of British Industry*
CCMS	*Centre for Coastal and Marine Sciences*
CCOP	*Intergovernmental Committee for the Co-ordination of Coastal and Offshore Geoscience Programmes in East and South-east Asia*
CEC	*Commission of the European Communities*
CEEC	*Central and Eastern European Countries*
CEFAS	*Centre for Environment, Fisheries and Aquaculture Science*
CEREGE	*European Center for Research and Education in the Environmental Geosciences*
CFTC	*Commonwealth Fund for Technical Co-operation*
CIRIA	*Construction Industry Research and Information Association*
CORSAIRES	*Coring Stable And Instable Realms in European Seas*
CSIRO	*Commonwealth Scientific and Industrial Research Organisation*
CTBT	*Comprehensive Test Ban Treaty*
DED	*Department of Economic Development*
DERA	*Defence Evaluation Research Agency*
DETR	*Department of the Environment, Transport and the Regions*
DFID	*Department for International Development*
DOE	*Department of the Environment*
DOE-NI	*Department of the Environment, Northern Ireland*
DTI	*Department of Trade and Industry*
EA	*Environment Agency*
EC	*European Commission*
EKS	*Electrokinetic Sounding*
ENAM	*European North Atlantic Margins*
EPA	*Environmental Protection Agency*
EPSRC	*Engineering and Physical Sciences Research Council*
EQUIP	*Evidence from Quaternary Infills for Palaeohydrogeology*
ETH	*Eidgenüssische Technische Hochaschule*
EU	*European Union*
EU/SYSMIN	*European Union assistance for minerals in the African, Caribbean and Pacific countries.*
FAMEST	*Fundamental Aspects of Metal Speciation and Transport in Metal-Contaminated Soils and Aquifers*
FIG	*Falkland Islands Government*
FOREGS	*Forum of European Geological Surveys*
GASPAL	*Groundwater as Palaeoindicator*
G-BASE	*Geochemical Baseline Survey of the Environment*
GEUS	*Danmarks og Grønlands Geologiske Undersøgelse (Geological Survey of Denmark and Greenland)*
GHASP	*Geohazards Assessment and Susceptibility Programme (marketed as Residata Subsidence)*
GIC	*Geomagnetically Induced Currents*
GIFS	*Geomagnetism Information and Forecasting Service*
GIS	*Geographical Information System*
GRS	*Gesellschaft für Anlagenund Reactorsicherheit*
Hi-RES	*High-resolution Resource and Environmental Survey (airborne)*
HSE	*Health and Safety Executive*
IAEA	*International Atomic Energy Agency*
IAGC	*International Association of Geochemistry and Cosmochemistry*
ICP–MS	*Inductively coupled plasma mass spectrometry*
ICTJA	*Institute de la Tierra Jaume Almera*
ICP–AES	*Inductively Coupled Pla Atomic Absorption Emission Spectrometry*
IIFR	*Interpolation In-Field Referencing*
IMM	*Institution of Mining and Metallurgy*
INCO	*International Co-operation (elements of EC framework programmes)*
IPT	*Induced Polarisation Tomography*
IUGS	*International Union of Geological Sciences*
JNC	*Japan Nuclear Cycle Development Institute*
KAR	*(DFID) Knowledge and Research programme*
KVI	*Kernfysisch Versneller Instituut*
LOCUS	*London Computerised Underground & Surface Geology Project*
LOIS	*Land-Ocean Interaction Study*
LUL	*London Underground Ltd*
MAFF	*Ministry of Agriculture, Fisheries and Food*
MAP	*Multiple Analytical Pathways*
MARIS	*Marine Information Service, The Netherlands*
MAUK	*Mining Association of the United Kingdom*
MES	*Marconi Electronic Systems Ltd*
MINGOL	*Minerals GIS On-Line*
MIRO	*Mineral Industries Research Organisation*
MMS	*Matra Marconi Space*
MOD	*Mineral Occurrences Database*
MRP	*Mineral Reconnaissance Programme*
MRS	*Materials Research Society*
NAGRA	*National Genossenschaft für die lagerung radioaktiver Abfalle*
NAMCOR	*National Petroleum Corporation of Namibia*
NAPL	*Non-Aqueous Phase Liquid*
NERC	*Natural Environment Research Council*
NGC	*National Grid Company*
NOAA	*(United States) National Oceanic and Atmospheric Administration*
NRE	*Natural Resources and Environment*
NRPB	*National Radiological Protection Board*
NRSC	*National Remote Sensing Centre Ltd.*
ODP	*Ocean Drilling Programme*
OECD	*Organization for Economic Cooperation & Development*
OGLD	*Oil, Gas and Licensing Division (of the DTI)*
OST	*Office of Science and Technology*
PACE	*Palaeozoic Amalgamation of Central Europe*
PECC	*Petroleum Exploration Computer Consultants*
PIP	*Petroleum Infrastructure Project*
PML	*Plymouth Marine Laboratory*
POL	*Proudman Oceanographic Laboratory*
POSC	*Petroleum Open Software Corporation*
PRC	*People's Republic of China*
ROSES	*Risk Of Subsidence due to Evaporite Solution*
SAMS	*Scottish Association for Marine Science*
SCK/CNRS	*Studicentrum voor Kernenergie/Centre D'Etude de L'Energie Nucleaire*
SEM	*Scanning electron microscopy*
SEPA	*Scottish Environment Protection Agency*
SGML	*Standard Generalised Mark-up Language*
SINTEF	*The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology*
SME	*Small and Medium Enterprises*
SOPAC	*South Pacific Geoscience Commission*
SURRC	*Scottish Universities Research and Reactor Centre*
TESZ	*Trans European Suture Zone*
TNO	*Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek*
TWU	*Thames Water Utilities*
UKCS	*United Kingdom Continental Shelf*
UKWIR	*UK Water Industry Research Ltd*
UN	*United Nations*
UNDP	*United Nations Development Programme*
UN ESCAP	*United Nations Economic and Social Commission for Asia and the Pacific*
UNESCO	*United Nations Educational Scientific and Cultural Organization*
UNICEF	*United Nations Children's Fund*
URO	*Urals Orogen*
US	*United States (of America)*
USGS	*United States Geological Survey*
WFA	*Western Frontiers Association (Oil Companies & BGS)*
WHO	*World Health Organization*
WMS	*World Mineral Statistics*
WWW	*World Wide Web*
XRF	*X-ray Fluorescence*

Organisation of the British Geological Survey, May 1999

DIRECTOR Dr D A Falvey

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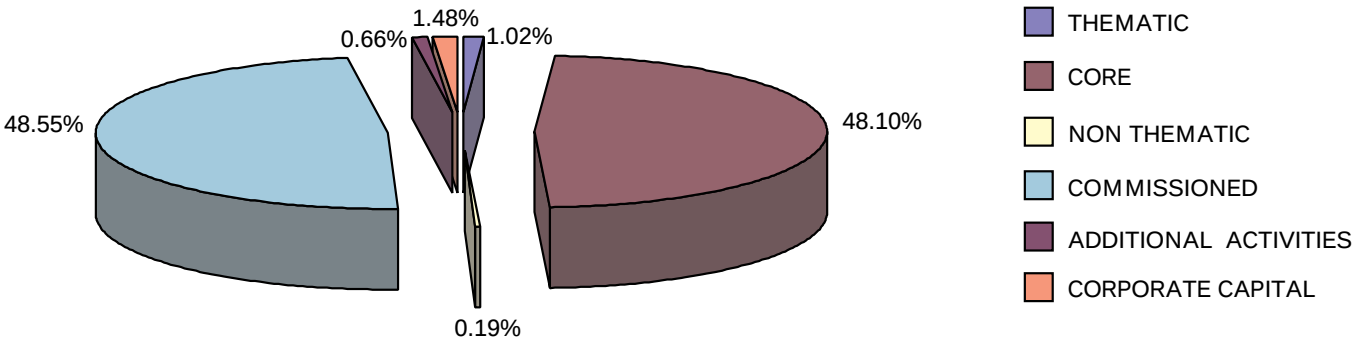
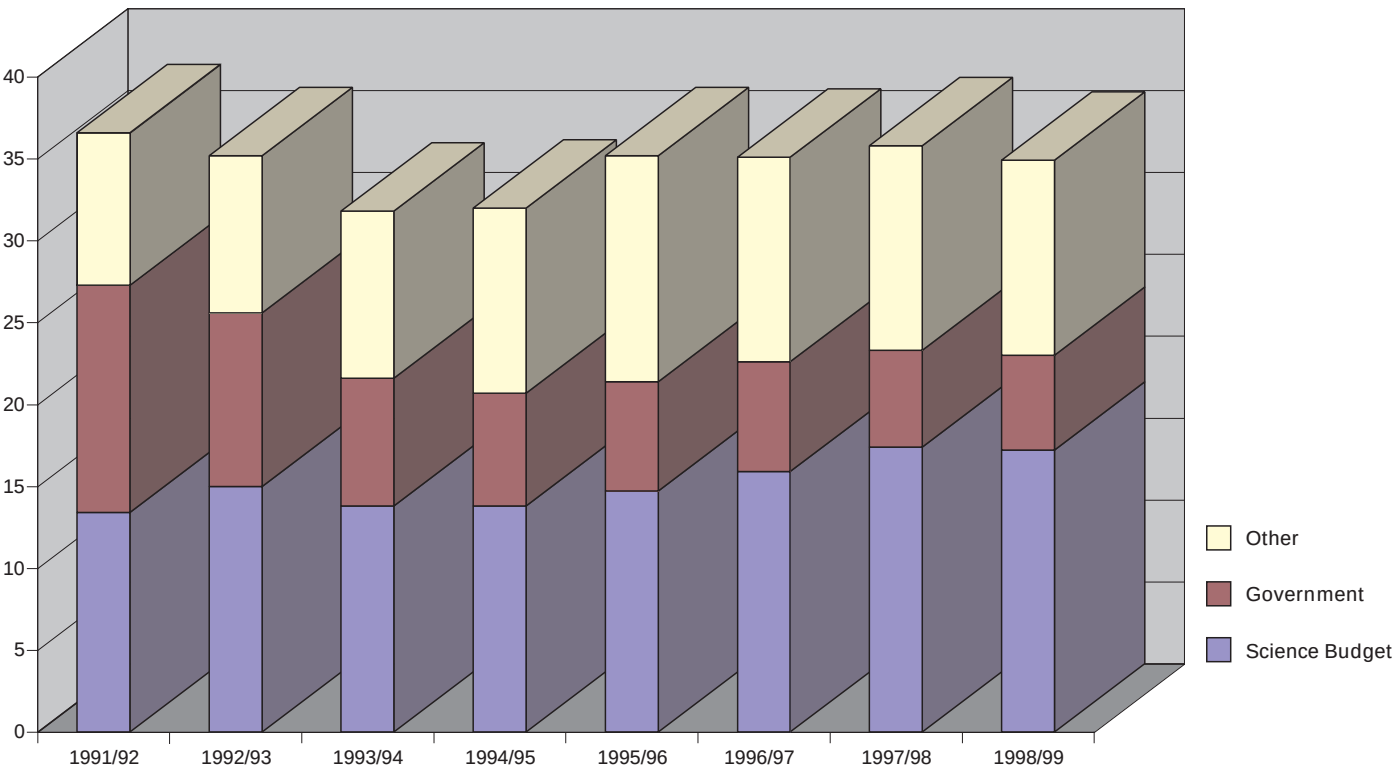
Appendix 3 Finance

BGS EXPENDITURE — 1998/99



SOURCES OF BGS INCOME 1991/92 — 1998/99

(at 1998/99 prices)



Appendix 4 Publishing

Interim issue of maps

To ensure the earliest possible release of current geological data to the public, all new 1: 50 000 maps are first made available in digital form and as electrostatic plots (on-demand), in advance of litho printing. The purchase of an electrostatic plot entitles the customer to a free copy of the printed map if and when this is published.

MAPS PUBLISHED

The following abbreviations are used throughout: S–solid; D–drift; S&D–solid and drift.

1: 1 000 000 UTM

Gravity anomaly map: Northern Britain
Gravity anomaly map: Southern Britain

1: 250 000

Shetland (sea-bed sediment) — second edition

1: 1 250 000 NATURAL ENVIRONMENT RADIOACTIVITY SURVEY SERIES

S3N 04W Liverpool Bay (radon potential based on solid and drift geology)
S3N 04W Liverpool Bay (outdoor gamma-ray dose rates based on solid and drift geology.

1: 50 000 (PRINTED)

ENGLAND AND WALES

34 Guisborough S&D (provisional)
38 Ambleside S&D
54 Scarborough S&D (provisional)
78 Wakefield S&D
235 Cirencester S&D
316 Fareham S&D
348 Plymouth S&D

SCOTLAND

6W Kirkbean S
6W Kirkbean S&D
9W New Galloway S
19 South Islay S&D (provisional)
22W Irvine S
101W Summer Isles S&D (provisional)
103E Helmsdale S&D (provisional)
113 Cape Wrath S&D (provisional)

NORTHERN IRELAND

7 Causeway Coast S

1: 50 000 (ELECTROSTATIC PLOT)

ENGLAND AND WALES

29 Keswick S
29 Keswick S&D
37 Gosforth S
37 Gosforth S&D
102 Market Rasen S&D (provisional)
103 Louth S&D (provisional)
108 Flint S
108 Flint S&D
132/148 Mundesley/North Walsham S&D
146 Fakenham S&D (provisional)
160 Swaffham S&D (provisional)
269 Windsor S&D
300 Alresford S&D
328 Dorchester S&D
353 Mevagissey S&D

SCOTLAND

15W New Cumnock S
15W New Cumnock S&D
22E Kilmarnock S
22E Kilmarnock S&D
29W Kilfinnan S&D (provisional)
32W Livingstone S&D
70 Minginish S&D
86W Huntly S

NORTHERN IRELAND

13 Coleraine S&D

1: 25 000

18/28 Black Combe S&D

INTERNATIONAL

Ecuador

Mapa Geologico de la Cordillera Occidental del Ecuador entre 0°–1° (1: 200 000)
Mapa Geologico de la Cordillera Occidental del Ecuador entre 1°–2° (1: 200 000)
Mapa Geologico de la Cordillera Occidental del Ecuador entre 2°–3° (1: 200 000)
Mapa Geologico de la Cordillera Occidental del Ecuador entre 3°–4° (1: 200 000)

Falkland Islands

Geology of the Falkland Islands — East Sheet solid (1: 250 000)
Geology of the Falkland Islands — West Sheet solid (1: 250 000)

BOOKS PUBLISHED

ANNUALS

British Geological Survey Annual Report 1997–1998
World Mineral Statistics 1992–1996
Geomagnetic Bulletin 27 — Magnetic Results 1997
United Kingdom Minerals Yearbook 1997
Directory of Mines and Quarries

ATLAS

Geochemical Atlas of Southern Sumatra
Regional geochemistry of parts of North-west England and North Wales

SHEET MEMOIRS

ENGLAND AND WALES

20 Newcastle
42 Northallerton
59 Lancaster
169 Coventry and Nuneaton

SCOTLAND

31E Falkirk district
8W/8E Carrick — Loch Doon district
74E Aviemore district

NORTHERN IRELAND

43/44/56 Derrygonnelly and Marble Arch

CD-ROM

The UK Sand and Gravel Database

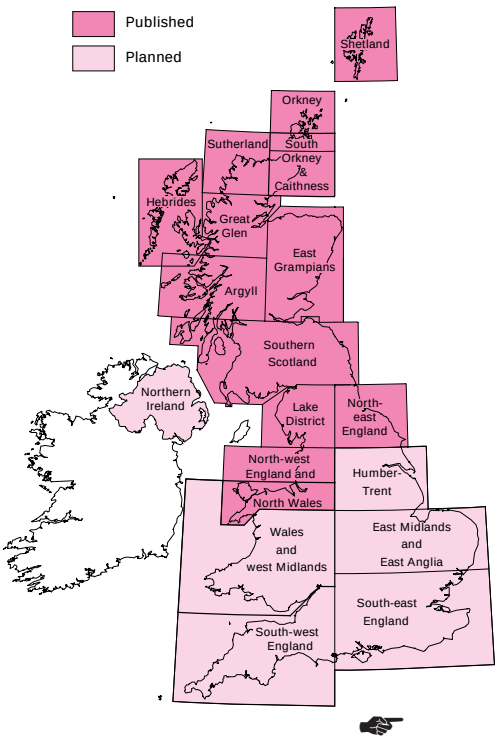
PUBLISHED TECHNICAL REPORTS

WA/97/84 Earth science information in support of major development issues
WA/97/85 Environmental geology in land use planning

POPULAR PUBLICATIONS

Whisky on the Rocks
Holiday Geology Guide — *Scarborough and Whitby*
Holiday Geology Guide — *Cornish Pebbles*
Fossil Focus — *Plants*
Fossil Focus — *Echinoids*
Earthwise Magazines — issue 12, *A special issue in support of Minerals '98 — Foresight linked*, and issue 13, *Sustainability*.

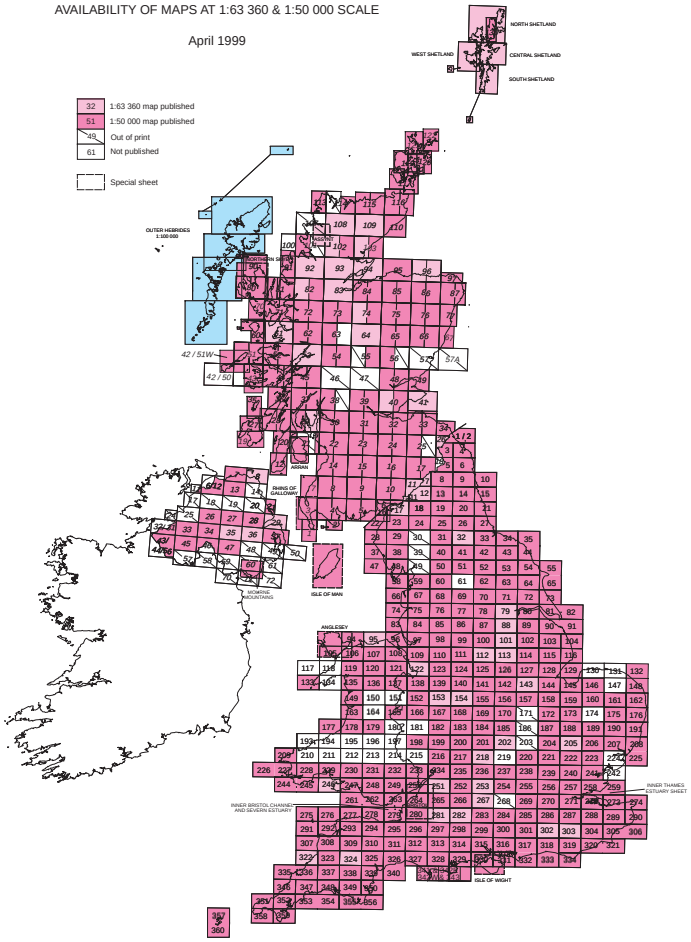
INDEX TO AREAS COVERED BY GEOCHEMICAL ATLASES



APPENDICES

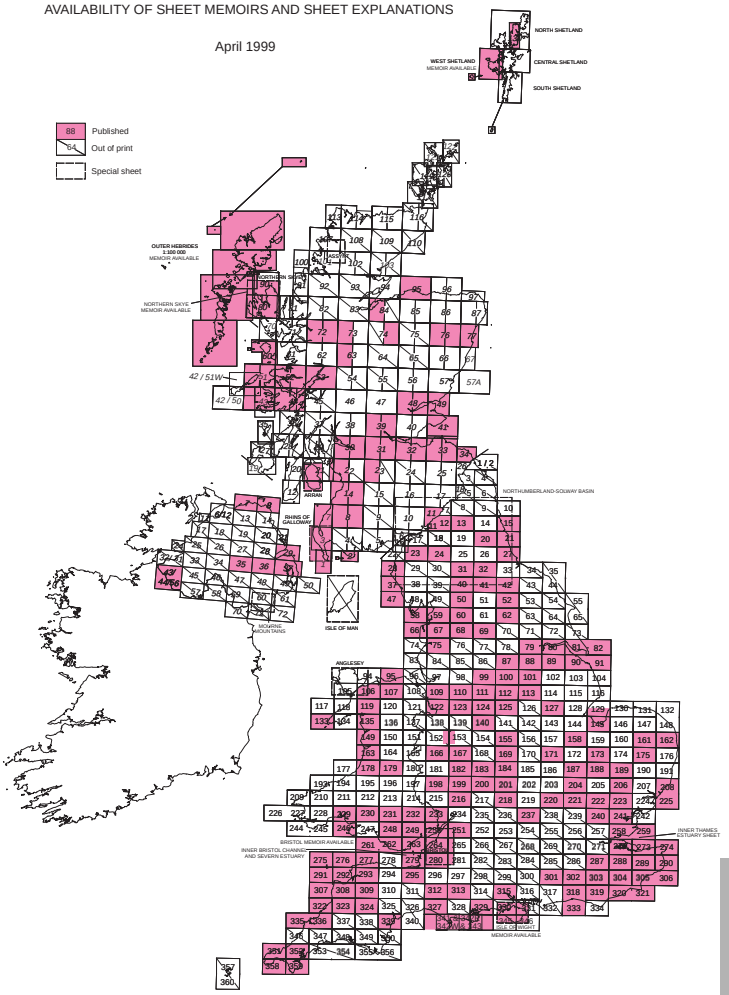
AVAILABILITY OF MAPS AT 1:63 360 & 1:50 000 SCALE

April 1999

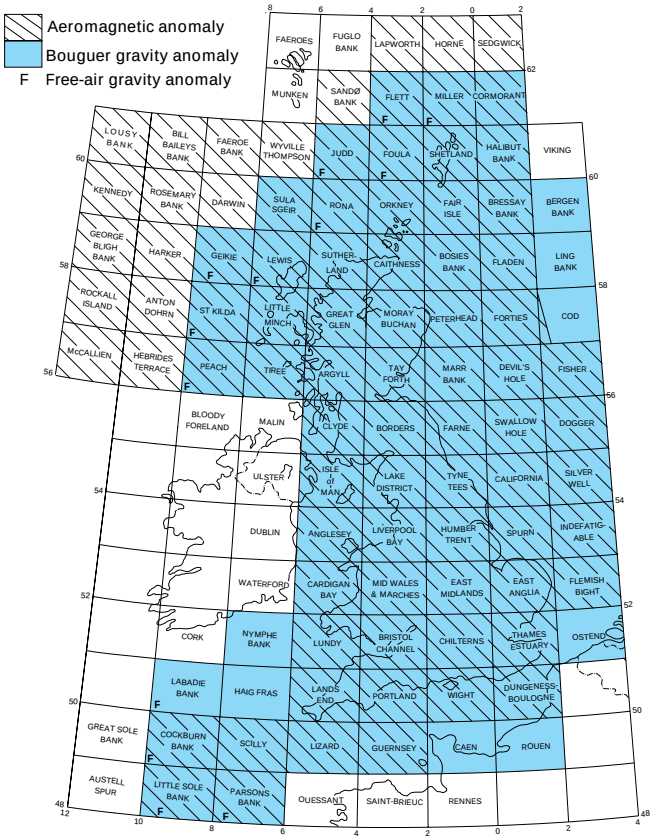


AVAILABILITY OF SHEET MEMOIRS AND SHEET EXPLANATIONS

April 1999

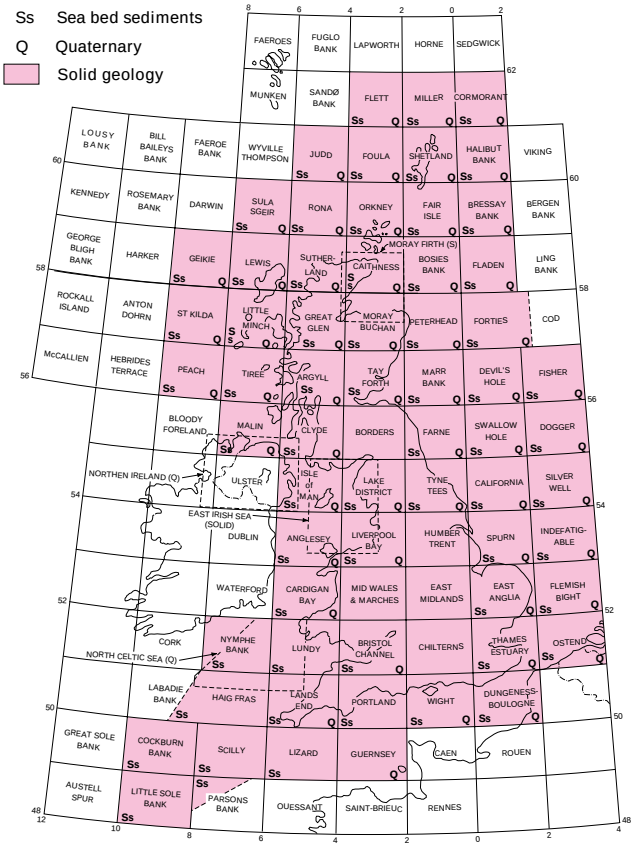


AVAILABILITY OF GEOPHYSICAL MAPS 1:250 000 SCALE U.T.M. SERIES



AVAILABILITY OF GEOLOGICAL MAPS 1:250 000 SCALE U.T.M. SERIES

Ss Sea bed sediments
Q Quaternary
Solid geology



TECHNICAL REPORTS

(made available by the authors' group)

Onshore Geology

WA/96/77 Geology of the Winshill-Newhall area. 1:10 000 sheet SK22SE. Part of 1:50 000 sheets 140 (Burton) and 141 (Loughborough).

WA/96/78 Geology of the Hartshorne area 1:10 000 sheet SK32SW. Part of 1:50 000 sheet 141 (Loughborough).

WA/97/7 Geology of the Crow Hill, Wadsworth and Oxenhope areas 1:10 000 sheet SD93NE, SD93SE and SE03SW. Part of 1:50 000 sheets 69 (Bradford) and 77 (Huddersfield).

WA/97/8 Geology of the Denholme area 1:10 000 sheet SE03SE. Part of 1:50 000 sheets 69 (Bradford) and 77 (Huddersfield).

WA/97/26 Geology of the Shifnal, Blymhill and Bishops Wood areas: 1:10 000 sheet SJ70NE, 80NW, 81SW and part of 81NW.

WA/97/30 Physical properties of Carboniferous sandstones from the Bradford area, West Yorkshire.

WA/97/40 Geology of the Melbourne area. Part of 1:50 000 sheet 141 (Loughborough).

WA/97/41 Geology of the Castle Donnington area: 1:10 000 sheet SK42NW Part of 1:50 000 sheet 141 (Loughborough).

WA/97/42 Geology of the Breedon on the Hill area 1:10 000 sheet SK42SW. Part of 1:50 000 sheet 141 (Loughborough).

WA/97/60 Geology of Otley and adjacent areas 1:10 000 sheet SE24NW, and parts of SE24NE and SE25SW. Part of 1:50 000 sheet 69 (Bradford).

WA/97/80 Geology of the Shipley area 1:10 000 sheet SE13NE. Part of 1:50 000 sheet 69 (Bradford).

WA/97/83 Geology of the Brewood area 1:10 000 sheet SJ80NE. Part of 1:50 000 sheet 153 (Wolverhampton).

WA/97/84 Earth Science Information in support of major development initiatives.

WA/97/85 A guide to sources of earth science information for planning and development.

WA/97/88 The geology of the Clyde Plateau Volcanic Formation of the Kilmarnock district (sheet 22E), central Scotland.

WA/97/92 An introduction to the Green Beds of the Southern Highland Group of the Scottish Dalradian: previous research and an account of preliminary work carried out in 1997.

WA/97/95 Ordivician rocks of the Low Furness Inlier, south Cumbria 1:10 000 sheet SD27NW. Part of 1:50 000 Geologicical Sheet 48 (Ulverston).

WA/98/3 Application of logratios to the statistical analysis of the geochemistry of metamorphosed limestones from the Northeast and Central Highlands of Scotland: the case for Appin Group correlations.

WA/98/4 Corallian lithostratigraphy of the Abbotsbury district (Dorset): A revised interpretation based on new borehole evidence.

WA/98/5 Fluvial sediments of the Tertiary Poole formation (Dorset): depositional environments and sequence stratigraphic significance.

WA/98/6 Geology of the Grange Moor and Emley Moor area. 1:10 000 sheet 21NW and part of 21SW. 1:50 000 sheet 77 (Huddersfield).

WA/98/7 The geology of the Wythburn, Thirlmere and Fairfield areas of the north-eastern Lake District.

WA/98/8 Geology of the Candovers and Wield district, Alresford, Hampshire 1:10 000 sheets SU54SE, SU53NE, SU64SW, SU63NW and SU64SE. Part of 1:50 000 sheet 300 (Alresford).

WA/98/9 The Liddesdale Group of 1:50 000 scale sheet 14 (Morpeth): lithostratigraphy and local details.

WA/98/10 The Morpeth Group of 1:50 000 scale sheet 14 (Morpeth): lithostratigraphy and local details.

WA/98/11 Geology of the Ide, Longdown, Holcombe Burnell and Great Fulford areas (Devon). Parts of 1:10 000 sheets SX89SE and SW and part of sheet SX79SE. Part of 1:50 000 sheet 325 (Exeter).

WA/98/13 Geology of the area between Privett and Wheatham Hill (Hampshire) 1:10 000 sheets SU62NE, SU72NW and part of SU72SW. Part of 1:50 000 sheet (Alresford).

WA/98/15 Geology of the Icomb area 1:10 000 sheet SP22SW. Part of 1:50 000 sheets 217 (Moreton-in-Marsh) and 218 (Chipping Norton).

WA/98/17 Summary of the geology east of Thirlmere.

WA/98/18 Geology of the Kimmeridge area (Dorset) 1:10 000 sheets SY97NW and part of SY87NE. Part of 1:50 000 sheets 342 (Weymouth) and 343 (Swanage).

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WA/98/41 Geology of the central Pentland Hills 1:10 000 sheet NT16SE (Scald Law) and 1:10 000 sheets NT15NW (Baddinsgill) and part of NT15NE (Carlops). Part of 1:50 000 sheet 32W (Livingston), 32E (Edinburgh) and 24W (Biggar).

WA/98/42 The base of the Upper Coal Measures in the Markinch, Dysart, Leven coalfield, Fife.

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WA/98/49 Geology of the area around Alton and Selborne, Hampshire. 1:10 000 sheets SU63NE and SE, and SU73NW, NE, SW and SE. Part of 1:50 000 geological sheet 300 (Alresford).

WA/98/53 Geology of the Moreton-in-Marsh area 1:10 000 sheet SP23SW. Part of 1:50 000 sheets 217 (Moreton-in-Marsh) and 218 (Chipping Norton).

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Appendix 5 Staff List, May 1999

CENTRAL DIRECTORATE

Keyworth

Director Dr Falvey, David A
SPSec 7(A) Mrs Cross, Elaine A *AIQPS*

Secretary Grade 6
3 Mr Hackett, Dennis
PSec 8(A) Miss McDonald, Claire

Central Directorate Support Group

SSO 5(S) Dr Turner, Nicholas†
HSO 6(S) Miss Baxendale, Hazel J
Mr Kingdon, Andrew
Mrs Punter-Collins, Gaynor L
Ty 9(A) Mrs Crosby, Wanda J
Mrs Screaton, Margaret H¶

ADMINISTRATION

Personnel

Keyworth

Personnel Officer (SEO)
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Mrs Stocks, Susan
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Mr Crosby, Adrian L
Mrs Gil-Bennett, Patricia*
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AA 9(A) Mrs Cartwright, Susan¶

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Keyworth

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Mrs Newham, P Anne¶
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Tec 1 8(T) Mr Adkin, Adrian J
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Mr Glover, John T
Mr Mills, Roy
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Mr Upton, G Steve
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Ty 9(A) Mrs Glover, Marilyn A
SGB2 9(T) Mr Barton, Graham
Mr Cohen, Bryan A
Mr Goode, Geoffrey T
Mr Holbrook, Robert D
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Mr Jordan, Christopher
Mr Kirk, Jeremy R

Murchison House

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Miss Robertson, C Jane
EO(C) 7(C) Mr Cummings, Scott R
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Miss Kovac, Geraldine M
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Mrs Matheson, Diane R
AO 8(A) Mrs Kennedy, Karen

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Miss Riley, Lynne K
EO 7(A) Mr Jackson, Steven D
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Miss Hobson, Rachel M*
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Mr Kerr, J Gavin
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AO 8(A) Mrs Abrahams, Elizabeth, C¶
Mrs Broughton, Jane¶
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Scotland & Northern England

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Mrs Kinnear, Margaret W¶
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Dr Barnes, Robert P
Mr Browne, Michael A E *FGS* CGeol
Dr Floyd, James D *FGS CGeol*
Dr Gould, David *FGS CGeol MIMM*
Dr Hughes, Richard A¶
Mr Lawrence, David J D
Mr Laxton, John L
Mr McAdam, A David *FGS CGeol*
Mr McMillan, Andrew A *FGS CGeol*
Dr Mendum, John R
Mr Merritt, Jonathan W
Dr Millward, David *FGS CGeol*
Dr Monro, Stuart K *FGS CGeol*
Dr Petterson, Michael G
Dr Smith, Martin *FGS CGeol*
Dr Stephenson, David
Dr Stone, Philip *FGS CGeol*
Dr Woodhall, Derek G *FGS CGeol*
Mr Young, Brian *FGS CGeol FIMM CEng*
Dr Young, Simon R*
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Mr Barron, Hugh, F *CGeol*
Mr Dean, Mark T
Mr Halley, David N
Dr Highton, Andrew J *FGS CGeol*
Mr Holmes, Keith A
Dr Johnson, Eric W *FGS CGeol*
Mr McCormac, Michael
Dr Robertson, Steven
Mr Ross, David L *FGS CGeol*
Dr Smith Richard, A *FGS*
Mr Thomas, Christopher W *FGS CGeol*
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Mr Lawrie, Kenneth I G

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Mr Bridge, David M
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Dr Cooper, Anthony H *FGS CGeol*
Mr Greally, Kevin B
Dr Howard, Andrew S *FGS*
Mr Lake, Robert D
Dr Waters, Colin N *FGS CGeol*
Dr Waters, Richard A *CGeol*
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Mr Hough Edward
Mr Hulland, Vincent J
Mrs Newsham, Rhonda
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Mr Ellison, Richard A *FGS CGeol*
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Mr Sumbler, Michael G *FGS CGeol*
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Mr Morigi, Anthony N
Mr Smith, Alan
Dr Westhead, R Keith *FGS CGeol*
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Mr Humpage, Adrian J
Dr Royse, Katherine R
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Mr Mogdridge, Roy T

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HSO 6(S) Dr Cooper, Mark R *FGS*
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Mr Chilton, P John *FGS CGeol*
Dr Darling, W George
Mr Gale, Ian N *FGS CGeol*
Dr Kinniburgh, David G *MRSC CChem*
Mr Lawrence, Adrian R *FGS CGeol*¶
Mr Mckenzie, Andrew A
Mr Morris, Brian L *FGS CGeol*
Mr Robins, Nicholas S *FGS CGeol FIWEM*
Dr Smedley, Pauline L¶
SSO 5(S) Dr Bloomfield, John P *FGS CGeol*
Mr Calow, Roger
Mr Cheney, Colin S *FGS CGeol*
Mr Davies, Jeffrey *FGS CGeol*
Ms Hargreaves, Rosemary L
Mrs Lewis, Melinda A¶
Dr Shand, Paul
Mr Shearer, T Robert *FGS*
Mrs Stuart, Marianne E *MRSC CChem*
Mrs Williams, Ann T *FGS*¶
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Mr Gooddy, Daren C *MRSC CChem*
Dr Jones, Helen K¶
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Mr Marks, Richard J *FGS CGeol*
Mr Milne, Christopher J *MRSC CChem*¶
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Mr Merrin, Philip D
Miss O'Dochartaigh, Brighid E
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Miss McLean, Jennifer E
Mr Thorns, John F
Mr Williams, Peter J
AO 8(A) Mrs Cole, Mary
Mrs Jones, Samantha J
AA 9(A) Mrs Dorling, Susan J
Mrs Fry, Rosemary A
SGB2 9(T) Mr Townsend, Barry R

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Murchison House

SSO 5(S) Mr Ball, Derek F
HSO 6(S) Mr Macdonald, Alan M *FGS CGeol*

Coastal & Engineering Geology

Keyworth

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Mrs Ware, Linda¶
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Dr Evans, Christopher D R
Mr Forster, Alan *CGeol*
Mr Humphreys, Bernard
Dr Jackson, Peter D *CGeol*
Mr James, J W Ceri
Mr Northmore, Kevin J *CGeol*
Dr Ridgway, John *CGeol*
SSO 5(S) Dr Gostelow, T Paul
Dr Gunn, David A
Mr Hallam, Jonathan R
Mr Hobbs, Peter R N
Dr Rees, John G *CGeol*
HSO 6(S) Dr Brew, David S
Dr Donnelly, Laurance J *CGeol*
Mr Entwisle, David C
SO 7(S) Ms Glaves, Helen M
Mr Jones, Lee D *PGS C*
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AA 9(A) Mrs Meakin, Janet L

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Dr Barker, J A
Dr Bazley, R A B
Prof Bell FG
Mr Chisholm J I
Dr Downing, R A
Dr Gallois, R
Dr Howells, M F
Prof McCann, D M
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MINERALS, ENVIRONMENT AND GEOCHEMICAL SURVEYS

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PSec 8(A) Mrs Fairhurst, Kathe E

Minerals

Keyworth

Group Manager Grade 6
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PSec 8(A) Mrs Cordwell, Christine¶

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		Mr Colman, Tim *MIMM CEng*
		Dr Cooper, Derek C *CGeol*
		Mr Gunn, A Gus
		Mr Highley, David E *FGS CGeol MIMM CEng*
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		Mr Shaw, Mark H
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EO	7(A)	Miss Hillier, Janice A
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AO	8(A)	Miss Mills, Andrea J
		Miss White, Rebecca

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(Grd 7)	4(S)	Dr Scrivener, Richard C *FGS CGeol*

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		Mr Harrison, David J *MIMM*
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		Dr Metcalfe, Richard †
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		Dr Styles, Michael T *FGS CGeol*
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		Dr Naden, Jonathan
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		Mr Mitchell, Clive J *FGS*
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SO	7(S)	Dr Hards, Victoria L
		Mr Wetton, Paul D
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		Mr Fletcher, John
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		Dr Phillips, Emrys R
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Analytical and Regional Geochemistry

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		Mr Green, Philip M
		Dr Haslam, Henry W *MIMM*
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		Dr Jones, David G *CGeol*
		Mr Nicholson, Richard A *MRSC CChem*
		Dr Smith, Barry *MRSC CChem*
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		Dr Chenery, Simon R N *MRSC CChem*
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		Mr Ingham, Mark N
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		Mr Roberts, Philip D
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		Ms Fordyce, Fiona M
		Dr Gowing, Charles J B
		Dr Harrison Ian, *CChem, MRSC*
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		Mr Lister, T Robert
		Mr Mackenzie, Alan C
		Dr Rawlins, Barry G*
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		Mr Talbot, David K *MRSC CChem*
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SO	7(S)	Mr Blackwell, Paul A
		Mrs Green, Kay A¶
		Mr Robinson, Jonathan J
		Mr Strutt, Michael H
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		Mrs Baines, Rachael
		Mr Brettle, Charles
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		Mr Burden, Simon R
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		Mr Ferguson, Alex J
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SGB2	9(T)	Mrs Gardner, Amanda¶

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Fluid Processes & Waste Management

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		Dr Noy, David J
		Dr Ogilvy, Richard D *CPhys CGeol*
		Dr Shaw, Richard P *FGS CGeol, MIMM CEng*
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		Prof Williams, Geoffrey M *FGS CGeol*
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		Mr Dumpleton, Stephen *FGS CGeol*
		Dr Rochelle, Christopher A
		Dr Rogers, Stephen F *MIMM CEng*
		Mr Shedlock, Stephen L
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		Mr Meldrum, Philip I
		Mr Sen, Marcus A
		Mr Wealthall, Gary P*
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		Miss Moore, Yvette A
		Mr Trick, Julian K
		Ms Williams, Lorraine A
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NERC Isotope Geosciences Laboratory

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		Dr Spiro, Baruch F
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		Dr Leng, Melanie
HSO	6(S)	Mrs Chenery, Carolyn A
		Dr Kim, Alex
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		Dr Nowell, Geoff M
SO	7(S)	Miss Arrowsmith, Carol
		Miss Sloane, Hilary J
TEC 1	8(T)	Mr Wood, Adrian¶

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Mr Harris, P M
Mr Miles, D L
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PETROLEUM GEOLOGY, GEOPHYSICS & OFFSHORE SURVEYS

Murchison House

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Petroleum & Marine Geology

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		Mr Gatliff, Robert W *CGeol*
		Mr Graham, Colin C
		Mr Hitchen, Kenneth *FGS CGeol*
		Mr Holmes, Richard
		Mr Long, David *FGS CGeol*
		Mr McInnes, John L
		Dr Richards, Philip *FGS CGeol*
		Mr Ritchie, James D
		Mr Skinner, Alexander *FGS CGeol*
		Dr Stoker, Martyn S *FGS CGeol*
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		Mr Sankey, Michael J
		Mr Stevenson, Alan G
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		Dr Egerton, Paul D*
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Mr Smith, David J *IEEIE*
Mr Wallis, David G *MIEE CEng*

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Mr McGuigan, John
Mr Tulloch, Graham J
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Mr Derrick, John F
AO 8(A) Mrs Meadows, Julia A¶

Gilmerton

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Mr Smith, Kevin
Mrs Stoker, Susan J *FGS*
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Keyworth

(Grd 7) 4(S) Mr Tappin, David R

Loanhead

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Regional Geophysics

Keyworth

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Mr Greenwood, Peter G *FGS CGeol*
Mr Kimbell, Geoffrey S
Mr Peart, Roger J
Mr Rollin, Keith E
Mr Smith, Ian F
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Mr Pedley, Robert C
Mr Williamson, J Paul
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Mrs Kimbell, Sarah F ¶
Mr Kingdon, Andrew
Mr Raines, Michael G
Mr Royles, Christopher P
Mr Walker, Adrian S D
SO 7(S) Mrs Self, Suzanne J¶
ASO 8(S) Mr Morgan, David J R

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Global Seismology & Geomagnetism

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Dr Macbeth, Colin D
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Mr Flower, Simon M
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Dr Liu, Enru
Mr Lovell, John H
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Mr Fyfe, Charles J
Mr Harris, Theodore J
Mr Ohlsen, Frank
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HPTO 6(T) Mr Petrie, David
SO 7(S) Mr Dawes, Daniel
Mr Ford, Glenn D
Mr Galloway, David D
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Mr Owen, Roderick J
Mr Simpson, Bennett A
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Mr Millership, Peter
Mr Stewart, David A
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PTO 7(T) Mr Young, Robert M*

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PTO 7(T) Mr Gibson, George M
SGB2 9(T) Mrs Scott, Margaret¶
TEC 2 9(T) Mr Scott, William E

Hartland

PGS E 8(T) Mr Pringle, Colin R

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Basin Analysis & Stratigraphy

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Dr Lott, Graham K
Dr Molyneux, Stewart G
Mr Morton, Andrew C*
Dr Pharaoh, Timothy C *FGS CGeol*
Dr Riding, James B *FGS CGeol*
Mr Smith, Nigel J P *FGS CGeol*
Dr Warrington, Geoffrey *DSc FGS CGeol*
Dr Wilkinson, Ian P *FGS CGeol*
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Ms Hallsworth, Claire R¶*
Dr Jones, Neil S
Mr Rowley, W John
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Dr Williams, Mark
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Mr Woods, Mark A
SO 7(S) Mr Hulbert, Andrew G
ASO 8(S) Mrs Johnson, Kerry L
Miss Kyffin-Hughes, Jane E
Miss Shaw, Karen L
Mrs Taylor, Pauline

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Dr Cornwell, J D
Dr Owens, B
Dr Whittaker A

CORPORATE SERVICES & BUSINESS DEVELOPMENT

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PSec 8(A) Miss Oxby, Laura J

BGS International

Keyworth

Head BGS International Grade 6
3(S) Dr Reedman, Antony J *FGS CGeol*
PSec 8(A) Mrs Musson, Pamela S
Mrs Freeborough, Jacqueline¶
Mrs Evans, D Ann¶
Mrs Gibson, Sue¶
(Grd 7) 4(S) Dr McCourt, William J
Dr Greenbaum, David
Dr Piper, David P *FGS CGeol*
Dr Powell, John H *CGeol*
HSO 6(S) Mr Bate, David G
HEO 6(A) Mrs Hurley, C Mary
EO 7(A) Miss Haslam, Joanne
AO 8(A) Miss Mills, Charlotte C

Overseas Postings

(Grd 7) 4(S) Dr Aspden, John A
Dr Campbell, S Dairmad G*
Mr Mosley, Peter N
Mr Pitfield, Peter E J *FGS CGeol*
SSO 5(S) Dr Gonzalez Clavijo, Emilio
HSO 6(S) Mr Herd, Richard A
Dr Luckett, Richard

MINING ADVISOR TO DFID

(*Grd 6*) 3(S) Mr Walduck, Geoffrey P *FIMM CEng*

SECRETARY GENERAL, EUROGEO SURVEYS

(Grd 7) 4(S) Dr Annells, Richard N* *FIMM CEng*

Honorary Research Associate

Dr Cobbing, E J
Mr Evans, R B

UK Business Development

Keyworth

Group Manager Grade 6
3(S) Mr Ovadia, David* *MBCS CEng*
PSec 8(A) Mrs Drury, Janet A¶
(Grd 7) 4(S) Mr Brown, Malcolm J *MIMM CEng*
Mr Gatliff, R
Dr Holliday, Douglas W
Dr Piper, David P *FGS CGeol*
SSO 5(S) Dr Alexander, Jean *DipM MCIM*
IO 6(T) Mrs Heason, Hilary J *CAM MIPR*
AIO 7(T) Mrs Gutteridge, Linda

Wallingford

(Grd 7) 4(S) Mr Allen, David J *FGS CGeol*

Information Services

Keyworth

Group Manager Grade 6

	3(S)	Dr Dobinson, Alan
PSec	8(A)	Ms Heard, Tracey L

Collections Administration (Materials)

Keyworth

(Grd 7)	4(S)	Mr Hollyer, Stuart E
SO	7(S)	Mr Wheatley, Christopher W
AO	8(A)	Mrs Wright, June L
Tec 1	8(T)	Mr Bennett, David J
Tec 2	9(T)	Mr Naylor, Michael D
		Mr Renshaw, Scott
		Mr Stacey, Neil

Collections Administration (Documentary)

LIBRARY

Keyworth

PLib Grade 7(L)

	4(L)	Mr McKenna, Graham *ALA MIIS*
SLib	5(L)	Mrs Anderson, Jennifer E¶ *ALA*
Lib	6(L)	Miss Benson, Janet E *ALA*
		Miss Bird, Joan V *ALA*
		Mrs Fileman, Janet *ALA*
		Miss Hurst, Jennifer *ALA*
		Mr Prince, Stephen J *ALA*
AO	8(A)	Mrs Barkworth, Julia A¶
		Mrs Pattison, Joanne
		Mrs Langton, Louisa J¶
		Miss Self, Joanne J
		Mr Swift, Martyn C
SGB2	9(T)	Mrs Hodges, Sheila A
		Mr Holley, George C¶

Murchison House

Lib	6(L)	Mr McIntosh, Robert P
AO	8(A)	Mrs Gray, Gale E

RECORDS

Keyworth

HSO	6(S)	Mr Bowie, Roderick C
AO	8(A)	Mrs Blatherwick, Susan J
		Miss Booth, Joanne H
		Mrs Bridge, Geraldine
		Mr Davis, John J
		Miss Disney, Avril C
		Mrs Fitch, Lisa J
		Mr Newham, Wayne T
		Mrs Rippingale, Jayne
AA	9(A)	Mr Stocker, Joseph

Murchison House

SO	7(S)	Mr Gillanders, Richard J
AO	8(A)	Miss Dunlop, Alison
		Mrs Mann, Elizabeth¶
		Mr Smith, Matthew J
		Mr Swanney, Michael S

CUSTOMER SERVICES

Keyworth

SSO	5(S)	Ms Parnham, Jennifer J *ALA*¶
HSO	6(S)	Mr Clayton, Alan R
EO	7(A)	Mr Page, Ivan K
AO	8(A)	Mrs Boote, Deborah M
		Mrs Hackett, Tina P¶
		Mrs Harvey, Juliet M[S]
		Mr Haughton, Brian T
		Mrs Murray, Christina
		Mrs Oldham, Yvette J¶
		Mrs Smith, Kathleen G
		Mrs Wafforne, Paula
		Mrs Wiseman, Helen P¶
AA	9(A)	Mrs Boorman, Angela J¶
SGB1	8(T)	Mr Goodman, Stephen J
SGB2	9(T)	Mr Smith, Graham J

Murchison House

AO	8(A)	Mrs Moir, Wanda J
		Mrs Turnbull, Lesley

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SO	7(S)	Mrs Messenger, Vivienne *RS*
		Miss Tombleson, Clare M

Enquiries Officer

Keyworth

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DATABASE MANAGEMENT

Keyworth

SSO	5(S)	Dr Lowe, David J *FGS CGeol*
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		Mr Stirland, Karl C
ASO	8(S)	Miss West, Amanda R

Geospatial Information Systems

Keyworth

Group Manager Grade 6

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(Grd 7)	4(S)	Mr Giles, Jeremy R A *FGS CGeol*
		Dr O'Connor, Eugene A
SSO	5(S)	Mr Adlam, Keith A M
		Mr Cannell, Brian
		Dr Marsh, Stuart H
HSO	6(S)	Mr Baker, Garry R
		Mr Howcroft, John R
		Mr Jordan, Colm J
		Mr Riddick, Andrew T
		Mrs Wallwin, Sally¶
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		Mr Bell, Patrick D
		Miss Cotton, Claire
		Mr Marchant, Andrew P
		Mr Passmore, James H
ASO	8(S)	Mr Napier, Bruce
		Mr Weller, Alan
AO	8(A)	Miss Hart, Joy

Murchison House

(SSO	5(S)	Mr Robson, Peter G
		Mrs Kilpatrick, Karen M
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Overseas Posting

SSO	5(S)	Mr Killen, Anthony J*

Publication Services

Keyworth

Group Manager Grade 7

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BOOK PRODUCTION

SSO	5(S)	Dr Jackson, Audrey A¶
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GO	7(T)	Mrs Rayner, Deborah C
SM3	8(T)	Ms Evans, Jennifer B A
		Mr Minks, Adrian R
		Ms Norman, Jacqueline
		Mr Smedley, John B
Ty	9(A)	Miss Hill, Amanda J
		Miss Yarwood, Emmajane

CARTOGRAPHY

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		Miss Bray, Susan
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		Mr Murray, Christopher G
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		Mr Rayner, James I
		Mrs Scott, Elizabeth J¶
		Mrs Simpson, Caron
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		Mr Turner, Paul
		Mr Wardle, Christopher
		Mr Wilkinson, Ian J
		Miss Wood, Sophie E
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		Mrs Kmieciak, Jayne E
		Mr Tuggey, Graham J
		Mr Wilkinson, Stephen C

Overseas Posting

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Murchison House

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HMCO	6(M)	Mr Mennim, Keith C
		Mr Stewart, Alistair M
MCO	7(M)	Miss Anderson, Christina
		Miss Barclay, Joyce
		Mr Blenkinsop, Anthony
		Mrs Cherrie, Marjory M
		Mr Herbertson, Keith F
		Mr Horsburgh, Stuart W
		Mr Long, Roderick M
		Mr Meikle, John L
		Mrs Oliver, Lesley M
		Mr Ritchie, Calum
		Mrs Sanders, Carol J
		Mrs Wild, Sally A L¶
		Mr Wood, Gary R
MCTG1	8(M)	Mrs Carson, Christine E
		Mr Drennan, Eric P

PHOTOGRAPHY

Keyworth

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PhO	7(P)	Mr Cullen, Timothy P D S
PhT1	8(T)	Mrs Adkin, Caroline F
AA	9(A)	Mr Goddard, Mark A

Murchison House

HPhO	6(P)	Mr Bain, Thomas S M
PhO	7(P)	Mr MacTaggart, Fergus I

PUBLIC UNDERSTANDING OF SCIENCE

Keyworth

Grd 7	4(S)	Dr Litherland, Martin *FGS CGeol MIMM CEng*
SSO	*5(S)*	Dr Bailey, David E¶

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Training & Staff Development

Keyworth

Co-ordinator (Grd 7)

	4(S)	Dr Penn, Ian E *FGS CGeol*
AO	8(A)	Mrs Hale, Pamela I
Ty	9(A)	Mrs Hutchinson, Angela R

Honorary Research Associate

Dr Loudon, T V

Grade abbreviations

AA	Administrative Assistant
AIO	Assistant Information Officer
ALib	Assistant Librarian
AO	Administrative Officer
ASO	Assistant Scientific Officer
EO	Executive Officer
GO	Graphics Officer
GTG	Graphics Technical Grade
HEO	Higher Executive Officer
HMCO	Higher Mapping and Charting Officer
HPhO	Higher Photographic Officer
HPTO	Higher Professional and Technical Officer
HSO	Higher Scientific Officer
IO	Information Officer
Lib	Librarian
MCO	Mapping and Charting Officer
MCT	Mapping and Charting Technical Grade
Mess	Messenger
PGS	Process and General
PhO	Photographic Officer
PLib	Principal Librarian
PSec	Personal Secretary
PTM	Principal Technical Manager
PTO	Professional and Technical Officer
SEO	Senior Executive Officer
SG	Support Grade
SLib	Senior Librarian
SM	Support Manager
SMCO	Senior Mapping and Charting Officer
SMess	Senior Messenger
SO	Scientific Officer
SPSec	Senior Personal Secretary
SPTO	Senior Professional and Technical Officer
SSO	Senior Scientific Officer
StO	Stores Officer
Tech	Technical Grade
Tel	Telephonist
Ty	Typist

¶ Part-time
✯ Temporary promotion
✳ On unpaid leave

Appendix 6 Academic collaboration

The BGS collaborates with research institutes within the NERC and the other research councils. It also collaborates with other academic institutions in a worldwide network of research projects, which include contracted imput to the core programme and research and teaching arrangements. The following cover most examples:

Abdou Moumouni University (Niger): *GASPAL*

Aberdeen University: *Heavy mineral stratigraphy; Origin of the Rhynie cherts.*

Aberystwyth (University of Wales): *Quaternary of West Wales, and of Teifi Estuary; Geological mapping of Welshpool district; Land-ocean interactions; Abrupt Holocene arid intervals, Ethiopia; Calibration of a lacustrine record of climate change, Ethiopia; Hydrology, water quality and solute transport in subglacial environments, Norway; Intra- and inter-annual temperature and salinity measurements of the Quaternary Oceans; Late Quaternary climatic history, Argentina; Ostracod geochemistry as a record of Holocene climate change, Ethiopia; The inter-calibration of proxy indicators of late Holocene hydro-climatic change, Morocco; Volcanic evolution and stratigraphical significance of bentonites from the Silurian Welsh Basin*

Abo University, Finland: *Sulphur isotope systematics in peat*

Anglia Polytechnic University, Cambridge: *Quaternary of Glaven valley, Norfolk*

Athens University, Dept of Geophysics: *Tectonic early warning system*

Australian Geological Survey Organisation: *Zircon dating*

Australian National University (Canberra): *Geology and age of Lizard Complex*

Autonomous University of Yucatan (Mexico): *Impact of landfill leachate on groundwater quality*

Aviero University (Portugal): *PALAEAUX*

Avignon University (France): *PALAEAUX; GASPAL*

Bangalore University (India): *ARGOSS*

Bangor (University of Wales): *MSc teaching*

Barcelona University: *Anthropogenic inputs to the Llobregat River, Spain*

Bath University (Mining and Environment Network): *Small-scale gold mining*

Berne University (Switzerland): *PALAEAUX*

Binghampton University and Oak Ridge Laboratories (USA): *Secular changes in sea-water chemistry*

Birkbeck College (University of London): *Metamorphism studies, Kendal and Kirkby Lonsdale districts, and West Wales; Geology of Raasay; Land-ocean interactions; The lower crust of the Archaean Baltic Shield*

Birmingham University: *Palaeomagnetic study in Leicestershire; Stratigraphy and sedimentology, NE Greenland; Supervision and examination of PhD students; High-resolution stable isotope investigation of speleothems; Karstic capture of climatic chemical signals; Geology of copper and polymetallic deposits, Muster Basin, Ireland*

Bogazici University (Istanbul): *Westward drift, historical geomagnetic field data*

Bonn University (Germany): *FRACFLOW*

Bradford University: *Chemical composition of human juvenile teeth; Isotopic composition of human teeth as an indicator of ancient population dynamics; Investigation of anthropogenic zinc isotope fractionation*

Brighton University: *Provenance of tills of Norfolk; Chalk database; Stratigraphy of English Chalk; PhD supervision*

Bristol University: *3D resistivity inversion PhD project and in-house PhD; Seismic tomography and scattering; Volcanic hazard studies, Montserrat; Geochemistry of vertebrate fossils*

British Antarctic Survey: *Long-term changes in the solar terrestrial environment*

British Oceanographic Data Centre (BODC): *Marine environmental databases*

Brunel University: *Fault reactivation*

C A Diop University, Dakar (Senegal): *GASPAL*

Cambridge University: *Stratigraphy of the Kendal district; Fracture modelling; Vapour transport in Triassic Sandstone; Volcanic hazard studies, Montserrat; Hydrothermal alteration and geochemical fluxes in young oceanic crust; Stable isotope dendroclimatology; Biostratigraphy and palaeolimnology of lake marls; Biostratigraphy palaeoecology and geochemistry of a Quaternary lacustrine sequence, Greece; Formation of clear facies basal ice at Alpine glaciers*

Castellon University (Spain): *Potentially toxic elements in aerosols in an urban area*

Catalunya Polytechnic University (Spain): *PALAEAUX*

Centre of Geophysical and Geochemical Exploration, Tirana, Albania: *Tectonic early warning system*

Chiang Mai University (Thailand): *Impact of landfill leachate on groundwater quality; ARGOSS*

Coimbra University (Portugal): *Metallogenesis in Central Portugal*

Commission Internationale du Microflora Paleozoique: *Palaeozoic palynology*

Copenhagen University (Denmark): *TESZ research*

Coventry University: *Stable isotopes and luminescence in Holocene slug calcite.*

Czech Geological Survey: *TESZ research*

Derby University: *Bivalves as environmental monitors*

Dhaka University (Bangladesh): *Arsenic in groundwater; ARGOSS; Urban groundwater management*

Durham University: *CASE studentship on Lizard Complex; Tertiary Volcanic Districts Regional Guide; Stublick Fault Zone; Conodont biostratigraphy of the Crawford Group; Coal Measures of Plenmeller area, Northumberland; Biostratigraphy of Sea Sands Borehole, Cleveland; Estuarine evolution; Constraints on the source regions of kimberlites and lamproites; Mantle dynamics and subduction fluxes in the SW Pacific; Lu-Hf isotope system; Geochemistry and petrology of the Snaefell subglacial complex, Eastern Iceland; Borehole research*

East Anglia University: *CASE studentship on Lower Carboniferous palaeoclimatic and lake history; Permo-Trias and Triassic/Jurassic magnetostratigraphy; Estuarine geochemistry and coastal evolution; Seismic source mechanism determination*

Edinburgh Institute of Occupational Medicine: *Volcanic hazard studies, Montserrat*

Edinburgh University: *Quaternary sheet memoir contribution; Southern Uplands geochemistry and biostratigraphy; Estuarine evolution; Oersted magnetic survey satellite; Sea-bottom seismic data; Diagenetic fluids and reservoir cements (with SURRC)*

Ekaterinburg Institute of Geophysics, (Russia): *Uralides research*

Estonian Academy of Sciences: *PALAEAUX*

ETH Zürich (Switzerland): *Method development in laser ablation ICP-MS*

European Center for Research and Education in the Environmental Geosciences (CEREGE, France): *GASPAL*

Europrobe: *Co-ordination of pan-European tectonic project*

Exeter University: *Correlation of gas emissions with seismicity; Examiner Geology HND; Lecturing*

Faculty of Exact and Applied Sciences (Chad): *GASPAL*

Far East Geological Institute (Vladivostok, Russia): *Kamchatka hydrothermal areas*

Free University, Amsterdam (Netherlands): *PALAEAUX*

Gdansk Maritime Institute (Poland): *Marine monitoring methods and databases*

GeoForschungsZentrum (Germany): *TESZ research*

Geological Survey of Denmark and Greenland: *FRACFLOW; PALAEAUX.*

Geological Survey of Lithuania: *Gypsum subsidence*

Geology and Mines Commission, Guyana: *Small-scale gold mining*

Ghent Geological Institute (Belgium): *PALAEAUX; TESZ research*

Giessen University (Germany): *TESZ research*

Glasgow University: *Quaternary of north-east Scotland; Tertiary Volcanic Districts Regional Guide; Skye Central Complex; Timing of orogenic events, Scottish Highlands*

Gottingen University (Germany): *Evolution of brine chemistry and evaporite formation*

Granada University (Spain): *Uralides research*

Guelph University (Canada): *Quaternary and Permo-Triassic stratigraphy*

Hebrew University (Israel): *FRACFLOW*

Heidelberg University (Germany): *GASPAL*

Heriot-Watt University: *Geotechnical properties of tills in north-east Scotland; Use of Ground Penetrating Radar in turbidite successions; Advanced seismic methods*

Hull University: *Estuarine evolution; Adviser on Geochemistry Course*

INFRA-Instituto Technologico da Aeronautica-CTA (Brazil): *ARGOSS*

Institute de la Tierra 'Jaume Almera', Barcelona (Spain): *Uralides research*

International Centre for Diarrhoeal Disease Research, Dhaka (Bangladesh): *ARGOSS*

Imperial College (University of London): *PhD supervision; Mine waste; Sediment-hosted gold mineralisation, SW Guizhou, PRC*

Intermediate Technology Development Group, UK: *Small-scale gold mining*

Intermediate Technology Zimbabwe: *Small-scale gold mining*

Irish Marine Data Centre: *Marine environmental databases*

ITN-MPAT (Portugal): *PALAEAUX*

Karlsruhe University (Germany): *FRACFLOW; Uralides research*

Keele University: *CASE studentship, geochemistry of the Central Scottish*

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Highlands; Palaeozoic Amalgamation of Central Europe; Hydrochemistry and weathering fluxes in an Icelandic sandur: TESZ research

London (Kings College): *Modelling of carbon flux, Malham Tarn, N Yorkshire; Environmental proxies in Holocene sediments and speleothems, Malham Tarn; Stable isotope characterisitics of calcite and its palaeoenviromnetal applications*

Kingston University (Canada): *Dating of slates in SW England*

Kingston University (UK): *Visiting professor; Palaeoenvironmental reconstruction of Holocene environmental change, Mexico; Silicic magmatism in continental breakup; Ostracod shell chemistry in palaeoclimatic reconstruction*

Kernfysisch Versneller Instituut (KVI) Groningen: *Environmental radioactivity*

Lampeter (University of Wales): *Quaternary palynology of NE Scotland*

Lancaster University: *Volcano monitoring; Examiner; Oxygen isotope analysis of lacustrine diatoms*

Leeds University: *MSc project supervision; Historical geomagnetic field data; Volcano monitoring; Leaching behaviour of fly ash from incineration; Determination of 18O in silicate and oxide phases by laser-assisted fluorination; Geomorphic, isotopic and sedimentological signatures of glacier surging; Tectonic influence on magmatic evolution and alteration of crustal and mantle rocks; External examiner*

Leicester University: *Geophysical studies of E Midlands; Monazite in the Southern Uplands; CASE studentship on Carboniferous sedimentology; Sedimentology and industrial minerals; Palaeozoic stratigraphy/biostratigraphy; Fine-scale petrophysical studies; Investigating faulting through modelling dipmeter data; Crustal structure; MSc projects; Techniques to detect halobacteria and halobacteria DNA in salt deposits; Anabar Shield anorthosite complex, Siberia; Geological controls on a new geochronometer: Sm-Nd and U-Pb systematics of authigenic monazite; Diagenetic evolution of concretionary carbonates and sulphates in the Oxford Clay; Grenvillian eclogites, NW Scotland; Intrusive activity at the Escondida and Zaldivar porphyry Cu deposits, Chile; Plume-related magmatism, Gobi Desert; Geochemistry of the deep crust beneath the Andes; Isotopic characterisation of plume components; Palaeoproterozoic magmatism, SW Sweden; Petrogenesis of the Trans-Scandinavian Igneous Belt; Petrogenesis of dyke swarms, Nain Plutonic Suite, Labrador; Effect of chemical exchange on closure temperature in isotopic systems; Generation of primitive continental crust; Borehole research*

Leiden University Rijksherbarium, Netherlands: *Limestone resources*

Lithuanian Institute of Geology: *Marine monitoring methods*

Liverpool John Moores University: *Quaternary of Nithsdale*

Liverpool University: *Study of the Millstone Grit; Ordovician stratigraphy; Unst-Fetlar Memoir; Guide to Glen Coe; Tertiary dykes of S Scotland and N England; Namurian sequence stratigraphy; Estuarine evolution and contamination; PhD supervision; Visiting professor; Regional palaeoclimate reconstruction, W Greenland; Tertiary dykes in the Southern Uplands*

London School of Hygiene and Tropical Medicine: *Wastewater reuse, Mexico*

Loughborough University: *Extraction technique for solid-phase partitioning of trace metals in soils; Chemistry of aqueous leachate solutions of an Opalinus Marl sample; Ultra-high resolution hydro-climatic change, Eski Acigol, Turkey; Late Quaternary palaeoclimates and paraeoenvironments, Turkey; Examiner*

Maiduguri University, Borno State (Nigeria): *GASPAL*

Makerere University, Kampala (Uganda): *ARGOSS*

Manchester University: *Schiehallion (Sheet 55W) map and memoir; Mantle sources of extreme isotopic heterogeneity, Sierra Leone; Enclave-host relations in Scottish granitoids*

Ministry of Natural Resources of the Russian Federation, Moscow: *Tectonic early warning system*

Moscow Institute of Physics of the Earth, (Russia): *Uralides research*

Nancy University (France): *Developments in laser ablation analysis*

Natal University (South Africa): *Engineering geology and geotechnical properties*

National Survey for Seismic Protection, Yerevan, Armenia: *Tectonic early warning system*

Natural History Museum (London): *Ordovician ostracodes in N Britain; Isotope variations in Sri Lankan land snail; Fossil vent fauna associated with volcanogenic massive sulphides, S Urals; Role of organic matter in the formation of the Lahoca-Recsk Cu-Au-S deposit; Fluid sources and interactions in high-sulphidation epithermal mineralisation, Bor, Yugoslavia*

Newcastle University: *Evaporite subsidence; Estuarine evolution; Engineering geological mapping*

Nottingham Trent University: *Gypsum subsidence and karst; Engineering behaviour of brickearth/loess; Visiting professor; MSc and MPhys student projects in environmental radioactivity; Risk assessment of contaminated soils; Course provider in Contaminated Land Management MSc*

Nottingham University: *Local history; InSAR data inputs and outputs, geological and topographic survey, data, reporting; Visiting professor; Dissolution of zeolite minerals; Indigenous tree species in tropical agroforestry systems; Mineralogy and geochemistry of canal muds*

Open University: *Lithosphere generation in the South American mantle; PhD supervision*

Oslo University (Norway): *Uralides research*

Osservatorio Vesuviano, Naples: *Aeolian Islands*

Oxford University: *Stratigraphy of the Kimmeridge Clay, Dorset; Magnetic field in the Earth's core; Copper and tin isotopes in geoarchaeology; Crustal melt granites of W Himalayas; H/D ratios in collagen; Exhumation of the Menderes Massif, W Anatolia; Metamorphism and melting, Karakoram Range, N Pakistan*

Oxford Brookes University: *Surveying in the N Highlands; Structure of the Isle of Man*

Pacific Institute of Geography, Vladivostok (Russia): *Kamchatka hydrothermal areas*

Paris-Sud University (France): *PALAEAUX*

Petropavlovsk Institute of Volcanology (Russia): *Kamchatka hydrothermal areas*

Plymouth University: *Engineering geological mapping; PhD supervision student; Application of chemometrics to geochemical data; Uranium series nuclides*

Polish Academy of Sciences: *TESZ research*

Polish Geological Institute: *Marine monitoring methods; TESZ research*

Portsmouth University: *Silurian biostratigraphy in the Southern Uplands; Tertiary of the Isle of Wight; Examiner*

Proudman Oceanographic Laboratory (POL): *Continental shelf transport*

Queens University (Belfast): *Shear zones in the Highlands; Movement of contaminated groundwater; Professorship; Geophysical surveys, Grampian region*

Queens University (Canada): *The Lizard Complex*

Reading University: *Geophysical log correlations in the Upper Jurassic; Fracture characterisation in the Chalk aquifer; Examiner MSc in Hydrogeology and hydrochemistry; MSc course teaching; Selenium in sedimentary environments; Atmospheric deposition of Pb, S and N in England and Wales*

Rio Cuarto National University (Argentina): *ARGOSS*

Royal Institute of Technology, Stockholm (Sweden): *ARGOSS*

Royal Holloway (University of London): *Quaternary of East Anglia; Isotope studies, Borrowdale Volcanic Group; Lecturing; Hafnium characterisation of the Icelandic plume source*

Russian Academy of Sciences: *Stratigraphy/biostratigraphy*

St. Andrews University: *Magnetic signatures of glaciogenic sequences; Sequence stratigraphy, Lower Carboniferous; Sr isotopic ratio in apatite from Silurian Bentonites of N Europe; 'Torridonian' Palaeogeographies in the N Atlantic region*

Scottish Association for Marine Science (SAMS): *Sensitivities of cold water corals and other large benthic fauna in relation to oil/gas activities W of Scotland*

Sheffield University: *Tertiary sediments, London Basin; Stratigraphy of the Kendal district; Biostratigraphy; Engineering geology and geotechnics; Induced Polarisation Tomography; Non-aqueous phase liquids; Attenuation of organics in groundwater; Organic contamination in the Sherwood Sandstone of the West Midlands; Climatic change and anthropogenic impact, central Mexico; Crop storage practices in the Greek Bronze age; Professorship; Lecturing; Hydrogeology course provider; PhD examiner*

Southampton University: *Devonian biostratigraphy of Orkney; Zircon geochronology and geochemistry of Zimbabwean Archaean granitoids; Zircon geochronology of a Precambrian megacrystic granite suite, Sierra Leone*

Surrey University (Robens Centre for Public and Environmental Health): *ARGOSS; Microbiological contaminants in groundwater*

Swansea (University of Wales): *Strontium, oxygen and carbon isotopes in Late Quaternary biogenic carbonates, Wallywash Great Pond, Jamaica*

TNO Netherlands Institute of Applied Geoscience (Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek): *Marine monitoring methods*

Trinity College Dublin (Ireland): *Kamchatka hydrothermal areas*

Tubingen University (Germany): *Evaporite subsidence*

Turin University (Italy): *GASPAL*

Scottish Universities Research and Reactor Centre (SURRC): *Radiometric dating of Midland Valley rocks*

Udine University (Italy): *Uralides research*

Ukraine Academy of Science: *Evaporite subsidence; Carboniferous stratigraphy/biostratigraphy*

United Schmidt Institute of Physics of the Earth, Moscow (Russia): *Tectonic early warning system*

University College (London): *Environmental change; Palaeohydrology in China; Flow in low permeability rocks; Porosity development in aquifers; PhD supervisor*

University College, Galway (Ireland): *Rockall Trough*

University of Science and Technology (Ghana): *ARGOSS*

Uppsala University (Sweden): *Uralides research*

Vernadsky Institute of Geochemistry, Moscow (Russia): *Tectonic early warning system*

Wageningen University (Netherlands): *Examiner*

West Indies University: *Landslide hazard*

Wroclaw University (Poland): *TESZ research*

York University: *Electrical tomography*

Zaragoza University (Spain): *Evaporite subsidence*

Appendix 7 Business collaboration

COLLABORATION WITH UK AND INTERNATIONAL INDUSTRIES

The BGS maintains a wide range of links with industry. These involve co-funded projects, technology partnerships, strategic business alliances and advisory groups. The following include most of the companies who collaborated:

- ABEM Instrument (Sweden)
- AEA Technology plc, Harwell
- Allied Associates Geophysical Ltd.
- Amerada Hess
- Anglesey Mining PLC
- ARK Geophysics
- Associated British Ports
- BBC
- BG plc
- BG Exploration and Production Ltd
- BG Technology plc
- Binnie, Black & Veatch
- BP Amoco
- British Petroleum
- British Antarctic Survey
- British Stone
- Building Research Establishment Ltd
- Centre for Environment, Fisheries and Aquaculture Science
- CIRIA
- CMTC Environmental
- Coal Authority
- Conoco
- DEMAS dredging consultants bv
- Defence Evaluation Research Agency
- English China Clays
- Enterprise
- Esso
- Euroconsult (Holland)
- European Union
- Exxon
- Fugro-Geoteam
- GeoMentor, Athens
- Geotek
- Geoterrex
- GROTA Hydrogeological Company, Lithuania
- Halcrow Maritime
- Historic Scotland
- Hydraulics Research, Wallingford
- Hydrocarbon Management International
- Hydrographic Office
- ICI
- ICI Chemicals & Polymers Ltd
- Informatic Management International
- Joint Stock Company Ecogeya, Moscow
- Joynes Pike and Associates Limited, Doncaster
- Land Use Consultants
- Lasmo, Enterprise, Core Laboratories
- London Underground Ltd
- Marathon Oil
- Marine Information Service, The Netherlands
- Marconi Electronic Systems Ltd
- Matra Marconi Space
- National Radiological Protection Board
- National Remote Sensing Centre Ltd.
- Niedersächsisches Landesamt für Bodenforschung (Germany)
- Norwegian University of Science and Technology
- Petroleum Exploration Computer Consultants
- Petroleum Open Software Corporation (POSC)
- Plymouth Marine Laboratory
- Poseidon Geophysics (Pty) Ltd
- Rail Link Engineering
- Royal Institute of British Architects
- Saga
- Schlumberger Geco-Prakla
- Scottish Natural heritage
- Shell
- Shell UK Exploration and Production
- Southern Water
- Sperry Sun Drilling Services
- Statens Kartverk (Norway)
- Trinity House
- Thames Water Utilities
- Western Geophysical
- World Geoscience

CLIENT LIST

UK Government organisations

- Aberystwyth University
- Atomic Weapons Establishment
- Ayrshire Joint Structure
- BBC TV
- British Antarctic Survey
- British Council
- British Waterways
- Calderdale District Council
- Coal Authority
- Countryside Commission
- Cumbria County Council
- Darlington District Council
- Defence Evaluation and Research Agency
- Department of Economic Development, Northern Ireland
- Department of the Environment, Transport and Regions
- – Building Regulations Division
- – Marine, Land and Liability Division
- – Minerals and Waste Planning Division
- – Radioactive Substances Divison
- Department for International Development
- Department of Trade and Industry
- – Metals, minerals and Shipbuilding Directorate
- Diocese of Southwell Advisory Committee for the Care of Churches
- Dorset County Council
- Drinking Water Inspectorate
- English Nature
- Environment Agency
- Essex County Council Planning
- European Union
- Foreign and Commonwealth Office
- Forfar Council, Department of Roads
- Harrogate District Council
- Health and Safety Executive
- Historic Scotland
- Hydrographic Office
- London Borough of Hounslow
- London Underground
- Maldon District Council
- Ministry of Agriculture, Fisheries and Food
- Ministry of Defence
- National Grid
- Newcastle University
- Northamptonshire County Council
- Northumberland County Council
- Nuclear Installations Inspectorate
- Ordnance Survey
- Orkney Islands Council
- Perth and Kinross Council
- Purbeck District Council
- Scottish Environment Protection Agency
- Scottish Natural Heritage
- Scottish Office
- Sheffield Hallam University
- SOAEFD
- Welsh Office

International and foreign organisations

- ACSAD (Damascus)
- ANDRA (France)
- Bagnoli SpA, Naples (Italy)
- Commission of the European Community
- CSIRO, Marine Research Division (Australia)
- Department of Mining and Petroleum, Papua New Guinea
- European Union
- Falklands Islands Government
- Gandil Mining Co, Khartoum, Sudan
- Geotechnical Engineering Office, Hong Kong.
- Hanson Aggregates Marine Ltd
- Hong Kong Observatory
- IAGC Working Group in Water Rock Interaction
- Irish Government Petroleum Affairs Department
- Government of Botswana
- GRS (Germany)
- HMCT Ltd/Ulrich Lutat
- Hosokawa Micron Ltd
- Hyundai Construction Co Ltd
- IMC Mackay & Schnellmann
- International Atomic Energy Agency
- Korea Institute of Geology, Mining and Materials
- Mevior S A (Greece)
- NAGRA (Switzerland)
- Namibia Geological Survey
- Namibia National Oil Corporation (NAMCOR)
- Nuclear Energy Agency (France)
- Norwegian Crystallites
- Petroleum Affairs Department (Republic of Ireland)
- Petroleum and Energy Division, Papua New Guinea
- Philips Analytical
- PNC
- Radiological Protection Institute of Ireland
- SCK/CNRS (Belgium)
- Setsco Singapore
- SINTEF Civil and Environmental Engineering (Norway)
- SKB
- South Pacific Geoscience Commission (SOPAC)
- Suriname University
- Terralogica AB (Sweden)
- UNESCO
- UNICEF
- UN Comprehensive Test Ban Treaty Organisation
- US Navy
- USGS
- US Environmental Protection Agency

- World Bank
- World Health Organization

Industry

- Adam Bench Architects
- AEA Technology Plc
- AGIP
- Agip UK
- Alan Wahlers (Architect)
- Amerada Hess
- Amerada Hess UK
- Amoco
- Amoco (UK) Exploration
- Anglian Water
- Anglian Water Services Ltd
- Aoki Soletanche
- ARC Central
- Arco
- ARCO International
- Aspen Burrow Crocker Ltd
- Baker Hughes INTEQ
- Bass Brewers Ltd
- BEB
- Belinda Eade Studios
- BG Exploration and Production Ltd
- BG plc
- BGS Rockall Consortium
- Block Stone Ltd
- Bolehill Quarry
- BP
- BP/Amoco
- BPB
- BPB Gypsum
- BP/Conoco
- BP Exploration
- Bridgewater Paper Company
- Bristol Water
- British Borneo
- British Gypsum Ltd,.
- British Nuclear Fuels plc
- Britsurvey
- Cadwraeth Cymru
- Cadwyn Leader II
- Camborne School of Mines
- Cambridge Minerals Ltd
- Campbell & Arnott Ltd, Leith
- Chevron
- City Analytical Services plc
- Cleveland Potash
- Conoco
- Conoco UK
- Crediton Minerals Ltd
- Cuthbertson Environmental Ltd
- D Tydesley Associates
- Dames & Moore
- Delta Civil Engineering Co Ltd
- Deminex
- Deminex UK Oil and Gas
- Desire Petroleum
- Devonport Management Ltd
- Doyle Partnership
- Druck
- Dunelm Drilling Ltd
- Dynamic Earth
- EA Technology
- East Coast Slag Products Ltd
- East Midlands Electricity
- Edinburgh Petroleum Services
- Elf
- Elf Enterprise Caledonia
- Elf Exploration UK
- Ellis Williams Architects
- Enterprise Oil
- Enterprise UK Ltd.
- Envirotreat
- Erindale Products Ltd
- Esso Exploration and Production UK
- Exploration Associates
- Falkland Islands Government
- Fife Silica Sands Ltd
- Fina
- Fina Exploration
- Fordamin Minerals
- Fosroc International Ltd
- Foster Yeoman Quarries
- Fugro
- Fugro-Geoteam
- Fugro UK Ltd
- GEM Services Ltd
- GeoExploration (Italy)
- Geophysical Services International (UK) Ltd
- Geoscience
- Gibb Ltd
- Golder Associates
- Grundon
- GU Projects
- H B Boring & Co Ltd
- Halcrow Waterman
- Halliburton Energy Services
- Harper Collins Publishers Ltd
- HMC Technology
- Ifipco (Greece)
- Industrial Minerals
- International Mining Consultants Ltd (IMCL)
- International Petroleum Corporation
- Irish Petroleum Infrastructure Programme
- Irongate Ventures Ltd
- J F Stephen (architects) Angus
- J R Marble
- Janus Design Consultants
- Jersey Public Services dept
- Joynes Pike & Associates (JPA) Ltd
- Kerr McGee Oil and Gas
- Kirkstone Quarries Ltd
- Lafarge Redland Aggregates Ltd
- Landmark
- Lasmo plc
- Linford-Bridgeman Limited
- Lundin Oil AB
- Maersk Drilling
- Magnox Electric plc
- MAI
- Mandoval Ltd
- Mercia
- Metal Bulletin plc
- Mid-Kent Water
- Mineral Solutions Ltd
- MMD
- Mobil
- Mobil North Sea
- Mott McDonald
- Mount Terri Consortium
- MRDA Architects and Conservation Consultants
- Murphy Petroleum
- NAM (Nederlandse Aardoliemaatschappij)
- National Grid Company
- National Power
- Nicholls and Baxter
- Nirex
- Norsk Hydro ASA
- Norske Conoco
- Norwest Holst Soil Engineering Ltd
- Nuclear Electric plc
- Nuclear Installations Inspectorate
- Onyx UK Ltd
- Oryx
- Palace Riding School, Hamilton
- Petroleum Development Oman
- PGS
- Philips Analytical
- Phillips Petroleum
- Pinnacle Consulting Engineers
- Portsmouth Water
- Powergen
- Preussag
- Quaternary TL Surveys
- Rackwood Colliery
- Ranger Oil
- RedRock Associates Ltd
- Rio Tinto Technology Development Ltd
- Roseward
- Roxburgh & Partners
- Rugby Cement
- Rutter Johnson Partnership
- RWE-DEA
- Saga Petroleum ASA
- Saudi Arabian Oil Company
- Schlumberger
- Schlumberger Geco-Prakla
- Scot Wilson Railways
- Scott Wilson Pavement Engineering Ltd,
- Scottish Coal
- Scottish Hydro-Electric plc
- Scottish Nuclear Ltd
- Scottish Power
- Severn Trent Water
- Shaw Whitmore Fyffe
- Shell
- Shell Exploration and Production
- Shell Norway
- Shell Research Ltd
- Shell UK
- Silver & Baryte Ores Mining Co
- SOCAR
- Soil Mechanics
- Solmek Ltd
- Southern Water
- Sperry Sun Drilling Services
- SRS Ltd
- Statoil
- Statoil Exploration UK
- Steffen, Robertson and Kirsten
- Stone Brokers
- Subsurface Midlands
- Sutton and East Surrey Water
- Svedala Ltd
- Sysdrill
- Talisman
- Talisman Energy
- Tarmac Roadstone
- Teikoku Oil Co
- Terradat (UK) Ltd
- Texaco
- Thames Water
- Thermal Syndicate Ltd
- Tilcon Ltd, Buxton
- Total
- Total Oil Marine plc
- UK Water Industry Research Ltd
- Ultra Electronics (Magnetics Division)
- Union Texas
- United Utilities
- Veritas
- Wardell Armstrong
- Water Management Consultants
- Water Research Centre
- Waterman BBT
- Wessex Water
- West Lakes Research Institute
- W-H Energy Services
- Whitbread
- Yorkshire Water plc
- Zenith Projects

Appendix 8 Committees

- AAPG International Conference 1999 Birmingham: *Organising Committee and Field Trip (Chairman)*
- Association of Geoscientists for International Development: *Secretary General*
- Atomic Spectrometry Updates: *Editorial Board of Journal of Analytical • Atomic Spectrometry*
- British Micropalaeontological Society
- Camborne School of Mines Industrial Geology Liaison Panel
- CBI Minerals Committee
- CIRIA Steering Group for remediation of VOC contamination.
- Cogeoenvironment: *Corresponding Fellow*
- Commission for the Geological map of the World: *UK Representative*
- Cooperating Countries Advisory Group, CCOP: *Chairman*
- Cooperation in Science and Technology Action 2000: *Karst vulnerability; International boundaries*
- Devonshire Association
- Dorset Coast Forum
- DTI committee on setting criteria for sustainable development—*Waste*
- East Midlands Geological Society: *Council*
- Edinburgh Geological Society: *Excursion Secretary; Treasurer ;* Publications Committee Chairman and Member
- Environment Council: *Councillor*
- Environmental and Engineering Geophysics Society (Europe): *Board Member and UK National Representative*
- Environmental Diagnostics: *Steering Group*
- Environmental Research Institute of Michigan's Applied Geologic Remote Sensing Conference Series: *Member of Executive Committee*
- EPSRC Steering Committee for Waste and Pollution Management
- EuroGeoSurveys: *Mineral Resources Topic Network; Urban Geology Topic Network; Remote Sensing Topic Network, Technical Secretary*
- European Journal of Environmental and Engineering Geophysics: *Editor-in-Chief, Editorial Board*
- European Marine Sand and Gravel Group
- European Seismological Commission: *various Working Groups*
- Extractive Industry Geology 2000: *Organising Committee*
- Fife Biodiversity Group
- FOREGS Task Group on Geochemical Inventory of Europe: *UK Representative*
- Forth Estuary Forum
- Geological Society of London: *Borehole Research Group, Treasurer;*
- *Conservation Commission Member; Environmental Group, Chairman; Environmental & Industrial Geophysics Group; Geological Remote Sensing Group, Chairman; Hydrogeological Group; Marine Studies Group, Secretary; Petroleum Group, Secretary; Publications Committee; Stratigraphy Commission; Working Group on Women in Geology*
- Geological Society/Quaternary Research Association Joint Association for Quaternary Research
- Geoscience 2000: *Convenors*
- History Scotland Scottish Stone Liaison Committee
- IEH, Leicester University: *Steering Group on Environmental sampling after a chemical accident*
- Institution of Mining and Metallurgy, Applied Earth Science: *Editoral Board*
- Inter-Governmental Coordinating Committee for Coastal and Offshore Programmes in East and South East Asia (CCOP): *UK Representative*
- International Association of Geoanalysts: *Executive committee*
- International Association of Geomagnetism and Aeronomy: *Executive Committee and various Working Groups*
- International Association of Hydrogeologists Commission on Groundwater Protection
- International Association of Seismology and Physics of the Earth's Interior: *various Working Groups*
- International Consultative Group on Non-Ferrous Metal Statistics
- International Council for Exploration of the Sea: *Working Group*
- International Geological Correlation Programme (UNESCO/IUGS): *Project No. 418, The Kibaran of South-west Africa*
- International Standards Organisation Technical Committee TC 202
- International Strategic Minerals Issues
- International Subcommissions on: *Carboniferous Stratigraphy; Jurassic Stratigraphy; Triassic Stratigraphy*
- International Working Group on Urban Geology
- IUGS Working Group on Global Geochemical baselines: *Co-Chairman*
- Jurassic Coast World Heritage Site Committee
- Mining Association of the United Kingdom
- Midlands Microanalysis Users Group: *Chairman*
- Mineralogical Society: *Trustees; Applied Mineralogy Group; Clay Minerals Group, Chairman and Committee*
- Mineral Industries Research Organisation: *Council, Research Executive*
- Nansen Arctic Drilling
- National Stone Centre, Council
- NERC Coordinating Group on Environmental Radioactivity
- NERC Steering Committees: Airborne Remote Sensing Facility: *Environmental Diagnostics; Equipment Pool for Field Spectroscopy; Micro to Macro; Radiocarbon Facilities*
- NERC–MRC liaison on Environmental Geochemistry and Health initiatives
- North Pennines Heritage Trust: *Trustee and Director*
- Nuclear Energy Agency of the OECD: *Working Group on measurement and understanding of groundwater circulation in clay formations*
- Ocean Drilling Programme: *Technical Committee (Chairman); UK Steering Committee*
- Oersted: *International Science Team; Science Advisory Committee*
- OST Natural Resources and Environment Foresight Challenge Panel.
- Palaeontographical Society
- Palaeontological Association
- Parliamentary Minerals Group
- Quarterly Jounral of Engineering Geology: *Assistant Scientific Editor (Hydrogeology)*
- Quaternary Research Association
- RIGS Groups: *Fife, Chairman; Tayside; Lothian and Borders, Chairman; Northumberland, Co-ordinator*
- Royal Astronomical Society: *Vice President and Council*
- Royal Society of Edinburgh: *Executive Editor*
- Russell Society: *President*
- Scot Lis Council
- Scottish Journal of Geology: *Editorial Board*
- Society for Underwater Technology: *Offshore Site Investigation and Geotechnics Committee, Secretary; Education and Training Committee; Research and Technology Policy Committee*
- Standing Committee of Analysts: *Panel 6.3 Pesticides*
- Technical Advisory Group (SOPAC): *Chairman*
- Third Expert Group on Cryptosporidium in Water Supplies (Bouchier committee): *Groundwater Subcommittee*
- UK Groundwater Forum: *Secretariat*
- UK Minerals '98: *Organising committee*
- URGENT: *Data Management and Quality Assurance Committee; Steering Group*
- US–Japanese Advanced Space-borne Thermal Emission and Reflectance Radiometer: *Science Team*
- Ussher Society
- Yorkshire Geological Society: *Council Members, Editorial Board*

Appendix 9 Core Strategic Programme Achievements

At its meeting on 18 May 1999 the BGS Board was presented with a review of the 1998/99 Core Strategic Programme; a summary of its achievements follows:

ONSHORE AND GEOPHYSICAL SURVEYS

A1 — Multidisciplinary Regional Surveys

- 4593 km^2 resurveyed and revised.
- 150 1:10 000 standards (of which 4 are digital) approved for release.
- 59 technical reports written.
- 17 1:50 000 sheet delivered to the Drawing Office.
- 2 memoirs approved by Director; 2 with editors.
- The first 2 sheet explanations approved by Director.
- 15 boreholes drilled by BGS rig, with a total length drilled of 628 m.

Co-funded Projects

- All draft maps and the report for the Afon Teifi area of west Wales sent to the consortia of local authorities for approval; Pembrokeshire CC have approved.
- Preliminary draft text completed for Precambrian GCR volume and sent to JNCC by March 1 deadline.
- Carboniferous-Permian Igneous GCR volume work ongoing.
- Dalradian GCR volume contract awarded by JNCC.
- Mull booklet text and figures submitted to SNH for publication.

A2 — Continuous Revision

Data Acquisition and Map Revision, Scotland and Northern England

- 170m of core from BGS boreholes examined, 45 commercial boreholes examined and data incorporated in correction copies.
- 80 new 'correction copy 10K and 25K maps registered.
- Information gathered from 20 temporary sections added to Correction Copy map set.
- 2300 mine entries digitised from BGS published maps and incorporated in shafts database.
- 5500 records from former or active quarries captured and entered in Access database.

Data Acquisition and Map Revision, Central England and Wales

- Yorkshire coalfield work continues; two 1:10 000 standards approved for complex opencasted areas of Barnsley district.

Data Acquisition and Map Revision, Southern and Eastern England

- Revision of N London 10K maps complete.
- 800 new borehole logs added to London database.

Digital Mapping Development

- DMCS – Prototype digital map compilation system trialled in eight project areas by Land Survey geologists; 18 10K maps at proof stage, 12 ongoing.
- Microstation Field entry mapping system - report on field trials completed; general reaction unfavourable.
- Development of prototype system for delimiting areas of possible undermining from borehole data.
- Version 1 of Section Database completed.
- Automated enquiry answering service (ALGI) functional and operating for Bristol and London areas (in conjunction with commercial ALGI project).

A3 — Database Support

Database and Computing Support

- Glasgow Project – Data transfer protocol developed for Earthvision to Mapinfo.
- Updates to FOSSLOCS, GSE and Field Notebooks databases.
- Programme developed for generating generic geological reports for enquiries etc.
- Work to build an ArcView-based graphic log generator from corporate borehole logs.
- Support for Land Survey through Help Desk and awareness sessions.

Onshore Geological Surveys University Contracts

- *Aberystwyth University*
  - Dr R Whittington is to investigate the Quaternary fill of the Teifi estuary.
  - Dr M Hambrey is studying Quaternary glacial facies in West Wales.
  - Dr R Cave has begun reconnaissance mapping of the Welshpool sheet.
- *Anglia Polytechnic University, Cambridge* – Dr P Hoare is analysing Pleistocene deposits in Norfolk.
- *Australian National University (Canberra)* – Prof D H Green is SHRIMP dating rocks from the Lizard Complex.
- *Birkbeck College* – Dr B Roberts has submitted a draft isocryst map for the Cardigan (193) and Llangranog (194) 1:50k sheets.
- *Birmingham University* – Dr P E Turner completed a preliminary palaeomagnetic investigation of the Precambrian/Cambrian unconformity in Leicestershire.
- *Brighton University*
  - Dr C Whiteman is drafting a paper on the provenance of tills in Norfolk.
  - Prof R Mortimore's chalk database is well advanced.
- *Durham University*
  - CASE studentship on the lower crustal rocks of the Lizard Complex.
  - Dr C H Emeleus has completed a draft of the Tertiary Regional Guide.
  - Dr B Turner has submitted a report on the Stublick fault zone.
  - Dr H Armstrong is working on the conodont biostratigraphy of the Crawford Group.
- *East Anglia University* – Dr M Hounslow has submitted a report on the magnetostratigraphy of the Permo-Trias rocks of Devon. A second project will commence in May.
- *Edinburgh University*
  - Dr A M Hall has submitted a contribution to the NE Quaternary memoir.
  - Dr G Fitton has made a preliminary inter pretation of the geochemistry of lavas in the Southern Uplands.
  - Dr E Clarkson is preparing a final report on S. Uplands biostratigraphy.
  - Dr S Rigby has completed initial work on biostratigraphy of S. Uplands.
- *Glasgow University* – Dr G Tanner has submitted all of the maps and an explanatory report for the Highland Border Complex.
- *Kingston University (Canada)* – Prof A Clark is Ar/Ar dating slates from SW England.
- *Leicester University*
  - Dr I Hill has completed his geophysical interpretations of the Charnian/Triassic unconformity and is currently drafting a paper.
  - Dr J Zalasiewicz is studying authigenic monazite nodules in S. Uplands.
- *Liverpool University*
  - PhD project on the Millstone Grit of northern England making progress.
  - Dr P Brenchley is to investigate Ashgill glacio-regressive sequences.
  - Dr D Flinn is making progress with the Unst-Fetlar sheet memoir.
  - Dr Kokelaar has delivered the revised draft of the guide to Glen Coe.
  - Dr P Dagley is making progress with the study of Tertiary dykes.
- *Oxford Brookes* – Dr R Strachan has completed on schedule sheet 108E (Loch Naver) and is progressing with sheet 108E (Kildonan).
- *Portsmouth University* – Dr D Loydell is making satisfactory progress with the Llandovery biostratigraphy of the Southern Uplands.
- *Queens University (Belfast)* – Dr G Leslie has submitted a report on shear zones in the Highlands.
- *Royal Holloway, University of London*
  - Prof J Rose has completed several papers on the provenance of Pleistocene sands and gravels in East Anglia.
  - Dr M Thirlwall has completed on schedule isotopic work on the Borrowdale Volcanic Group.

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- *Sheffield University*
  - Dr D Jolley's palynological study of the Middle Eocene sediments of the London Basin is well advanced.
  - Dr J Soper has completed work on the Kendal sheet on schedule.
- St. Andrews University – Dr J Walden has submitted a report on the magnetic signatures of glacigenic sequences.

A5 — Regional Geophysical Surveys

Regional Crustal Structure

- SSE study: a regional structural model was developed of the cover sequence to Variscan basement and 3D gravity stripping was completed.
- Publications: a paper on the crustal magnetic structure of northern England was accepted and contributions were made to two further papers (one published and one in press).
- SSNE study: major effort went into further development of the models and presentation of the results bringing the CD to near completion (800 HTML and 2000 image files).
- NB study: internal review of the CD was completed.

Geophysical Computing Support and Development

- Gmod/Bmod: Integration of the 3D grav/mag modelling programs into ARKfield has continued at ARK geophysics.
- Wellog: 3D visualisation of logs and cores via a web interface was developed.
- Gravmag: a prototype of a completely new version of Gravmag has been developed to improve functionality for whole-crust modelling and integration with seismic data.
- ARARAT: major upgrades were completed to provide a robust program.
- Infrastructure: the group has been upgraded to NT.

High Resolution Airborne Resource and Environmental Survey (HiRES)

- HiRES-1: the survey has been successfully completed comprising 50,000 km of magnetic, VLF and radiometric data over a 200x70 km area of the English midlands.
- World Geoscience has had considerable difficulty applying automated cultural noise removal from the magnetic data but BGS has commenced manual removal of noise with considerable success (additional deliverable).

Refraction Studies

- Limited progress due to non-availability of key staff. The project was closed during the year and the allocation transferred to 77BE (HiRES) which was considered to be of much higher priority.

ODP Research

- Interpretation of borehole images and logs from the ODP leg 176 has continued but the final data sets are still awaited from ODP.

National Geophysical Mapping and Data Management

- Two maps in the 1:1M UTM series were prepared (magnetic, North Sea and Southern Britain).
- Loading of digital local survey data continued.
- Development of the structure of the overseas databases was completed.
- BGS marine gravity and most marine magnetic data were converted and loaded in to the new databases.
- North Sea and NE Atlantic aeromagnetic data were co converted and loaded in to the new databases.
- A prototype Intranet front-end to the geophysical databases was developed and implemented.

URO Network

- Integrated modelling continued of seismic lines in the southern and central Urals and around the SG4 super-deep borehole. Papers have been prepared and the results presented at URO and EUROPROBE conferences.

PACE Network

- Gravity and magnetic compilations of the Trans European Suture Zone have been upgraded and maps prepared of filtered and derived fields and depth-to-source. The results have been presented at PACE and EUROPROBE conferences. Work commenced on interpreting seismic data in preparation for integrated gravity-magnetic-seismic modelling of the southern North Sea basement.

Hydrocarbons, Offshore Surveys and Geophysical Monitoring

B1 — Offshore Surveys

Offshore Map Production

- 1:250 000 Shetland Sea Bed Sediments map published.
- 1:250 000 Shetland Quaternary map in Drawing Office.
- 1:250 000 Guernsey solid geology map in Drawing Office.
- 1:250 000 St. George's Channel solid geology map initial compilation achieved.

Rockall Consortium

- The Rockall Consortium has agreed to continue its sponsorship for a further year.
- Further processing of the seismic data from the two ship seismic experiment is being undertaken and additional processing work is continuing with research groups at Imperial College and Cambridge University. Initial standard processing of long offset data has been completed by CGG. Final digital and hardcopy profile data has been distributed to consortium members.
- Site survey work for 11 shallow drilling sites has been completed in UK, Faroese and Irish waters. Drilling has been postponed until 1999.
- A small high-resolution seismic survey has been carried out over Hatton Bank revealing pre-Cenozoic sediments through windows in Basalt.

Western Frontiers Association

- The Western Frontier Association has agreed to continue supporting the programme for a further two years (March 2001).
- A revised and updated bibliography has been produced.
- An image of the sea bed for the eastern flank of the Faeroe – Shetland Channel has been prepared using the first signal return from 3D exploration seismic data.
- A sea bed temperature probe has been developed and tested. This will be used to gather data to improve the modelling of hydrate formation and distribution.
- A study of small enigmatic, biological or seepage mounds in the Faeroe – Shetland Channel has been completed.
- Staff provided the geological input to the Atlantic Margin Environmental Study (AMES) and provided a report.

Marine Operational Capability

- Refurbishment and development of equipment to support operations for the Rockall Consortium and the Western Frontiers Association has continued.
- The trials of the NERC/BRIDGE drill were completely successful and a valuable suite of cores were obtained from the Atlantis Bank, Indian Ocean.
- Drilling support provided off E. Greenland for Danish Lithospheric Institute.

ENAM II

- BGS staff participated in cruises and workshops; a number of publications are in preparation.

CORSAIRES

- EU concerted action project was completed.
- Workshop on GAS Hydrates held in Ghent.
- Bid prepared for submission to MAST III programme.
- Geological Society Special Publication produced.

HYACE

- Work Package 2 developed on tool development and characteristics of gas hydrates.
- Laboratory procedures for use of non-destructive X-rays developed.
- 3 Reports produced.

B2 — Coastal Geology

Coastal and Estuarine Evolution Project

- 4 external published papers on the evolution of the English East coast.
- 2 BGS Technical reports on the geochemistry and sediment properties of the eastern England coastal lowlands.
- 3 paper presented at the final LOEPS conference.

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- UK estuaries database commenced.

Nearshore Zone Strategic Survey

- Analysis of Portland-St Catherine's and St Catherine's-Shoreham sectors completed; reports published, maps digitised and workshop held. Project co-funded with DETR and MAFF. A CD-ROM was delivered to DETR.

B3 — Petroleum Geology

Regional Interpretation and Revision

- Work on the seismic stratigraphic nomenclature of the Neogene of the North West Margin has been completed and the final volume has been printed.

Database

- Maintenance and development of petroleum and offshore databases continues with increasing amounts of commercial well and seismic data becoming available.
- Maintenance of the core and sample archive continues including the transfer of offshore core from Keyworth to consolidate the offshore archive at one location in Edinburgh and to provide space at Keyworth for land core being transferred from the DTI store.
- Data continues to be received and curated from the Hydrographic Office.
- Development of a fully geologically attributed schema for spatial data in a GIS system has been completed.
- A GIS-based enquiry system has been developed along with data structures to allow on-line access to all offshore data.

Palaeogeographic Maps

- Seismic mapping and potential field studies of the Ymir Ridge/ SW Faeroes and seismic mapping of the Mid North Sea High have been completed and two external publications are in press.
- Preparation of North East Atlantic map series, commencing with Igneous rock distribution.

High Resolution Correlation

- A compilation of information relating to the type Ludlow Series (Upper Silurian) was published on the BGS website in January 1999. The compilation comprises 58 PDF files, including 266 pages of text, 11 tables and 20 figures, all provided with hypertext links to enable the user to navigate through it. Aspects covered include chronostratigraphy, biostratigraphy, lithostratigraphy, geochronology, bentonites, carbon isotope stratigraphy and important sections. A holostratigraphic chart attempts to bring together different data sets used in correlation, and to show the relationship between them. The Ludlow study is a pilot study, leading the way to an interactive presentation of stratigraphic information on the BGS website.
- A number of other chronostratigraphical divisions are the subject of ongoing study. Their current status and expected publication dates are indicated in the accompanying table.
- Three new starts are expected in 1999-2000, focussing on parts of the Silurian, Carboniferous and Cretaceous systems.

Subsurface Mapping Onshore UK 3D Project

This project involves data collation and geological interpretation from seismic & boreholes on the UK onshore (England & Wales). It has several components described below.

- Stratigraphic surfaces database. This is an essential requirement for the building and updating of maps of stratigraphic surfaces and intervals. Data on the depth and one way travel time (where available) to stratigraphic surfaces are recorded, together with information on the nature of that surface. Information from all significant boreholes, both onshore and offshore are included. Work in the past 6 months has concentrated on entering new data. Some of this data was related to t the Coal Atlas Project, but data entry was also targeted at achieving a broad coverage across the UK. Almost 50% of wells greater than 1000m are now entered in grid squares other than SK. Some offshore data associated with the Saline Aquifers CO_2 storage project was also entered.
- Cheshire-Staffs subsurface mapping. This is the third study in a series of memoirs describing the subsurface geology of large areas of the UK onshore area, concentrating on the pre-Mesozoic succession. Much effort has gone into completing this memoir. In contrast to earlier regional subsurface memoirs this area has a geology which was previously little known or understood. Work is carried out principally by two members of staff.
- Atlas of subsurface structures. This is intended as a definitive publication on major structures in the UK, integrating surface and subsurface observations to explain the development of the structures and relationship to the stratigraphic development of different parts of the UK. Much new seismic data has been obtained by the group in the previous 6 months and this has led to a review of the seismic data previously chosen to illustrate structures and a reassessment of which structures should be included in the Atlas.

Carboniferous Heavy Mineral Stratigraphy

- The project has achieved detailed lithostratigraphy for the Westphalian in the East Pennine Basin, and the Namurian in the Widmerpool Gulf. Mineralogical data and SHRIMP (zircon dating) has identified the main hinterlands and sediment dispersal systems that contributed detritus to different parts of the Pennine Basin. The programme has delivered responsively in assisting 1:50000 sheet mapping projects.

B4 — Geophysical Monitoring and Forecasting

Applied Seismology and Associated Engineering

- The 141 UK seismic stations are on a rapid-access on-line system.
- New strong motion instruments installed in Leeds and Moray.
- Remote calibration of strong motion instruments.
- Field testing of environmental monitoring of ozone and radon.
- Field testing of seismic data acquisition system with QNX multi-tasking PC operating system.

Seismicity and Hazard Assessment

- Ninth Annual Monitoring Report (1997/98) published in June 1998.
- 1997 UK Earthquake Bulletin published in April 1998.
- Monthly seismic event bulletins published 6 weeks in arrears.
- Immediate dispatch of felt event reports by fax.
- Reports on seismicity of offshore NW Scotland and the Aviemore area completed.
- 180 earthquakes located during the 12-month period from April 1998 (22 felt).
- Searchable catalogue of archive seismic bulletin collection now available on-line.
- Macroseismic surveys for Jura, North Wales and Arran earthquakes.

Multi Component Seismics

- Analysis of multicomponent sea-bed datasets.
- Application of innovative sub-basaltic imaging techniques.
- AVD processing using vertical cable, sea-bed seismics and walkaway VSPs applied to data from the marine environment.
- Demonstration of the ability to reprocess vintage 2-D and 3-D datasets to estimate fracturing in chalk fields.
- Transfer of software to ProMax for use by co-funding sponsors.

Core Geomagnetism

- GAUSS magnetic observatory systems improving data quality.
- Quarterly service visits to the UK observatories carried out to schedule.
- Automatic daily updating of the GIFS and INTERMAGNET on-line databases 7 days a week.
- UK observatory data sent weekly to the international agencies computing magnetic activity indices.
- UK magnetic observatory data used in support of drilling 31 wells in 12 UK oilfields.
- Monthly bulletins for the UK magnetic observatories published within 7 days of month end.
- 1998 revision of the BGS Global Geomagnetic Model issued in May 1998.
- 15 repeat stations occupied in the UK Magnetic Survey network.
- UK regional main field model for 1998.5 to 2001.5 produced in April 1999.

MINERALS AND GEOCHEMICAL SURVEYS

C1 — Geochemical Surveys

Geochemical Baseline Survey of the Environment (G-BASE)

- Regional geochemistry of parts of North-west

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England and North Wales, Published and officially launched.
- Completed drafting of geochemical images for regional geochemistry of Wales and the West Midlands and initiated drafting of text.
- Completion of chemical analysis of stream sediment, stream water and soil samples for the forth coming Humber Trent regional geochemical atlas.
- Systematic geochemical sampling over an area of 5000 km^2 of the East Midlands, with the collection of 1366 stream sediment, 1223 stream water and 2200 soil samples, and 413 soils samples from urban surveys of Corby and Peterborough.
- Completion of computer-generated geochemical imagery and draft of the text for the regional hydrogeochemical atlas of Wales.
- Three scientific papers accepted for publication in peer-reviewed journals and a further two papers submitted for publication.
- Incorporation of G-BASE data and methodologies (including project staff) into two commissioned projects within the NERC URGENT programme.
- Presentations on G-BASE methods and current developments at three international meetings.
- Completion of UK component of the FOREGS global reference network sampling exercise and publication of the FOREGS field sampling manual, largely based on G-BASE methodologies.
- Preliminary compilation and interpretation of urban geochemical data for Stoke on Trent and assimilation of data into a format for the further development of thematic products.

Development of Capability in Analytical Geochemistry

- Utilise enhanced capabilities of upgraded ICP-MS in the analysis of (i) fish otoliths; (ii) air ilters; and (iii) low salinity fluid inclusions. (i)Presentations at Fish Otolith Symposium, Norway, July 1998 and Winter Conference on Plasma Spectrometry, France, January 1999. One paper published in Journal of Fish Biology and another in preparation for submission to an analytical journal. (ii) Presentations at 6th International Conference on Plasma Source Mass Spectrometry, Durham, September 1998 and Winter Conference on Plasma Spectrometry, France, January 1999; publications in preparation. (iii) Presentation at EUG Conference, Strasbourg, April 1999; one paper published in European Journal of Mineralogy.
- Develop analytical capabilities of MS-MC-ICP-MS in areas of (i) environmental Pb isotope finger-printing and (ii) stable isotope tracers in biological materials. Results presented for (i) and (ii) Winter Conference on Plasma Spectrometry, France, January 1999; publications in preparation. Formed part of final report of Marie Curie Post-Doctoral Fellowship of Dr Ana Boix to EU.
- Method development in XRF. Methods for the rapid determination of 53 elements in geological and allied materials by energy dispersive polarised XRF spectrometry have been evaluated and a report is in preparation. Invited lecture and workshop on geochemical analysis by XRFS given in Melbourne, Australia, February 1999. The routine programme for fused bead oxides has been extended to include NiO, CuO, ZnO and PbO.
- Robust methods for the analysis of toxic metals in leachates. An ongoing programme of work is developing new ways of studying the solid phase speciation of metals in pore-waters, soils and sediments using a combination of sample leaching and chemometric data processing. A MSc thesis report (Loughborough University) has been produced and a paper is ready for submission for publication. A literature search on methods for the determination of hexavalent chromium has been completed. Several extraction and measurement techniques have been evaluated and a draft report completed. The technique of atomic fluorescence has been extended to include a capability to speciate between inorganic and organic forms of mercury in organic matrices, using a simple intermediate oxidation step.
- Effect of filtration on metal speciation from sequential leaching schemes. A study has been made of the effect of different filtration media, from a number of different manufacturers, on the chemical composition of aqueous leachates from clay materials and written up as a MSc thesis report (Loughborough University).
- Supervision of PhD students
  - Kevin Seed, Reading University (Start date October 1997). "Speciation of selenium in sedimentary environments". Work presented at Geochemistry Group of the Mineralogical and Geological Society, London, October 1998 and 17th European Conference of the SEGH, Glasgow, March 1999.
  - Ana Marcos, Plymouth University (Start date November 1997). "The application of chemometrics to improve the quality of geochemical data obtained from ICP Atomic Emission". Work presented at 9th Biennial National Atomic Spectrometry Symposium, Bath, July 1998 and Winter Conference on Plasma Spectrometry, France, January 1999.
  - Emily Unsworth, Plymouth University (Start date January 1998). "Measurement and modelling of low concentrations of uranium series nuclides in natural waters".
- Physiologically Based Extraction Test (PBET) bio-digestion to indicate bioavailability of toxic elements. A visit was made to University of Colorado in February 1999 to learn of improvements in the PBET methodology and discuss its application and validation (BGS Technical Report WC/99/8R). Following this visit a thermostatically controlled tumbling water bath has been constructed by the BGS workshops and initial tests performed using reference materials and soil samples. This methodology is undergoing testing by the USEPA for acceptance as a standard procedure for Pb. This project replaces research into the environmental distribution of sulphur isotopes.

Additional achievements

- Two authoritative reviews on "Environmental Analysis" and "Atomic Emission Spectrometry" published in Journal of Analytical Atomic Spectrometry.
- Three invited lectures at: (a) 9th Biennial National Atomic Spectrometry Symposium, Bath, July 1998; (b) ETH University, Zurich, January 1999; and (c) International Conference on Water Resource Management in Inter-Montane Basins, Thailand, February 1999.
- Two poster presentations at 9th Biennial National Atomic Spectrometry Symposium, Bath, July 1998.

Natural Environmental Radioactivity Survey (NERS)

- Liverpool Bay radon and gamma dose maps were officially launched at Liverpool University in December. They are included in the Regional Geochemistry of Parts of North-West England and North Wales (also launched at Liverpool) and are also available separately.
- Significant new indoor radon datasets were obtained through a DETR contract. Work on the Lake District and East Midlands maps awaited these data. The draft Lake District radon sheet was completed and awaits compilation by the Drawing Office. Preliminary data analysis for the East Midlands radon map has been completed. Classification of the Lake District gamma map is at an advanced stage. A major revision is being made to prepare a solid plus drift map, rather than a solid only sheet, by establishing relationships between airborne gamma survey data and lithogeochemical data. This approach provides a much more realistic indication of outdoor gamma dose and will then be extended to East Midlands (and Humber-Trent) using Hi-Res-1 airborne data.
- The new indoor radon data, plus a major local authority (LARRMACC) gamma dataset have been incorporated with existing data into the NERS database.
- A demonstration GIS, based on Lake District data was taken to an advanced stage of development. Work on the mineralogical controls of radon generation in a range of rock types has been drawn together to define more detailed follow-up studies.

International Environmental Monitoring

- Data reported to project co-ordinator for a wide selection of elements from four rounds of samples designed to assess interlaboratory accuracy and precision.
- Data used to provide supporting evidence for BGS laboratory accreditation.
- Acted as rapporteur for project co-ordination meeting in Warsaw (September, 1998). Minutes of Warsaw co-ordination meeting written and distributed.
- Experiment carried out using a standard protocol for aqua regia digestion agreed in Warsaw and data submitted to project data co-ordinator.
- Project Web pages have been designed to show all participants and aims of project. (Future progress will depend on exchange of

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information with Lithuanian partner co-author and a decision on where the web site will reside.)
- Personnel from partner laboratories in Poland and Slovakia hosted at BGS.
- Invited lecture entitled "Environmental and geochemical applications of inductively coupled plasma spectrometry", presented at 8th Conference on Analysis in Geoscience and Environmental Protection, Warsaw, September, 1998.
- Contribution to Project Annual Report to EU.

Tectonic Early Warning System (TEWS)

- Experimental instruments delivered June 1998 followed by separate software updates.
- Field site identified on Highland Boundary Fault November 1998. Instrumentation and radio transmission system deployed December 1998.
- Successful data acquisition during December/January.
- First data processing method received from Russia for review March 1999.
- Project presentation at 'Second International Conference on Earthquake Hazard and Seismic Risk Reduction', Yerevan, Armenia, 15 – 21 September 1998.
- Repeated failure of monitoring instruments necessitated frequent returns to manufacturer during January – March 1999.
- Repaired equipment now undergoing laboratory testing prior to redeployment at field site.
- Links to BGS Core Programme: NERS, Seismicity and Seismic Hazard Assessment and Development of Capability.
- Project ends August 1999.

Water Quality improvement through fluoride reduction in groundwater of Central Europe

- This project is being co-funded via the EU Inco-Copernicus programme. The EU approved funding for the project in December 1998. The project will run for three years and will address the prediction of areas likely to have fluoride problems and will develop remediation technologies to remove fluoride from groundwater. The project is collaboration between geological consultants in The Netherlands, Slovakia and Hungary, the Institute of Rock and Ore Mineral Formation in Ukraine, the Institute of Gerontology in the Ukraine, the Association of State Geologists, Moldova and BGS. BGS Geochemistry Group is involved in this project in the development of a geochemistry and health risk prediction GIS.
- The project kick-off meeting was held in Kiev, Ukraine in February. The structure of field investigations into environmental levels of F and the F status of the population were agreed for Ukraine and Moldova. The existing data sets and background information required for the GIS from Ukraine, Moldova, Hungary and Slovakia were agreed and the structure of the risk assessment GIS was formulated. The experimental programme for remediation technologies was also defined. BGS will lead the development of the risk assessment GIS in collaboration with Dr Kamil Vrana, Slovakia. The framework of the GIS will be established by autumn 1999. In addition to the background information, the GIS will be populated by information from the field studies when this is available. Initial field results should be available by December 1999.

C2 — Mineral Resources

Sedimentary Basin Resources: gold in orogenic extensional basins – the Dalradian

- Field studies and lithogeochemical analysis of samples from gold occurrences and selected Late Caledonian intrusives completed.
- Mineral and fluid parageneses established for mesothermal lode gold occurrences throwing new light on gold enrichment processes in these deposits.
- Compilation of newly acquired and previously published lithogeochemical datasets for Late Caledonian intrusives completed. Petrogenetic modelling of these intrusions well advanced.
- Integration of multivariate datasets into ArcInfo GIS continued. Seamless geological base-map prepared for the whole of the Dalradian belt based on the UK 1:250 000 digital geological map.
- Overview report on Dalradian gold completed. Preparation of final figures in hand.
- Preliminary Rb-Sr and Sm-Nd whole rock studies on Comrie and Lagalochan intrusions successfully completed. Confirmation of genetic signatures in progress.
- Pilot Sr and Pb isotope studies carried out on mineralised samples by laser ablation followed by Thermal Ionisation Mass Spectrometry using the new Plasma 54 instrument. These investigations have demonstrated the potential of the methodology for providing metallogenic information.

World Mineral Statistics

- The 1992-1996 World Mineral Statistics book was published and promoted. Promotion involved the placement of advertisements and distribution of a flyer with order form. Sales volume and income was maintained.
- The 1993-1997 volume has been compiled using a new MS Access system developed with the assistance of funding from 75GD and DTI.

MINGOL (Minerals GIS On-Line)

- The Lake District 1:250K map was completed in draft form. Final form release has been delayed to allow incorporation of new information from the DETR-funded Mineral Resource planning map for Cumbria on which work has just begun.
- Mineral resource areas and mineral planning permission areas from the DETR Mineral Resource planning map project is being incorporated into the draft Tyne-Tees 1:250K map to eliminate duplication of effort.
- DETR-commissioned county Mineral Resource Planning map data for an additional four counties (Staffordshire, Shropshire, West Midlands and Warwickshire, Hereford and Worcestershire) has been incorporated into MINGOL and work on incorporating other LPAs is in progress.
- Publication of the Directory of Mines and Quarries (5th Edition) and accompanying CD-ROM, which has proved popular with larger clients.
- New Lake District mineral occurrence information was converted to digital form and merged with existing records for a revised edition of the Lake District mineral glossary.
- Further commodity chapters drafted for the Mineral Resources of Britain publication. 25 have now been completed and the remainder are in hand. It is planned to modify the original format to take advantage of recent IT developments and allow distribution and sales via the Internet.
- Over 4000 Mineral Occurrence records transferred from Excel spreadsheets to the Oracle database.
- Following completion of the prototype system MINGOL has been demonstrated to a wide range of potential clients and products (digital and hardcopy) sold to commercial users.
- The MINGOL concept and staff skills have been used by the BGS to underpin new initiatives in Britain and work overseas.

Palaeofluid Flow (IMP)

- The highlight of this year R&D has been the successful analysis of fluid inclusions in Quaternary calcites from the Sellafield repository area by laser ablation, cold plasma ICP-mass spectrometry. This allows reconstruction of the chemistry of palaeogroundwaters for comparison with the present day waters. Initial results indicate a striking similarity; an important consequence for risk assessment modelling. Further development is now in progress to apply this methodology to low salinity, diagenetic waters and their influence on hydrocarbon reservoir cementation.
- Other high performance output measures include:
- Award of a 2 year, fully funded EC contract for the development of novel software and instrumental tools for SME mining exploration companies.
- Contribution to a special SEG publication on 'Hydrothermal techniques' and invited speaker at a Geol.Soc. America Workshop, Toronto, December1998.
- Evaluation study of a new ICP-multicollector isotope mass spectrometer (jointly purchased with NIGL/NERC) and its potential application to lead isotope environmental studies.
- Acquisition of quantitative data from brine inclusions in halite that will be used to assess secular changes in the chemistry of sea water (joint NSF research grant with University of Binghamton and Oak Ridge Laboratories, USA).
- Regrettably, the purchase of a laser microprobe attachment for the new ICP multicollector

instrument was postponed until the end of this year thus delaying its evaluation for planned strontium isotope and palaeofluid studies. Work will recommence in September 1999.

Development of Capability in Mineralogy and Petrology

- Completion of technical reports; presentation of results at two major conferences; publication of review of maturation indicators as two chapters in textbook; mineral dust monitoring capability trial is ongoing; rapid commercial take-up by hydrocarbons sector; increased participation in NERC thematic programmes.
- This project is constructed as a set of individual activities, reviewed annually, focussed at enhancing capability in sectors relevant to Core and Commissioned potential.
- Completion of an integrated procedure employing electron microscopy and digital image analysis for comprehensive high-precision petrological analysis and classification of reservoir sandstones has enabled the Group to win a commercial contract with a major hydrocarbons exploration company and has extended significantly BGS's potential in basin analysis.
- Results of the development by this project of cryogenic SEM for petrologic analysis of pollution in unconsolidated sediments have been presented at two major conferences and submitted for publication. This important extension of capability has wide applications in analysis of contaminated soils and other media as well as water laid sediment. Observations of active framboid growth are unique and contribute to understanding of diagenesis and metallogenesis.
- Development of a BGS capability to samples and analyse airborne mineral particulates has progressed to monthly monitoring of an active quarry site. Though an application for DFID funding was not successful, avenues to apply this capability to environmental and health impact of respirable mineral particles are being sought.
- Progressive improvement in application of X-ray diffraction has been achieved by a major upgrade of the existing apparatus and operating software, enabling successful completion of a commission involving a novel application to clay mineralogy to landslips in Hong Kong. A comprehensive review of basin maturity indicators in relation to diagenesis and very low grade metamorphism has been published as two chapters of an authoritative textbook, edited by Professors Peacor (Ann Arbor) and Frey (Zurich).
- The worldwide database of gold mineral chemistry has been populated to provide a reference tool for resource and provenance assessment, and a pilot investigation into use of voice recognition software for petrographic analysis is near completion.
- The project has continued to support validation and editing work required for completion of the BGS Rock Classification Scheme.
- The project supports BGS contribution to the MIRO-lead BRITE-EURAM project 'REFILL', involving collaboration with IGME (Greece) and a number of SMEs, investigating use of quarry waste fines as a substitute for mineral fillers to lower costs by recycling high volume mine waste products.

C4 — Divisional Databases

Databases and Software Development

World Minerals Statistics (WMS) Database

- The major effort in database work this year was concerned with the WMS Database and this was part funded by DTI. A major conversion exercise was concluded in moving the database from the proprietary Master Modeller software to Microsoft Access.
- Originally this was intended to be followed by a period of dual running both systems but the new database was found to be so much more efficient that the older software was dropped as soon as the Access system was tested.
- Year 2000 compliance of the Access database was also tested and several reports were written describing the changes.

Geochemistry Database

- Developments within BGS to ensure greater compatibility between databases as part of the BGS-geoIDS project have impacted on to the Geochemistry database. Strict enforcement of foreign keys (the process by which ORACLE checks the integrity of data in the database) form an important part of this process and the partial redesign of the database was undertaken during the year. This has been largely completed but will entail small changes to the data loading programs.
- Data loading continued for the G-BASE program and the backlog of MRP data was loaded from staff taking early retirement. Lithogeochemical data was checked and loaded where available.
- The GIS system has been further developed and tested which provides a graphical front-end to the Geochemistry database.
- Discovery metadata for the Geochemistry data was added to the BGS metadata index and is also displayed in the BGS Geoscience Data Index. This allows BGS and external users to locate the availability of geochemistry data.

BritRocks Database

- Improvements were made to the Access front-end.
- Data loading to the BritRocks database continued both from Edinburgh and Keyworth (about 7500 records).
- A working ArcView GIS interface to the Geochemistry and BritRocks databases was completed. This is compatible with and complements the Geoscience Data Index (GDI) developed by the BGS corporate GIS group.
- The Britrocks system was extended to Edinburgh and 5 users trained in its capabilities.
- Technical metadata about Britrocks was included in the BGS-geoIDS system

BritPits Database

- The design of the BritPits ORACLE database (a constantly updated database of active mines and quarries in the UK) was updated to meet the current requirements and an Access front-end designed.
- Work is progressing on migrating the data from Excel spreadsheets into the new structure but has been hampered by the need for constant updates. It is hoped to complete this task in the near future, as several BGS products: the MINGOL system and the Directory of Mines and Quarries depend on its accuracy.

Other Developments

- The Divisional shared disc drive was successfully used so that only a single copy of the common applications, such as the Access and GIS front-ends, needed to be mounted.
- Data is being provided to other Core Programme projects such as the Gold in Orogenic Extensional Basins.
- Database skills developed in this project are being used in various overseas projects, MINGOL, the Coal Resources Map and in contract work for the GSNI.
- Internet web pages were designed using maps prepared from the Geochemistry GIS and similar products included in a trial Internet development for the Minerals Programme.
- Five reports completed.

HYDROGEOLOGICAL AND GEOTECHNICAL SURVEYS

D1 — National Groundwater Survey

Major Aquifer Studies

- This part of the programme has undergone a major review in the light of the recommendations of the PRG. Advisory Panels at the Regional and National level have either been, or are in the process of being established. This has been combined with the structured reporting format, presented here to facilitate tracking of the programme.
- Consultation with a wider number of users in the regions has enabled closer links to water company and Environment Agency strategic and development plans. The consultation has also been seen as a forum and a catylist to collaborative research in the regions.
- The restructuring has resulted in some delays of this year's products in order to link the regional studies to the planned research programmes. However the stream of deliverables for the Chalk Aquifer Regional Studies is now clearly identified to the year 2004. Additional

APPENDICES

deliverables will be added as new cost-sharing activities are identified and the Sherwood Sandstone Regional Studies come on-stream in 2001.

- South Downs Chalk. The publication of the Hydrogeological Report has met with further production delays and is now due in May 1999. Southern Water has initiated a review of the groundwater resources of two blocks of the S. Downs chalk aquifer. The draft Hydrogeological Report formed a basis on which the programme of survey, research and modelling was based. The results of this work will be used to update the current report and will probably be produced as a supplement to the Hydrogeological Report in a couple of years.
- Chalk Aquifer: its science and management. Subsequent to discussions with the Advisory Panel, which concluded that this document would benefit from more input from outside BGS, a revised programme was prepared but little progress has been made due to initiatives in developing the Regional Aquifer Studies programme. The project will be reviewed in the light of available resources next FY.
- East Anglian Chalk. Attempts to collaborate in a major initiative by the Environment Agency to develop a Strategic Plan for the groundwater resources in the Anglian Region were unsuccessful. The programme in this region will therefore monitor progress over the next few years, providing added benefit where possible and reschedule the production of a Hydrogeological Report. The study of Lincolnshire can however proceed as planned and progress has been made in updating an outline report in line with the planned schedule.
- Wessex Chalk. Collaboration with the Environment Agency in the study of a chalk catchment in Wessex was started in March 1999. Discussions are continuing concerning a joint project with the aim of developing a conceptual model of the catchment using expertise from both organisations.
- Effect of old landfills on Chalk. Project delayed due to field access problems. Access negotiations are being carried out by the Environment Agency. It is anticipated that fieldwork will recommence in Spring 1999. The scientific programme will not be completed and reported until 9/2001. An extension of 1 year is requested to funding.
- Publication of reports on co-funded activities. Four major reports on co-funded work undertaken in the last few years were published, namely:
- Low flows, groundwater & wetland interaction. BGS-IH/EA/UKWIR funded study undertaken by BGS and IH. 200 copies distributed widely and launched at a meeting organised by the UK Groundwater Forum in November 1998 and a Geological Society/BHS sponsored technical meeting in February 1999.
- Groundwater Tracer Tests: a review and guidelines for their use in British aquifers. BGS/EA funded study undertaken by BGS. 150 copies of the report distributed widely.
- The potential for Aquifer Storage and Recovery in England and Wales. BGS/EA/UKWIR funded. 300 copies distributed to the water industry and launched at a UKWIR sponsored seminar in March 1999.
- Fracturing and the hydrogeology of the Permo-Triassic sandstones in England and Wales. BGS/EA funded study undertaken by BGS. Joint BGS/EA technical report produced in March 1999.

National Groundwater Databases

- Groundwater Databases. Archiving of water well data received under statute (Water Resources Act 1991) continues, and all boreholes are now electronically registered. Development of a comprehensive digital database, initially supported by the NERC Seedcorn programme, is proceeding. The database is now available to all BGS staff via the Intranet. Data entry has concentrated on areas under investigation by the National Groundwater Survey or required for memoir/map production. Some data entry was carried out on a commissioned basis for an interested commercial client. This is the first example of the user community funding the population of the database. The digitization programme will continue during 1999/2000. Hydrological monitoring activities during the year included:
- Publication (printed) of Hydrometric Register and Statistics 1990-95.
- Publication (electronic) of the 1997 Hydrological Data Yearbook.
- Continued monthly publication of hydrological summaries.
- Report on long term behaviour of Therfield Rectory hydrograph.
- Minor Aquifer Properties. In July 1998, agreement was reached with the EA to fund the publication phase with the deliverable being a manual and CD-ROM database. Project completion date extended to July 1999 to take account of this additional (£40k) phase. Additional funding has been negotiated with cost-sharing partners which will make deliverables more comprehensive.

D2 — Hydrogeotechnical Formation Properties and Hazards

Engineering Behaviour of UK Rocks and Soils

- This part of the programme has undergone a review in the light of the recommendations of the PRG. As a result, an Advisory Panel has been set up with representatives from industry, the public sector and academia. This followed a consultation with a wide number of users in the three communities represented on the new Advisory Panel. The results of the consultation were summarised in a short report to the BGS Directorate and Board. This consultation exercise has put added pressure on staff which may result in a slight delay in the publication of the Mercia Mudstone Group Monograph. Work has continued on the Lambeth Group Monograph and the initial literature study for the Lias Group Monograph has commenced.
- Progress on the 1998/9 deliverables for this project has been slower than anticipated due to several factors. Staff changes: One project member left the UK to work on a project in Papua New Guinea. One project member took early retirement. One project member resigned from BGS. This has required the redeployment of staff time to other project members.
- Project advisory panel. The project advisory panel has been set up (see above) and detailed terms of reference have been drawn up. This took an appreciable amount of time to ensure the provision of high quality advice and the framework in which it could be administered. This success can be regarded as an additional deliverable for this year.
- CIRIA meeting. The project team were asked to provide a lead speaker and supporting papers for a key meeting on 'The Engineering Properties of the Mercia Mudstone Group' to be held by the Construction Industry Research and Information Association in December. This was supported by a fee of £2000. This has diverted some resources from the immediate deliverables but will result in three papers from the project in a major publication by CIRIA which constitute additional deliverables this year. A similar request was received regarding participation in a meeting on the Lambeth Group and £2000 co-funding provided. A preliminary meeting was held at which a BGS paper was presented but the main meeting has been delayed due to a contractual dispute involving some potential participants.
- 'Unforeseen ground conditions'. The study of the Lambeth Group has shown it to be more complex with regard to lithological variability and engineer behaviour than anticipated. A longer period of time for its characterisation than anticipated will be likely.

Hydrogeological Characterisation of Clays

Transport properties of clays

- The preparation of the 'Geosphere Waste Containment Investigations: Part 1' volume is drafted based on a variety of papers and FPWMG reports. A paper on 'Gas migration in clay barriers' was presented on the use of clays for waste isolation in Lund, Sweden.
- Numerical modelling of gas flow down a discrete pathway was applied to data from a laboratory gas injection experiment run in the FPWMG Transport Properties Research Laboratory. Improvements were made to the modelling approach by making the transmissivity of the pathways dependent on gas pressure.
- The commissioning of the 'Envirotest Module' field unit, which will monitor the performance of clays as barriers to contamination, has continued with tests in the BGS Workshop. It will soon be fully installed at a landfill site in Northampshire, to monitor gas migration in a prepared section of the clay liner.
- A series of kinetic experiments has been set up to determine the dissolution rates of a number of key minerals of interest to low temperature groundwater-rock interactions.

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- Two new Environment Agency-led projects were co-funded:
- An investigation of contamination processes in the unsaturated zone of the Triassic Sandstone at an old cemetery site in Nottingham
- A study of rebounding minewater in the Nottinghamshire Coalfield using the 3-D visualisation tool, Vulcan.
- Approximately 400 boreholes records were databased prior to producing clay property maps using MapInfo GIS. A small borehole array was constructed providing new hydraulic and physico-chemical data for the clay properties database.
- The FPWMG laboratories, including the environmental geophysics section, continue to be safely maintained with contributions from this budget.

D3 — Technology Foresight and Capability Development

Hydrogeological Capability and Hydrogeochemistry Research

- Hydrogeological capability. Maintained laboratories in good working order. New ICP-AES instrument purchased March 1999. Anticipate major improvements in sensistivity and economy.
- UK Groundwater Forum. Report to DETR on draft EC Water Framework Directive. Distribution of 300 copies of "Groundwater: our hidden assets" to opinion-formers in water industry. Meeting on Low Flows, Groundwater and Wetlands Interaction held – attendance over 100. £40,000 of funds secured for a video on the role played by groundwater in river flow – production of video begun. Database of groundwater research in the UK updated – accessible through the internet. Funding secured for a further 3 year period from 1 April 1999.
- Hydrogeochemistry (IMP). Completion of several refereed papers on UK hydrochemistry, palaeohydrology and arid-zones. Participation and publication in UNESCO (IHP) and other International Programmes.
- ENRICH. Development of database for Lake Chad area during visits by scientists from Niger/Nigeria. Links established with IAEA, Vienna for wider investigations. Second visit by Nigerian counterpart to UK and Vienna. Database nearing completion for countries selected. Plenary meeting in Tunisia in April.
- PALAEAUX. Final analysis & interpretation of UK coastal aquifer data. Design of final report, preparation of Geological Society, London, publication. Final meeting held in Mallorca in January. Completion of final report for May is on schedule. Papers presented at 3 EC meetings on climate change and hydrology (Vienna, Warmbad-Villach and Helsinki).

Development of Geotechnical Capability

Geotechnical Capability

- Feedback from civil engineers is being incorporated into contributions to the CIRIA/Geological Society Working Party Report on the civil engineering uses of geophysics. Although nearing completion, further interaction with users is shaping the document. Of particular importance is the need to advise engineers of the practical limitations of geophysical tomography as well as the enhancements that are now possible. Two confidential meetings have been organised by CIRIA/Geological Society during the reporting period.
- The first draft of a report defining a strategy for linking existing geophysical and geotechnical properties data has been completed. The need to assign specific geophysical properties to existing ground models, derived from geoscientific spatial data, has been established as being a pre-requisite for the desk study phase of geohazard risk assessments.
- A peer reviewed paper has been published at the Annual Meeting of the Society of Core Analysts during September at the Hague, concerning the improved characterisation of fine scale structure by the integration of downhole and core electrical image data. This work is collaborative with the University of Leicester, in partnership with Shell and Mobil.
- A paper has been presented demonstrating the strengths and weaknesses of seismic and electrical tomography for assessing the structural integrity of masonry viaducts to an audience of potential users at the Railways '98 conference.
- An invited paper has been presented to the Acoustical Society of America concerning the assessment of two and three dimensional and heterogeneity and pore-morphology in carbonate sediments by a novel combination of resistivity imaging and X-radiography. This research is in partnership with the Naval Research Laboratory of the US Navy.
- A report has been completed concerning a novel use of non-invasive 3-D seismic tomography to aid the stabilising of a domestic property which has undergone substantial subsidence. The work has delineated the extent of the unstable ground, in the Reading Beds, providing engineers with the information required to select appropriate remedial measures. The work has been in partnership with 1st Ground Investigation Ltd.

Waste Containment Capability

- Induced Polarisation Tomography (IPT) for monitoring contaminated land: Field trials (at old gasworks sites) identified a technical fault in the IP data capture software which is being rectified but will necessitate repeat visits to some sites. A six month time extension for the contract has been requested from the Commission and a delay of six months in reporting is requested.

A New Integrated Geophysical Approach for the Rational Management and Exploration of Groundwater Resources

- Geophysical fieldwork in Cyprus was completed and the data were interpreted. Two technical reports and an EU progress report were written.

NATIONAL GEOSCIENCES INFORMATION SERVICE

F1 — Enquiries Service

General Enquiries

- All targets were met in the operation of the enquiry service to performance targets.
- Gross income from the enquiry service was £219k, an 8% increase over the figure of £202k for the previous year. This represented a cost recovery of 53% of FEC, a slight drop on the 55% achieved last year and below the increased target of 60%. The cost of staff on the Keyworth and London general enquiries desks who only answer non-chargeable enquiries, are not included.

F2 — Information Systems

Remote Sensing

- Digital Photogrammetry and Terrain Modelling. Underpinning work to support a variety of geological mapping and coastal erosion projects. Significant effort expended on specification, procurement and commissioning of new distributed digital photogrammetric facilities for Keyworth and Murchison House.
- High Spatial Resolution Satellite Sensors. Launch delays meant only trial application studies on the Canadian Radarsat data could be progressed. From this it is evident that for the UK, optical data, such as that from Landsat TM, provide more geological information than currently available radar datasets.
- High Spectral Resolution Satellite Sensors. With the postponement of the ASTER satellite launch only limited applications research on simulation data was possible.
- Portable Infrared Mineral Analyser. Report produced detailing all scientific and commercial applications. Successful applications to date include collaboration with Minerals Group on exploration projects for mining companies, spectral studies of core for Shell and analysis of a variety of rock, soil and mineral samples for other projects.
- Thermal Imaging. Data from the NERC Airborne Thematic Mapper was obtained for a site in the Cotswolds and at Baildon Moor, Bradford. The latter was used to appraise its effectiveness in detecting abandoned mineshafts. The results have been presented to the Coal Authority and a larger project may result.
- Integration of GIS and Remote Sensing Techniques. This item was a casualty of staff losses and diversion onto higher priority projects and little progress has been made. However the synergy between these technologies will be exploited in two DFID KAR projects next FY at least.
- International Contracts. Remote Sensing staff serve on the ERIM Executive Committee, the EGS Remote Sensing Topic Network, the ASTER Science Team and the Geological Remote Sensing Group of the Geological Society of London.

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Coordination of information systems

- BGS Intranet. Successfully installed and maintained, usage shows a continuing growth. In the future dynamic links to live geoscience databases will extend its value and usage considerably.
- Maintenance of Existing Systems. Lexicon; Rock Classification Scheme Database (now populated with metamorphic, sedimentary and unconsolidated data as well as igneous), software running the BGS WWW site and DMPS were all maintained within the limit of available resources. Help Desk support continued to be provided to users.

GIS and information systems R&D

- DIGMAPGB Interface. Graphic interface designed and while much of work on implementation is complete, diversion of key staff onto RESIDATA Subsidence means the interface is not yet ready. New index tables created and populated with data extracted from existing sources. CS are populating remaining fields. System for dealing with requests for digital maps implemented and conversion of DMPS97 data to ArcView Shape file and MapInfo format investigated.
- Digital Report Generating System. Excellent progress with this research into structured text mark-up, storage and retrieval. SGML/XML used as text-tagging technology. Glasgow and Airdrie memoirs marked up. Workshops held with geologist/ authors. OMNIMARK procured as chosen technology.
- Column Correlation. Searches revealed no existing software to be available. Following initial work reviewing terminology and relationships between lithology, lithostratigraphy, chemostratigraphy and biostratigraphy, Goniatite and Conodont zones for the Tournaisian and Westphalian were selected for the trial. A biostratigraphical zone interface was designed and implemented in Oracle and an updated version of the BGS Chronostratigraphical Index database produced. A prototype graphical front-end (in ArcView) was implemented and reviewed. Plans for 19999/2000 include the release of the revised version and development of a pilot Intranet version.
- Expert Systems. Being progressed through a co-supervised MSc project with Edinburgh University's Department of Artificial Intelligence. The project – A Knowledge based Expert System – will use Nirex borehole discontinuity datasets.
- Neural networks. Resources permit only a watching brief of this subject. The results of searches have been documented.

BGS Geo-IDS

- The BGS-geoIDS Project had nine deliverables in the first year. Seven of the nine deliverables were met, two of these exceeding their original targets. Two deliverables were not met in full for reasons documented below.
- Corporate Data Model. Achieved 70% Primary Keys and 35% Foreign Keys on the main BGS Database which comprises over 1400 tables. A lot of effort has been put into identifying data managers. Problems have been caused by the resignation of a key staff member and the subsequent resignation of their, newly recruited, replacement caused major delays.
- Discovery Metadata. Achieved all its goals producing a design meeting international standards, a database, and an application for data entry. Data capture has commenced.
- Maintenance of Existing Infrastructure. Ensured that the data on the multiple BGS Oracle Databases have been kept in parallel. This involves a suite of programmes, known as TRANSACT, that monitor activity on the database and copy updates, inserts and deletions from one system to another. This system has been re-written this year following the closure of the VAX.
- Data Standards. The nominated leader was not available for long periods due to commercial work overseas. The lost ground will be recovered in the second year of the project.
- BGS Data Policy. This has been produced and disseminated to staff. Guidelines for the production of Data Management Plans of the principal datasets have also been produced as has a high-level data management plan for the BGS.
- Applications Standards. Draft report produced recommending database access software for use on the BGS Intranet and possibly the BGS Internet. The migration of data access from the Client/Server environment to the Thin Client environment offers savings in terms of support of users.
- Borehole Geology Database. Redesigned and a database and associated applications have been produced to meet user requirements.
- BGS Intranet. Used to publish the results of the BGS-geoIDS Project, meeting objective of Deliverable 8.
- Intranet Geoscience Data Index (GDI). Investigated and a user requirement has been drafted, software studied, costed proposal made and prototypes built.

Cartographic Development

- On-going maintenance, and system and application support of cartographic production computers; training of production staff on new techniques and systems. Maintenance and support are on going. Staff training in management, health and safety, and technical courses were carried out throughout the year: over 100 attendances over 23 formal courses, in addition to internal cartographic seminars. Cartographic User Notes were web-enabled for easy and immediate access. Intergraph UNIX to NT migration: purchase of 18 NT stations, 2 NT servers and a data backup system to replace UNIX workstations; purchase of upgraded map production software licences. New kit is currently under installation. The Reprographics Imagesetter was replaced. The Cartographic Mapsetter suffered 6 weeks downtime due to failed laser unit. Replacement and subsequent re-calibration was a major exercise affecting the number of maps available for printing. Purchase of new A0 inkjet plotter for site-wide use, with priority to Cartography, managed by Reprographics staff.
- Consolidation of DMPS97 after introduction and pilot running in 1997/98; associated database development for DigMapGB. 20 new maps started within DMPS97. Completion of the UNIX to NT migration will enable all new maps to be structured to DMPS97. Database development work completed to enable DigMapGB production (see below).
- Training and consultancy for the DMCS. Liaison/consultancy and system development (menus, scripts) provided as required. User training provided: two "MicroStation for DMCS" courses. First DMCS sheets from five geologists, linecleaned and polygon processed.
- Investigation of current state of semi-automatic digitising software to evaluate its suitability for geological map linework. Investigations showed software suitability for only a limited range of linework. Geological lines proved too complex to achieve acceptable results. The software is ideally suited to simple, continuous, uniquely identifiable lines with no complex interactions. Success has been achieved only on contour lines. A monitoring eye will be kept on evolving techniques.
- Implementation of cartography QA procedures. Proposed new QA procedures are not fully in place for all work; awaiting discussions with the BGS QA Manager to ensure procedures comply with BGS standards.
- In addition. Data translation s/w was evaluated and installed in order improve performance of translating data from the map production system DMPS97 to ArcView and MapInfo GIS. Cartographic Intranet pages launched February 1999. The Cartographic Geological Symbol Index was updated, compiled into PDF format, and put on the BGS WWW site.

GEIXS

- BGS continued the overall project management, organising the fifth, sixth and seventh Steering Group meetings. The fourth and fifth Reviews by the European Commission were also organised including preparation of comprehensive progress reports and documentation. The project has successfully passed all Reviews to date and is on target to deliver its objectives. It must be reported, however, that GEIXS project management is absorbing significantly more time than was budgeted in the original proposal. This burden was not eased by the extension of GEIXS to 8 CEC countries and Norway. The revised completion date for the project is 31 December 1999. EuroGeoSurveys Directors have agreed to fund GEIXS maintenance and upgrading after this date. Other issues; working contact with the EUMARSIN project has been established and extensive discussions have been held about GEIXS2 project proposals for 5FP.

Year 2000 Project

- Of the 200+ business critical systems that have been identified, over 75% are now Year 2000 compliant. The remaining systems are due to be compliant by 30 September 1999, subject to adequate resources being available. External suppliers providing either conflicting information regarding compliance or have delayed issuing Year 2000 patches are cited as the main causes for concern for BGS to achieve full compliance as yet. Contingency planning has commenced with finalised plans due to be in place by 30 September 1999. Keeping staff fully informed of Year 2000 developments and contingency procedures are seen as a high priority this financial year.

F3 — Publication and Sales

Customer Services

- A WWW catalogue of publications is centred around a brochure of popular publications and maps and is being updated on a regular basis. Web designs have been restructured to a more user-friendly format and are being expanded to allow the inclusion of specialist, technical and overseas publications. Orders can be placed on-line via e-mail.
- Gross revenue from sales of publications was £570k compared to £535k for the corresponding period last year, an increase of 7%. This included over £42k of over the counter sales from the London Information Office, an increase of 14% on last year, reflecting the growing impact of the improved customer-orientated sales facility.
- Approved stockist status has been discussed with 14 retailers resulting in the appointment of 4 new Approved Suppliers and 5 national and regional wholesalers. In addition, 3 of the Approved Suppliers are acting as local wholesalers for the educational and museums sectors.
- Performance targets for published items despatched within 2 and 3 working days were not met. This was caused by staff changes and increased workload. Despite this, 94% of all requests for published items were satisfied within 5 working days, exceeding the 90% target. Performance targets for the supply of unpublished items were all met.

Royalties/Copyright Receipts

- Revenue from copyright permissions totalled £25.3k, an increase of 11% over that achieved last year.
- The planned copyright seminars to explain implementation of the new Central Government Organisations/Ordnance Survey Service Level Agreement were postponed as the SLA was not finally signed until April 1999. A series of seminars will be held early in the next financial year covering the SLA and the new role of the IPR Manager, who will now have corporate responsibility for all copyright and digital data licensing.
- The following Office Notices were issued: 30/98 – CASE Awards and Intellectual Property Ownership. 1/99 – Intellectual Property Rights. 6/99 – Corporate confidentiality statements.

Published books

- Eight sheet memoirs published (Falkirk, Aviemore, Lancaster, Newcastle, Coventry, Northallerton, Carrick-Loch Doon, Derrygonnelly). 23 in production at the beginning of the year; 4 received since.
- Specification for sheet explanations was agreed. Two received (Windsor, Bradford) and in production, awaiting final approval before printing.
- Cheshire Basin special book nearly completed for publication.
- Minerals of Northern England report is in production, generating final films prior to printing. Production was affected by late problems that were resolved by the author.
- Two Hydrogeological monographs are in production (Upland Britain; South Downs Aquifers), late amendments being carried out.
- World Mineral Statistics 1992 1996, UK Minerals Yearbook 1997, Directory of Mines and Quarries, Earth science information in support of major development issues, Environmental geology in land use planning, Geomagnetic Bulletin 27 – Magnetic results 1997, Jersey groundwater study

Published maps

- 25 new 1:50k maps released as advance copies (9 North including 1 Northern Ireland, 16 South). In addition, 16 newly printed 1:50k maps (9 North, 7 South); one printed 1:25k map. 35 maps were in Cartography at the beginning of the f/y; and 20 were submitted since (8 North, 12 South).
- Two Gravity Anomaly maps (Northern and Southern Britain) released. Two magnetic maps suspended awaiting proof returns from RG Group, and two gravity maps in production.

F4 — Public Understanding of Science

Public relations

- Management and maintenance of the BGS WWW site. This is a continuous process. The site is controlled by the Web Management Group (WMG), who have been active in keeping the site up to date and enforcing corporate standards. New author guidelines were issued. Free WWW downloads: Lexicon of Named Rock Units (revised); Rock classification scheme (revised); two Research reports; Holostrat; Map symbols and Ornaments (revised); one Earthwise; two Earthworks; Annual Report; Environmental Geology in land use planning report.
- The BGS Annual Report for 1997/98 (in hard copy and on the BGS WWW site) was approved and put on the BGS WWW site.
- Propagation of BGS and earth science through meetings, site tours and talks. Regular activities including: SET99 (National Science, Engineering and Technology week) "Fossil and Rock Show" hosting some 750 junior school children; Scottish Geology Week; Nottingham University adult education programme "Geology and Man" 8th series; numerous tours for professional/amateur/student Groups and visitors; schools' liaison meetings, talks, careers evenings; Murchison House open days entertained some 650 visitors; work experience students.

Earthwise

- Two editions (Minerals'98, Sustainability) published, and one put on the BGS WWW site (the other awaiting copyright clearance).

Popular Publications (Earthwise label)

- Whisky on the Rocks published to good critical review and media attention.
- Two Holiday Geology Guides released (Cornish Pebbles; Scarborough and Whitby); two in press (Isle of Wight; Greenwich); and one awaiting approval (Tower of London). Production affected by the main designer of the guides taking maternity leave.
- Two Holiday Geology maps in production (Peak District and Yorkshire Dales). Production affected by the resignation of the main officer working on the DTM creation and visualisations.
- Two Discovery Geology (Fossil Focus cards) released (Plants; Echinoids), and two in press (Crinoids; Bivalves).

Popular Publications (small scale maps)

- Engineering geology of GB or UK (1:1m scale). First proof of generalised/reclassified 1:625k map data completed; map in late stages of production. Production affected by higher priority commissioned work.
- Sites of geological interest in the UK (1:1m scale). Renamed "Tourist's Rock, Fossil and Mineral Map of Great Britain". First "concept" proof completed and approved, additional information currently being added. Close to 2nd proof for critical comment.
- Building Stones of Britain (1:1m scale). First proof produced and approved; production at advanced stage and now awaiting author to return from overseas before finalisation of 2nd proof.

F5 — Collections and Database

Digital geological map database

- Conversion of 1:250k onshore database to (attributed) DMPS97 format. Completed, and publicly launched December 1998. Solid geology data are reclassified and linked to the lithostratigraphy and lithology attributes stored within the BGS Stratigraphic Lexicon and Rock-Type dictionary respectively. Dataset was re-tiled into 100x100 km tiles.
- New digital map base at 1:625k and new editions of printed 1:625k Solid maps. Generalisation of the new 1:250k Solid geology onshore data above (linework and coding) is currently underway to derive the

new 1:625k dataset, in preparation for new printed editions. The 1st edit stage (coarse linework) is complete, the 2nd edit stage (linework and coding) is underway.

- Digitisation of offshore 1:250k maps. A decision was taken to seek commercial sponsorship or co-funding. Product specification is being drawn up in conjunction with Marine units. Digitisation of the 1:250k offshore linework from the printed map series started, completing 5 map sheets during the year.
- Conversion of existing digital 1:50k data to DMPS97 format. Preliminary work has been carried out to test and establish the procedures. Spreadsheets are being prepared to enable geologists to start equation of DMPS89 numeric seeds to DMPS97 lithostratigraphy-lithology codes for when conversion starts. Availability of co-funding from DETR meant that some project and staff resources were diverted to capture more of the analogue legacy 1:50k sheets instead of doing the digital to digital conversion. 18 of these sheets were started, and 13 were completed. Specifications for external digitising were prepared, and a Request for Information (RFI) sent to a number of digitising agencies. Responses from the RFI allowed a short list to be drawn up for a proper evaluation of their capabilities.

Collections Administration

- Borehole registration was completed at the rate of 15,150 records per person year.
- Borehole data was entered onto the Borehole Index at the rate of 75,700 records per person year. During October, a new combined borehole registration and data entry procedure was implemented. This corresponds to a new target for registering and entering data at the rate of 12,000 records per person year. After an initial period of training this new target is now being met.
- On April 1 1998 there was a backlog of 118,500 borehole registration records. At April 1 1999 the backlog stands at 87,000 records, including new donations of over 47,000. This represents a reduction of 27%. It was not possible to meet the target due to extended staff sick leave and non-recruitment of staff vacancies. In addition there was a significant increase in the number of new donations.
- A total of 47,326 site investigation records have been donated to NGRC from external bodies representing an increase of 20% over last year's total of 39,387 records. This has been partly due to companies being reminded of their statutory and 'quid pro quo' obligations.
- BGS Value Added Resellers Landmark Information Group and Catalytic Data have been supplied with quarterly updates.
- The complexity and volume of borehole enquiries received at Keyworth resulted in only 41% being dealt with the same day against a target of 50%. All other targets were met including 88% of enquiries being answered within 3 days against the target of 80%. The combined Central Enquiries and NGRC responses met all performance targets.

Database Management

- In conjunction with GISG the Single Onshore Borehole Index was implemented in Keyworth and Edinburgh and is now operational. A User Group has been established as a focus for user comment and to drive developments. The user manual is in its final editing stage and will be released in May 1999.
- The Happs-Hall Field Notebook Index database, accompanied by a user manual, has been released and incorporated into the Geoscience Data Index (GDI) for improved access and functionality. A separate user manual is no longer required as the user instructions form part of the main GDI guide.
- A variety of new codes and definitions have been added to the Lexicon, and the Lexicon's content of fully defined entries has been increased by 22% this year.

Appendix 10 The BGS Board

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 it was dissolved in December 1997. Whereas the Programme Board's remit was to determine the overall objectives and to set the priorities for the BGS Core Programme, the BGS Board has a much wider remit encompassing all the activities of the BGS. The Board will meet six times during 1998.

Terms of Reference

The BGS Board will:

- advise and support the Director in the management and the furtherance of the Survey's mission, aims and objectives;
- specify the priorities, timescales and detailed outputs of the core strategic programme in order to meet the overall objectives specified by Council;
- approve the annual business and operational plans for the Survey and submit these to Council's Chief Executive;
- review and monitor the quality and relevance of all aspects of the Survey's work;
- report, according to standards of review and at a frequency set by Council, to Council's Science and Technology Boards on the progress against milestones, achievements and quality of all the Survey's core strategic programmes funded by Council and make recommendations, as necessary, concerning the future of those programmes;
- monitor the Survey's management and administration and assist the Director in matters concerning efficiency, effectiveness and economy in the use of resources (funds and tangible and intangible assets);
- ensure an appropriate balance and synergy between the core strategic, core partnership and commissioned research programmes; and
- report annually to Council.

Membership

Board members are appointed by the NERC Chief Executive from nominations made by the Director and others, and approved by Council. Membership comprises: a non-executive, part-time Chairman; the Director, **Dr D A Falvey;** Council's Chief Executive or his nominee, currently the NERC Finance and Information Systems Director **Mr C M Read;** and 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 user community. They include senior representatives of industry, government agencies and academia as listed below. Members may be appointed for up to four years in the first instance and may be reappointed for up to a further four years. **Dr B R Marker** of the Department of the Environment, Transport and the Regions sits on the Board as an Observer. The Secretariat is provided by **Mr D Hackett** and **Dr S H Marsh** of the BGS.

Board Chairman

Dr E R Hassall CBE has been appointed Chairman of the BGS Board until 31st December 1999. He is also Deputy Chairman of the Coal Authority, a member of the Natural Environment Research Council and Keele University Court and Council. He was formerly the Chairman of Wardell Armstrong and the Crown Mineral Agent. He previously worked in the Production and Mining Departments of the National Coal Board.

The Chairman of the BGS Board will report to Council through its Chief Executive and take particular responsibility for:

- developing, with the Board, the long-term vision for the Survey;
- providing leadership on strategic matters which are the collective responsibility of Board members;
- supporting the Director in representing the views of the Survey to the public;
- ensuring that the Board observes high standards of corporate governance; and
- ensuring that the Board meets regularly throughout the year.

Board Members

Prof D J Blundell is Professor of Environmental Geology at Royal Holloway, University of London. He has mainly researched in seismology and marine geophysics. He was a co-founder of the British Institutions Reflection Profiling Syndicate and took a leading role in the European Geotraverse supported by the European Science Foundation. He is a past President of the Geological Society.

Dr J V Bramley is a minerals consultant. He is the President of the Mining Association of the United Kingdom, a past President of the Institution of Mining and Metallurgy, and serves on the Council of the Mineral Industries Research Organisation. He was formerly the General Manager of Laporte Minerals in Derbyshire.

Prof A L Harris is Dean of the Science Faculty at Liverpool University, and former Head of its Earth Sciences Department. For twelve years a member of staff at the BGS, he joined Liverpool University in 1971. He is a member of RWMAC, a past President of the Geological Societies of London and Liverpool, and has served on NERC Committees dealing with studentships and grants.

Dr J P B Lovell OBE is a Senior Research Fellow in Earth Sciences at Cambridge University. Previously, he spent fifteen years with BP Exploration, joining as Chief Sedimentologist in 1981 and subsequently working mainly in international exploration. He remains a consultant to BP. In the 1970s he was a lecturer and consultant at Edinburgh University.

Dr C J Morrissey recently retired as Group Chief Geologist, Western Hemisphere, for Rio Tinto. He was previously Managing Director of RTZ Mining and Exploration in Europe and held several other senior positions in RTZ. Before this he was a Research Fellow at Imperial College London and Lecturer in Economic Geology at the Royal School of Mines.

Mr J Mortimer is Technical and External Affairs Director at ARC, for whom he has held a number of other positions in production management. He is Chairman of the CBI Minerals Committee, the Quarry Products Association Public Affairs Committee, and Minerals '98.

Dr A C Skinner is Environmental Protection Manager for the Midlands Region of the Environment Agency. He is the Secretary General of the International Association of Hydrogeologists and was formerly the Regional Technical Manager for the National Rivers Authority.

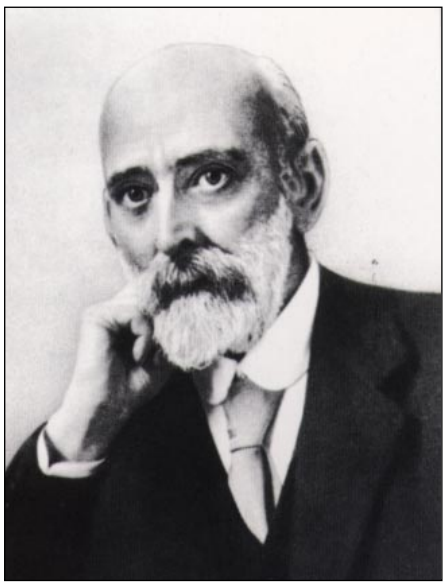
Prof G Walton is the Senior Partner at the Geoffrey Walton Practice and Visiting Professor of Mining at Leeds University. He was formerly the Headquarters Geotechnical Engineer for the National Coal Board's Opencast Executive, and was also seconded to the Rock Mechanics Research Group at the Royal School of Mines.

History and contact details ☞

Directors of the British Geological Survey

Sir Henry Thomas De la Beche
1835–1855
Sir Roderick Impey Murchison
1855–1871
Sir Andrew Crombie Ramsay
1871–1881
Sir Archibald Geikie
1882–1901
Sir Jethro Justinian Harris Teall
1901–1914
Sir Aubrey Strahan
1914–1920
Sir John Smith Flett
1920–1935
Dr Bernard Smith
1935–1936
Sir Edward Battersby Bailey
1937–1945
Dr William Francis Porter McLintock
1945–1950
Sir William John Pugh
1950–1960
Sir Cyril James Stubblefield
1960–1966
Sir Kingsley Charles Dunham
1967–1976
Dr Austin William Woodland
1976–1979
Sir George Malcolm Brown
1979–1985
Mr George Innes Lumsden
1985–1987
Mr Ferdinand Geoffrey Larminie
1987–1990
Dr Peter John Cook
1990–1998

Dr David Alan Falvey 1998–



Sir Jethro Justinian Harris Teall, Director of the Survey from 1901 to 1914.

Sir Jethro Justinian Harris Teall was born in 1849 after the death of his father, in Northleach, England, and was educated locally. He studied natural sciences at Cambridge where he attended Adam Sedgwick's last course of lectures, and was engaged for several years lecturing widely under the University Extension Scheme. Meanwhile he had taken to the microscope, and years of hard rock studies culminated in his magnum opus, **British Petrography,** with which his name will always be associated. This led to his appointment as petrographer to the Geological Survey where he was mainly concerned with Scottish hard rocks, particularly the schists, igneous rocks and contact metamorphic rocks then being discovered in the NW Highlands.

On being appointed Director of the Survey in 1901, Teall was able to carry through the reforms on staffing and pay recommended by the Wharton Committee and chart the future of the Survey for at least fifty years. He established the system of publishing one inch geological sheets of the country, each accompanied by a memoir. These sheets were based on six inch maps which were published for economically important districts. Other aspects of his appreciation of applied science were the studies of coalfields and underground water supplies. He stimulated the scientific enthusiasm of his staff by recalling them from the field in winter to mix with their peers, and encouraging them to publish and travel overseas to broaden their experiences. Teall's qualities of impartiality and disinterestedness won the faithful collaboration of his staff. He retired with universal goodwill having greatly enhanced the reputation of the Survey.

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For information on the whole range of the BGS's activities visit the BGS website: www.bgs.ac.uk

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British Geological Survey

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